TOWARDS AN ONLINE KNOWLEDGE MANAGEMENT SYSTEM FOR REACTIVE MAINTENANCE PROJECTS

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ABSTRACT

In the UK, building maintenance makes up more than 50% of total construction output while reactive maintenance covers two thirds of the overall building maintenance projects. It was therefore found not surprisingly that reactive maintenance work receives the most complaints and gives more negative impacts on business activities in terms of time, cost, and the health and safety of the users. As this type of maintenance work is mostly carried out by firms with less than 20 employees, which constitutes 84% of the industry, reactive maintenance is hence, the major focus of this study. The aim of the research is to demonstrate how inexpensive IT and communication tools can lead to enhanced effectiveness and efficiency in the delivery of minor construction projects. Process analysis was carried out to provide valuable insights into the existing business process of reactive maintenance and also the information and communication technology that is being used by the parties involved in the process. It unearthed problems that impede the process in terms of time, cost, quality of work and the health and safety of the users. These problems can be encapsulated as poor communications between different parties, lack of knowledge sharing and poor quality of information, which often leads to longer time taken to fix a problem and incurs higher cost. A prototype online knowledge management system called "MoPMIT". MoPMIT (**M**ore **P**roductive **M**inor Construction Projects through Information **T**echnology) was developed based on these problems and the improvements required which the main idea is to bring all parties onto the online system so that they can share the necessary project information for better management of knowledge. The system allows them to communicate and share the information available to them via a common interface with pre-allocated password access as a control mechanism that restricts each user to its role. System evaluation was conducted among potential MoPMIT users and generally the results were positive. They were of the view that this system would lead to better management of knowledge, improve communication and better sharing between all parties.

DECLARATION

The researcher declares that no portion of the work referred to in the thesis has been submitted in support of an application for another degree of qualification of this or any other university or other institute of learning.

Kherun Nita Ali
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DEDICATION

This is for

Ayah – Hj Ali bin Ahmad

Mak – Hjh Kadariah binti Daud

Abang & Acik – Khairul Azhar & Nur-Zarina

And

My beloved nephews

Muhammad Amirul Najman

Arasy @ Arief Najman

Anieq Najman

Thank you for all your prayers, emotional supports, loves and spirits

"And if all the trees in the earth were pens,
and the sea, with seven more seas to help it, (were ink),
the words of Allah could not be exhausted.
Allah is Mighty, Wise"
Al-Quran (Luqman:27)

I thought this was the end
but no, this was not
I have just opened a new door
door to another entrance
to start a new beginning

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salford, uk
2004

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Building maintenance projects involve improvement or refurbishment, maintenance and repair works of varying size and complexity. Examples include the design and construction of new roofs or internal structural arrangements, with any associated mechanical and electrical equipment and those concerned with repairing minor problems such as electrical failures, plumbing leaks and building fabric or equipment failures.

Building maintenance is to restore the life of a building and ensure the health and safety of the users throughout the building life cycle. British Standard BS 3811 defines maintenance as "Work undertaken in order to keep or restore every facility, i.e. every part of a site, building and contents to an acceptable standard". Report of the Committee on Building Maintenance (CIOB, 1990) added, "...every part of the building, its service and surrounds, to a currently accepted standard and to sustain the utility and value of the facility". CIOB (1990) supports the committee's definition by adding that the service must be to an agreed standard, determined by the balance between need and available resources. The main aim of maintenance is, therefore, to preserve a building in its initial state, as far as practicable, so that it effectively serves its purpose.

BS3811 divides maintenance into Planned and Unplanned maintenance. The latter, also known as reactive maintenance, is the type of work resulting from unforeseen damage or failure due to external causes (e.g. vandalism). CIOB (1990) classifies this category as emergency maintenance where immediate action is needed to rectify failures. Other than external causes, the failures might stem from failures in planned maintenance. Planned maintenance is the action taken in order to avoid expected or avoidable failure (Seeley, 1976). It is categorised into preventative maintenance, which is to prevent the failure of facility or to ensure its continued operation; and corrective maintenance where work is performed to restore a facility to an acceptable standard. Planned maintenance, also similar to routine maintenance (CIOB, 1990) or predictable maintenance (Seeley, 1976), is the regular periodic work necessary to retain the performance of a product that requires repair or replacement of defective items.

The research initial study has revealed that two third of jobs complaints are reactive maintenance work where problems reported require immediate action to rectify the failures. For example, one contractor interviewed in the study does 80,000 reactive out of 120,000 maintenance works they received (Willmott Dixon, 2000). This high number of unplanned maintenance not only causes most complaints but also affects business productivity in terms of time and cost, as well as the health and safety of the users.

In the last few decades, the share of building maintenance projects in the UK construction industry has been steadily increasing. For examples, in the late 60s, such work represents 28% of the total construction output, which accounts for about 40% of the labour force of the construction industry

(Seeley, 1976). Between the year 1979 until 1989, this small work class of activity rose from 38% of the total output in 1979 to 46.4% in 1985 and slightly decreased to 41% towards the end of the decade (Griffith, 1992). Currently, the projects make up over 50% of construction industry (DETR, 2000). Unplanned or reactive maintenance covers two third of the overall building maintenance projects and causes most complaints and management difficulties. This is due to its unexpected nature. This type of work are carried out by firms with less than 20 employees that constitute 84% of the industry (DTI, 2000). Therefore its economic significance is clearly evident. Changes or innovations that are geared towards improvement in building maintenance works could enhance the efficiency and quality of the construction industry. Besides, not only will the total expenditure be reduced significantly, essentially, it will also ensure that the nation's stock of buildings is used as effectively as possible (Seeley, 1976). This thesis explores how the area of building maintenance particularly maintenance of minor works can be improved through knowledge management. In the early industrial era, organisations tried to improve their competitive edge by automating labour and reducing redundancy. However, through lean management, organisations adopted business process re-engineering and started eliminating redundant workers and jobs (Gupta, Iyer and Aronson, 2000). But the increasingly global competition with a more knowledgeable and sophisticated customer, organisation has to find ways to stay competitive and at the same time remain innovative in reducing their cost and expanding their markets (Dixon, 2000).

Nowadays, knowledge is more relevant than capital, labour or land (Olomaiye & Egbu, 2004; Newman, online). Organisations have begun to realise that knowledge, which in the past has been largely neglected by companies, is an asset that diffused and grew within the organisation in an unstructured way. This is the knowledge that helps the organisation in innovative decision making, problem solving and hence, maintains competitive advantage (Malhotra, 1998). Thus, knowledge management has emerged to assist organisations to manage the knowledge that resides within the organisation.

Most current methodologies of knowledge management in construction industries in the UK seem to be biased towards a particular type of knowledge. Methodologies that are biased toward explicit knowledge most often only document the explicit or formal task elements of the organisation's business process. Rarely is the tacit or informal process, which actually took place, documented. Thus, they do not capture the dialogue, telling of the dynamics, uncertainties, insights, interactions and deliberations that made the process successful. While they may set down the 'what' of a process, they usually fail to set down the 'why' of its steps. Even if authors try to capture the 'why', such methodologies are written after the event, when people have forgotten the informal process and the 'why'.

Consequently, they fail to capture the reality of 'how'. The subsequent user of the methodology either needs to spend time with someone who was involved in the documented process, or get that person into the new team. Much of the hardest-won and highest-value operational information about the process still resides in the heads of people who were personally involved, and remains uncaptured, unshared and unapplied by others (Allee, 1997; Wong & Radcliffe, 2000).

Another problem with current knowledge management systems lies in their adoptability and adaptability by organizations. Because different organizations require different organizational structure, needs, information expertise and unique experiences and at times different language, it is difficult to adapt one organisation's knowledge base system to another. A peculiar problem of minor construction projects is that the existing fragmented structures seem not to be efficient to support effective knowledge management.

Despite the fact that considerable research effort has been carried out in the past that bear on integrated environments for the design and construction projects (Aouad et al, 2001; Faraj & AlShawi, 2001; Aouad et al, 1997; Sulaiman, 1997), little research has been carried out that touches on the life cycle of minor construction projects. In the UK, however, minor construction projects are under-represented in research portfolio despite their prevalence in practice. Supply chain studies for construction tend to examine only the physical, material, logistics perspectives and de-emphasize the strategic and client satisfaction perspectives. This thesis will demonstrate how an innovative approach can be developed to overcome some of these problems.

1.1 AIMS AND OBJECTIVES

The main aim of this study is to illustrate how the innovative use of desktop productivity tools, such as the Internet, can improve the business process of reactive maintenance projects. This study develops a knowledge management approach that is based on capturing as much as possible of the reality of construction work as it is performed by the team who did it. In this approach, the knowledge about the work is captured and can be used as soon as it is shared in the organisations. Specific objectives include:

1. To examine the existing business process of minor maintenance projects with a view to ascertain the underlying problems and potential areas necessary for improvement
2. To review knowledge management tools and systems with a view to understand their applicability and adaptability to building maintenance projects
3. To develop a prototype of a knowledge management system that can fit into the business process of minor maintenance in order to overcome the challenges in the business process
4. To evaluate the feasibility of the prototype system that would be developed

1.2 JUSTIFICATION OF THE STUDY

Construction firms, as other industrial and financial organisations face increasing sophistication and volatility in their products and services. Management of knowledge assets is being recognized as a major means to remain competitive. Common knowledge management approaches adopted by organisations include dedicated knowledge-based systems, document management systems, database systems, and recently data warehouse technologies. In these approaches, the underlying data formats impose a lot of constraints on the type of information processed, and the way in which it is stored and accessed. For instance, in database systems and knowledge-based systems, a fine-grained structured information model is stored for automatic processing, but raw documents are not easily handled. By contrast, traditional document management systems store raw documents efficiently but are not built for complex queries except full-text search on the document text and data. Data warehousing focuses on the integration of existing databases and intelligent software. However, it does not propose to users anything for conscious management of knowledge in their daily activity.

Effective knowledge management pays off in fewer mistakes, less redundancy, quicker problem solving, better decision making, reduced research and development costs, increased worker independence, enhanced customer relations, and improved products and services that add up to keep the companies at least a few steps ahead of their competitors Davenport (1996). Although minor construction projects do have fairly formal management systems, their strategy of self-containment has denied them the opportunity realise the above payoffs.

The significance of this research lies in the strength of filling these research gaps and evolving a flexible knowledge management process that does not attempt to formalize all problem solving knowledge into rules (and subsequently discard intangible less explicit knowledge) but rather create looser and more informal environments that encourage employees to share knowledge, to collaborate and learn.

The findings of this research will enable construction firms to know how to use low cost existing information and communications technologies (ICT), to increase their capacity to process information.

1.3 SCOPE OF THE STUDY

This study will examine closely the minor construction projects that make up over 50% of construction activity in some large organisations. These organisations are the major construction clients in the UK i.e. Whitbread Plc, Boots the Chemist, Lloyds TSB Plc. The study also involved facilities management consultant company i.e. WS Atkins Consultant and WS Atkins Facilities Management; and some contractors i.e. Willmott Dixon Ltd and GS Hall Ltd. The minor construction projects cover both reactive and planned construction; and property maintenance activities that are involved in a wide range of task scale, complexity and technical discipline. Examples include the design and construction of new roofs or internal structural arrangements, with any associated M&E equipment and those concerned with repairing minor problems such as electrical failures, plumbing leaks and building fabric or equipment failures.

Knowledge management could be viewed from a two-dimensional perspective (Small & Jean, 2000). The first dimension consists of the activities that are critical to knowledge creation and innovation necessary for knowledge exchange, knowledge capture, knowledge reuse, and knowledge internalization.

The second dimension consists of those elements that influence knowledge-creation activities. These include Strategy such as the alignment of corporate and knowledge management strategies; Measurement - the measures or metrics captured to determine if improvement is occurring or if a benefit is being derived; Policy - the written policy or guidance that is provided by the organization; Content - the subset of the corporate knowledge base that is captured electronically; Process - the processes that knowledge workers use to achieve organization mission and goals; Technology - the information technology that facilitates the identification, creation, and diffusion of knowledge among organizational elements within and across enterprises; and Culture - the environment and context in which knowledge management processes must occur (often described in terms of values, norms, and practices).

In the study of the knowledge management in major and small construction firms, this study will cover all the elements in the first dimension and two elements in second dimension, which are process and technology. Essentially the study will focus on ways in which minor construction firms will:

1. Enhance the quality of the information for employees in order to reduce costly clerical errors and the number of customer complaints;
2. Enable the reuse and share of experience and;
3. Allow for precise and timely creation and update of documents in order to reduce the time to supply and deliver on a new project.

1.4 RESEARCH METHODOLOGY

The research method for this research is primarily qualitative research. Qualitative research is broadly defined, as any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification (Strauss and Corbin, 1990). Qualitative approach seeks, for the illumination, understanding, and extrapolation of subjects from context specific and stresses the socially constructed nature of reality of what is studied. Cronbach (1990) claims that statistical or quantitative research may not be able to take full account of the many interacting effects that take place in social settings because it ignores effects that may be important, but that are not statistically significant.

Case study is a method of conducting qualitative research (Winegardner, online). It is an ideal methodology when a holistic and in-depth investigation is needed to understand a complex issue or object (Feagin, Orum, Sjoberg, 1991). Given the complex and dynamic nature of events that seems to influence knowledge creation and sharing, it is the researcher's view that the qualitative approach which centres directly on the persons influencing actions will better capture reality than the quantitative approach which focuses only on variables. Besides, with case study research, the real situation can be captured from the inside of the organisation and not from outside (Sarantakos, 1998).

Thus for primary data, this study employs three types of qualitative data collection (Patton, 1990): (1) in-depth, open-ended interview (2) direct observation and (3) written document. It entails intensive and extensive collaboration with major construction industrial partners and their subsidiaries and construction firms in the UK.

The major source of secondary data is literature search. These include related works from universities, national and specialised libraries, company reports and government publications, seminar papers and workshop materials and the use of web sites.

1.5 ORGANISATION OF THE STUDY

This study is organised into eight chapters. Chapter one is an introduction to the essence and problems that necessitate this study. It addresses the research objectives, which the researcher intends to answer, and the scope that highlights the confines of the study. Chapter two discusses the research methodology, the scope and methods of data collection and analysis. The strategy for the procurement of research is also presented in this chapter.

Chapter three is a review related to literature and works (published or unpublished) on minor construction projects and knowledge management. Chapter four examines the minor construction business process and the underlying problems. Chapter five presents the development of the proposed knowledge management system followed by the evaluation of the system in chapter six.

The result of the research is discussed in chapter seven and chapter eight concludes the thesis.

CHAPTER 2

RESEARCH METHODOLOGY

2.0 INTRODUCTION

The goal of this research was to seek for improvement in building maintenance project through the use of information technology (IT). In doing so, it is important to study the reality in building maintenance project and identify the weaknesses that could be highlighted for that purpose. The current rapid development in IT has created an opportunity for the building maintenance industry to not only improve the way maintenance project is managed and carried out, but also to ensure the industry could stand side by side with other industries such as manufacturing, where IT has become so prominent in many aspects of their Research and Development.

Clough and Nutbrown (2002) suggested that the distinction between *methods* and *methodology* is that the former comprise *some of the ingredients of research* and the latter *provides the reasons for using a particular research recipe.* Thus, this chapter sets out the research methodology adopted to investigate maintenance projects and its justifications. The discussion begins by reviewing research philosophies, followed by research approaches and the techniques. It will also discuss the data collection and analysis techniques.

2.1 METHODOLOGY

Methodology can be used either to *refer to the principal paradigms of* *an approach to researching a problem* - a methodological strategy widely known as qualitative or quantitative approach; or as *operational research techniques;* i.e. the Delphi approach, questionnaire-based study, case study technique and semi-structured interview (Salford University, 1999).

There has been a widespread debate in recent years regarding the difference in qualitative and quantitative research strategies. In a very simple definition, the term quantitative is concerned with the collection and analysis of data in numeric form, where on the other hand qualitative is empirical research where the data is not in the form of numbers (Punch 1998 as in Blaxter, Hughes and Tight, 2002). Quantitative approach is founded on the assertion that there is a single reality, which is objective (Salford University. 1999). It is possible:

a) to separate the phenomenon from the surrounding environment and make a free standing assessment of the objective reality
b) to maintain the distance from the subject of the research

This approach allows the researcher to observe as an outsider in the research area. It also tends to emphasize on relatively large scale and representative sets of data.

The qualitative approach however was developed from the social science and is therefore more socially and philosophically oriented. It is concerned with collecting and analyzing information in non-numeric forms. It tends to achieve the "depth" of the research study rather than "breadth" and to focus on exploring any instances or examples in as much details as possible. This approach is the opposite view of the quantitative where it is based on the assumption that there is no singular objective reality and real world phenomenon needs to be accessed from within the context of that reality.

Table 2.1 explains the differences between qualitative and quantitative. Table 2.2 also shows a summary of the differences that has been categorized into activities, beliefs, steps and rigour (Holliday, 2002).

Table 2.1: The Differences between Qualitative and Quantitative Research (Adapted from Oakley, 1999)

QUALITATIVE PARADIGMS	QUANTITATIVE PARADIGM
• Concerned with understanding behaviour from actors' own frames of reference	• Seek the facts/ causes of social phenomena
• Uncontrolled observation	• Controlled measurement
• Subjective	• Objective
• Close to data: the *insider* perspective	• Removed from the data: the *outsider* perspective
• Grounded, discovery-oriented, exploratory, expansionist, descriptive, inductive	• Ungrounded, verification oriented, reductionist, hypothetico-deductive
• Process oriented	• Outcome-oriented
• Valid: realm rich, deep data	• Reliable: hard and replicable data
• Ungeneralisable: single case studies	• Generalisable: multiple case studies
• Holistic	• Particularistic
• Assume a dynamic reality	• Assume a stable reality

2.1.1 Research Philosophy

Both qualitative and quantitative methodologies are derived from two opposing research philosophies – positivism and phenomenology. Positivism *uses quantitative and experimental methods to test hypothetical-deductive generalization* (Amaratunga, 2000). The research should be objective and detached from the objects of research (Blaxter, Hughes and Tight, 2002). Reality is captured through research instruments such as experiments and questionnaires with statistical analysis approach.

Table 2.2: Two Paradigms (Holliday, 2002)

QUANTITATIVE RESEARCH	QUALITATIVE RESEARCH
Activities i. Counts occurrences across a large population ii. Uses statistic and replicability to validate generalization from survey samples and experiments iii. Attempts to reduce contaminating social variables	a) Looks deep into the quality of social life b) Locates the study within particular settings which provide opportunities for exploring all possible social variables; and set manageable boundaries c) Initial foray into the social setting leads to further, more informed exploration as themes and focuses emerge
Beliefs iv. Conviction about what it is important to look for v. Confidence in established research instruments vi. Reality is not so problematic if the research instruments are adequate; and conclusive results are feasible	d) Conviction that what it is important to look for will emerge e) Confidence in ability to devise research procedures to fit the situation and the nature of the people in it, as they are revealed f) Reality contains mysteries to which the researcher must submit, and can do no more than interpret
Steps vii. First decide the research focus (e.g. survey questionnaire or experiment) viii. Then devise research instruments (e.g. survey Questionnaire or experiment) ix. Then approach the subject	g) Decide the subject is interesting (e.g. in its own right, or because it represents an area of interest) h) Explore the subject i) Let focus and themes emerge j) Devise research instruments during process (e.g. observation or interview)
Rigour x. Disciplined application of established rule for statistics, experiment and survey design	k) Principled development of research strategy to suit the scenario being studied as it is revealed

Phenomenology approach inquiry, also known as interpretivism, *uses qualitative and naturalistic approaches to inductively and holistically understand human experience in context-specific settings* (Amaratunga, 2000). Max Weber (1864 – 1920 as in Blaxter, Hughes and Tight, 2002) suggested that the social sciences are more concerned with *understanding* rather than *explaining*, which forms the basis of seeking causal explanations of the natural sciences (Easterby-Smith et al. 1991). The main differences between the positivism and phenomenology can be summarized as shown in Table 2.3.

Table 2.3: Key Features of Positivist and Phenomenological Paradigms (Easterby-Smith et al, 1991)

	POSITIVIST PARADIGM	PHENOMENOLOGICAL PARAGIGM
Basic Beliefs	• The world is external and objective • Observer is independent • Science is value free	• The world is socially constructed and subjective • Observer is part of what observed • Science is driven by human interests
Researcher should	• Focus on facts • Look for causality and fundamental laws • Reduce phenomena to simplest elements • Formulate hypotheses and then test them	• Focus on meanings • Try understand what is happening • Look at the totality of each situation • Develop ideas through induction from data
Preferred methods include	• Operationalising concepts so that they can be measured • Taking large samples	• Using multiple methods to establish different views of phenomena • Small samples investigated in depth or over time

This research philosophy formed as the first level of research methodology as represented in a model *Research Methodology Nesting* shown in Figure 2.1 (Kagioglou, et al, 1998). The other two levels are research approaches and research techniques, which will be discussed further in section 2.1.2 and 2.1.3. In some literature, philosophy has been simplified as research families (Blaxter, Hughes and Tight, 2002), where apart from drawing a line between qualitative or quantitative approach, it was also divided into deskwork or fieldwork.

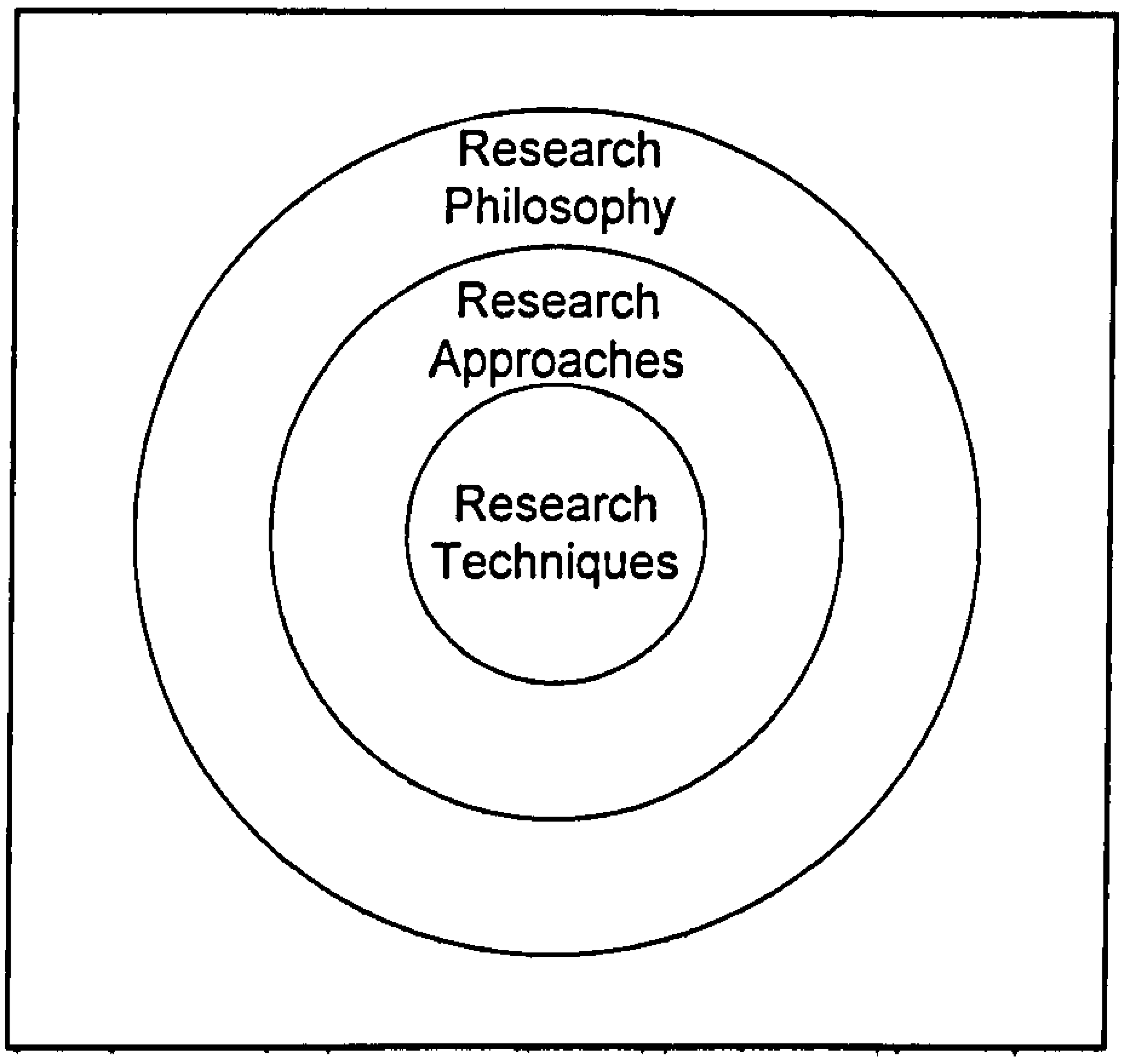


Fig 2.1: Research Methodology Nesting (Kagioglou, et al, 1998)

It has been briefly explained in chapter one that the method for this research is primarily qualitative. One of the objectives of the research is to examine the existing management process of building maintenance. In order to achieve this, one has to investigate organizations that are involved in the project and explore every aspect that may or may not contribute to the management process. Issues such as who are the parties involved in a maintenance project?; how do they communicate with each other?; what IT application/ system do they use?; or how does the system work?; are some examples of questions that would be answered if the researcher could give his perspective as an insider. In this way, the researcher becomes closer to the data and the closer it gets to the source of data, the more information could be discovered. The questions will be developed and in further details such as; what aspects that the management expect to improve?; or what are the tacit knowledge that resides in the individuals' head?.

Since the management process was investigated from the inside (within the organisation), the research was able to highlight some deficiencies that often occur within the existing process. These identified deficiencies provide impetus for justifying the needs for improvement in building maintenance project. From here, potential areas were identified and emerged as the basis of system design for the prototype.

The second objective of the research also requires an examination of some IT tools and systems. Qualitative approach allows the exploration of various technologies currently available for similar management processes depicted in this study. The outcomes derived from both objectives contribute to the development of the prototype, which the researcher wants to achieve in the third objective.

Because this study seeks to understand real workings and characteristics of a building maintenance project, a qualitative approach using an interpretive paradigm based in phenomenology was judged best for understanding both the empirical data and the values and interpretations of the subjects. It is descriptive; focusing on process, understandings and interpretation rather than on deductive and experimental approaches (Olscheske, 1999).

2.1.2 Research Approach

The research approach to this study is a case study embedded in action research. Case study approach is ideal when a holistic, in-depth investigation is needed (Patton, 1990; Feagin, Orum and Sjoberg, 1991; Amaratunga, 2000, Guba and Lincoln, 1989). Merriam (1988) cited qualitative case study research as a preferred choice for those researchers who are seeking *insight, discovery and interpretation rather than hypothesis testing* and where there is a desire for *holistic description and explanation.* A case study is a detailed examination of an event (or a series of events). Yin (2003a) defined case study as *an objective, in-depth examination of a contemporary phenomenon where the investigator has little control over events.* He also says that *the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events – such as individual life cycle, organizational and managerial processes, neighbourhood change, international relations, and the maturation of industries* (Yin, 2003a). It is an examination of specific phenomenon such as a program, an event, a person, a process, an institution, or a social group (Merriam, 1990).

Based on the nature of the research, it was appropriate to conduct an exploratory case study involving three cases to achieve the research aim and objectives in which two of the clients are managed by an outsourced Facilities Management and the other one is managed by an in-house Facilities Management. This entails holistic examination of the management of building maintenance projects. Yin (2003b) supported the capability of case study research to provide scientific generalization. He observed that the triangulation of multiple sources of evidence permits convergence and corroboration of findings and builds a stronger, more convincing basis for conclusions. This research approach sets up an investigation to capture holistic and meaningful characteristics of real-life evidence such as organisational and managerial processes.

Robson (1993) in supporting the selection of the case study design recommended it as a preferred *strategy to conduct an empirical investigation* *of a particular contemporary phenomenon within its real-life context, using multiple sources of evidence.* This study examined a management group of building maintenance projects deliberating a real-life situation of concern to the business process. After conducting preliminary literature and interviews, the researcher went to the actual location of the case study to conduct fieldwork through interviews, observations and examination of any documentation related to the context of the study (the research techniques will be explained in the next section) where data was collected from various sources. These findings were synthesized with each other to produce empirical evidence in response to the research aim and objectives.

Stake (1981) observed that the research derived from qualitative case study research tends to be more concrete, contextual and further developed through the case study researcher's own experiential understanding, combined with the findings. Stake also stated that *previously unknown relationships and variables could be expected to emerge from case studies, leading to rethinking of the phenomenon being studied.* This is what was expected to occur in this research where deep insights and understandings into the business process will lead to a discovery of *unknown relationships and variables* and seek for rethinking of the business process in search of improvement to the maintenance projects.

Action research is a technique involving a process of changing a particular structural organizational practice through the use of technology, a methodology for obtaining unavailable information and, and a strategy for the diffusion of knowledge (Wilson, 2000). Given technology, the major variables that are expected to change in action research are organizational practice (structure) and the people who use that technology within the organizational structure. Each of these variables is subject to change as a result of change in the other. For example technological change leads to new information services requiring new organizational structures or a need for adaptation of people to use the new technology. In action research involving organization, users of information are affected by four variables – structure, task, technology and people as illustrated in Figure 2.2. A change in the needs of users over time may require changes in the way service tasks are performed; or changes in technology may enable an information service to perform tasks in service for the user not possible previously; or the needs of users may require the appointment of subject-specialised personnel to deal with them; or the growth of the number of users to be served may lead to new organizational structures. Action research may be used to create a match between:

1. Users and the organizational structure;
2. Users and the tasks performed in serving them;

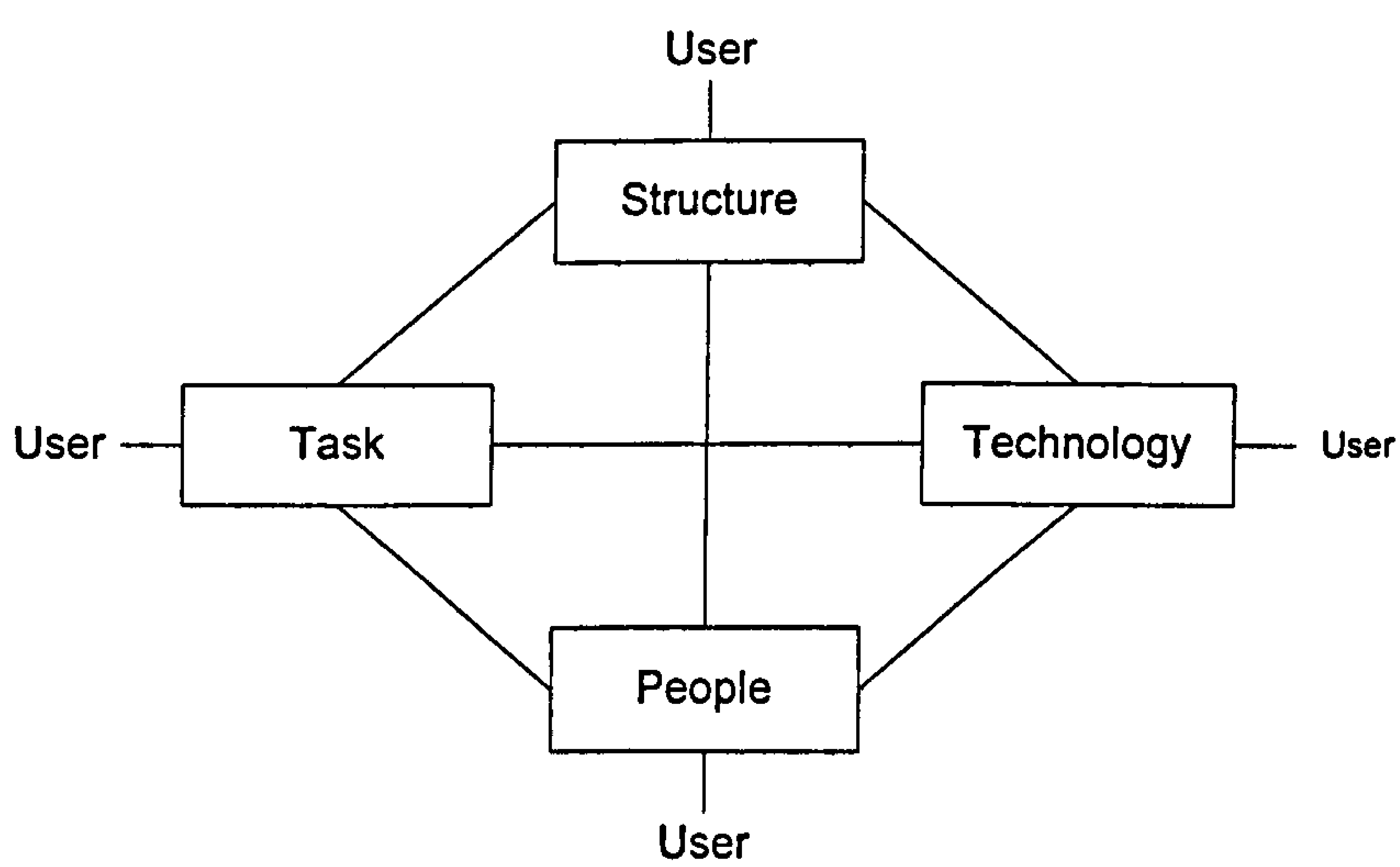


Figure 2.2: Organisational Variables in Action Research (Wilson, 2002)

3. Users and those who serve them; and
4. Users and the technology used to deliver service.

In the case of this study, the prototype system that is expected to emerge (being a technology) will have significant influence on the organizational structure of building maintenance, the users such as Unit Managers, Clients, Facilities Managers, Contractors and tasks performed.

An important element of action research that is of utility to this study is data feedback. According to Wilson (2000), an essential element in action research, which distinguishes it from much other research, is data feedback. Unlike in other methods where research is never reported directly to those from whom the data was collected, in action research, feedback is essential if management and other organizational members are to be persuaded of the need for action. In this study data feedback was mainly carried out by oral presentation at meetings with parties involved, and discussions that follow the presentation.

2.1.3 Research Technique

Silverman (2001) listed out four techniques used by qualitative researcher i.e. observation; analyzing text and documents; interviews and recording. Table 2.4 shows the different uses of each method for qualitative and quantitative research.

Table 2.4: Different Uses for Four Methods (Silverman, 2001)

METHODS	QUANTITATIVE	QUALITATIVE
Observation	Preliminary work; e.g. prior to framing questionnaire	Fundamental to understanding another culture
Textual Analysis	Content analysis; i.e. counting in terms of researchers' categories	Understanding participants' categories
Interviews	Survey research: mainly fixed choice questions to random samples	Open-ended questions to small samples
Audio and Video recording	Used infrequently to check the accuracy of interview records	Used to understand how participants organize their talk and body movements

According to Silverman (2001) observation is often not suitable for quantitative method as it is difficult to conduct observational studies on a large sample. This research involves small samples, upon which observation techniques could be conducted among experienced individuals in the management process. Also, since knowledge creation and sharing is an essential part of this research, observation techniques could be used to capture the undocumented tacit knowledge such as experience and skills that resides in every individual involved in the maintenance process.

Qualitative interviewing is usually intended to refer to in-depth, semi-structured or loosely structured forms of interview. Interview is one of the most commonly recognized forms of qualitative research method (Mason, 1996). Merriam (1988) advocates the use of interviews particularly when the researcher is unable to observe how people interpret the phenomenon or situation. For the purpose of the qualitative case study approach, adopted in this research, open-ended interviews were conducted with different individuals in the maintenance project. Given the fact that it was the researcher's desire to explore every aspect and issue in the research area, open-ended interview allows the interviewee to respond in his most convenient way and give a wider scope of information. This is by contrast with structured interview that will produce a structured response (Bell, 1993). Open-ended interview is more like a discussion between interviewer and interviewee where the purpose is simply to facilitate the respondent into talking at length (Blaxter, Hughes and Tight, 2002). However, semi-structured interviews were used during observation session as a checklist while monitoring the participants' real working environment.

Some interviews were recorded, depending on the circumstances and the reasons of the interview. This is because tape-recorded interview may restrict the respondents' answers. On most occasions, transcribed interviews or reports from the interview were sent back to the interviewees for their comment to validate the information given by them. Any further clarification required, would be subsequently sent to them in writing.

The aim of analyzing texts and documents is to understand the participants' explicit knowledge. By examining their documents, combined with observation on their tacit experience and skills, the researcher has gained an appropriate understanding of the whole maintenance process and identified some deficiencies that impede their process. This secondary data is always seen as complement to the primary data as they may confirm, modify and contradict the research findings. Other than the secondary data from participants in the study, documents from other resource was also gathered such as library- and internet-based publications.

2.2 RESEARCH PROCESS

The research process was divided into five main stages i.e. preliminary study, conceptualization, data collection and analysis, prototype development and testing. Figure 2.3 shows the layout of the stages taken by the researcher in order to complete the research.

Preliminary literature reviews and interviews on the background of the study were carried at the preliminary stage. This has led to identifying the aim and objectives of the study and defining the research methodology. Research techniques i.e. interviews, observations, document analysis and literature review were carried out during data collection and analysis stage. This stage aims to achieve objective one and two. Based on this findings, the prototype system was designed and developed which was to achieve the third objective. The system was tested for its reliability from time to time throughout the system design and development. It was then validated by the process owner against the requirements identified during process analysis. The evaluation was carried out by some intended users of the system to recognise the weaknesses and strengths of the system and to obtain comments and recommendations as a guide for future developments

2.3 DATA COLLECTION

Preliminary study has identified the parties involved in the building maintenance project and their interrelationship. Figures 2.4 and 2.5 show the initial discovery during this preliminary study.

A wider view of this supply chain in the maintenance process is depicted in Figure 2.6. This figure shows not only the major parties that surround a building maintenance project but also other components that contribute to the process such as the call centre, operatives and facilities management systems. Thus, sample for this research were selected based

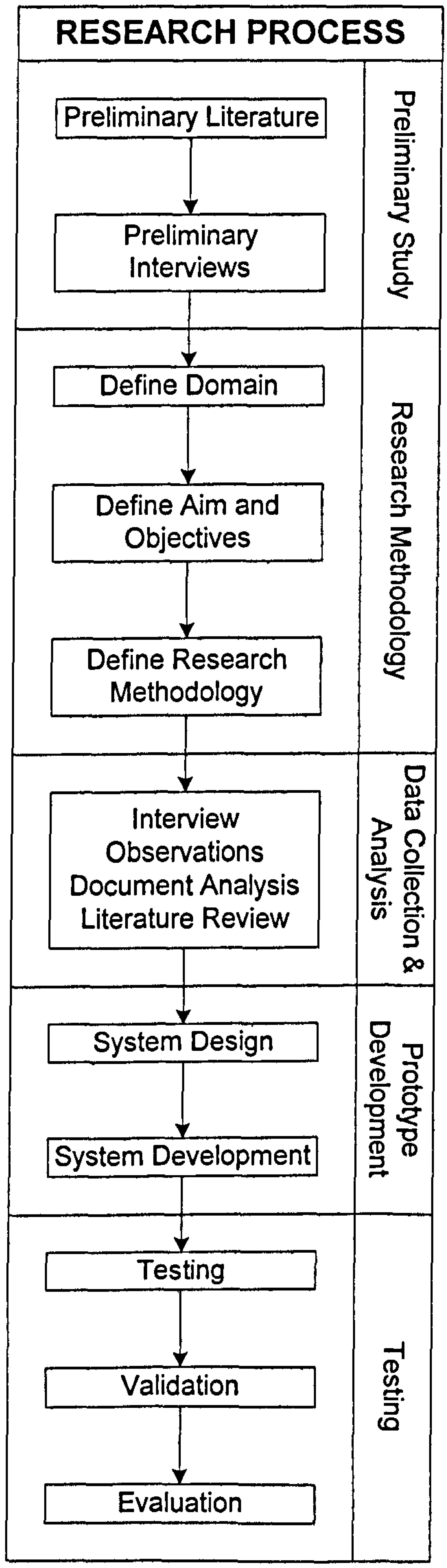


Figure 2.3: Research Process

on this diagram. The types of documents required were also determined from here.

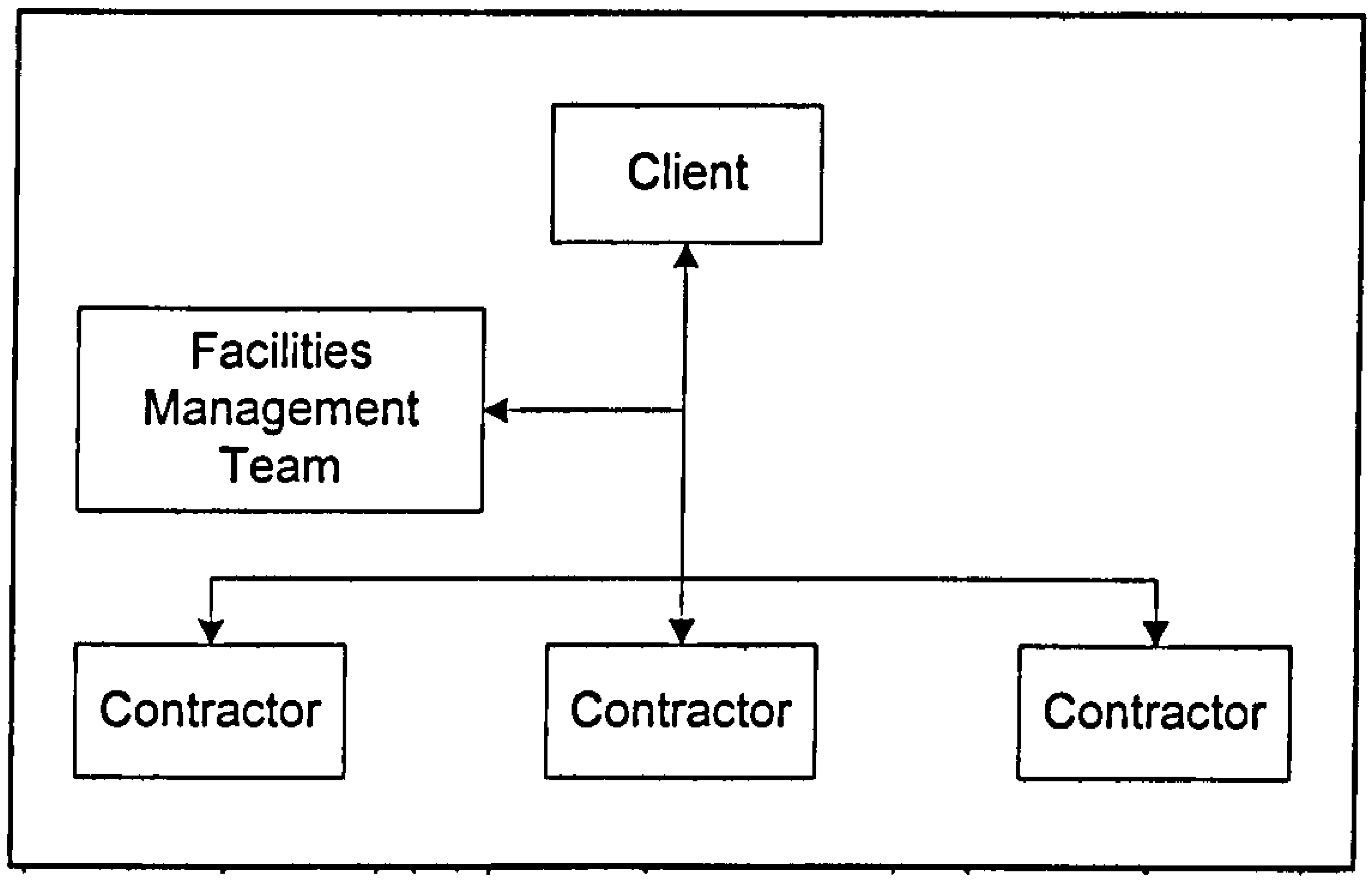


Figure 2.4: Main Parties Involved in the Minor Construction Process

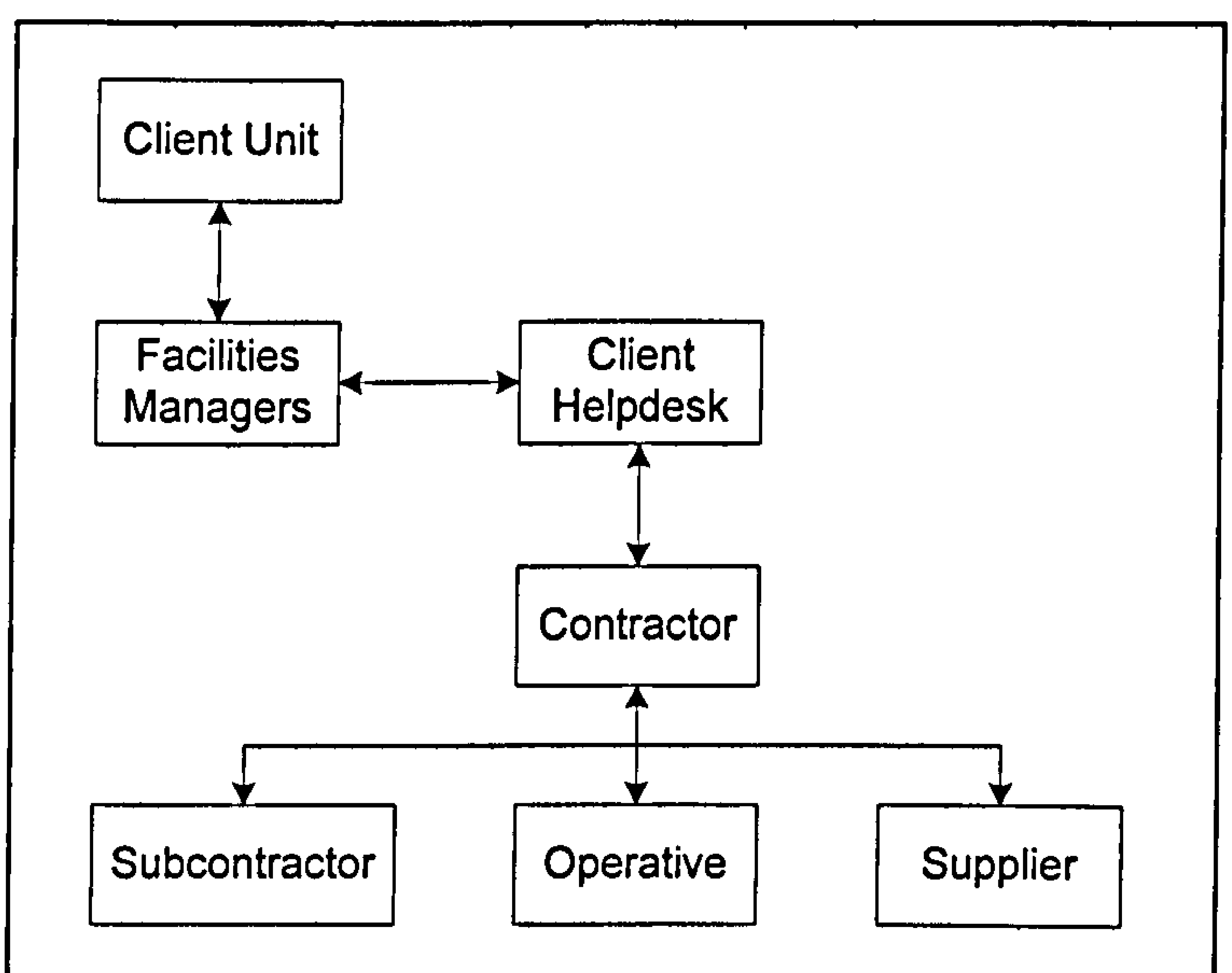


Figure 2.5: Relationship among the Parties in the Minor Construction Projects

2.3.1 Primary Data

Interview (recorded or non-recorded) and observation are both techniques used to gain primary data. Interview was conducted in two

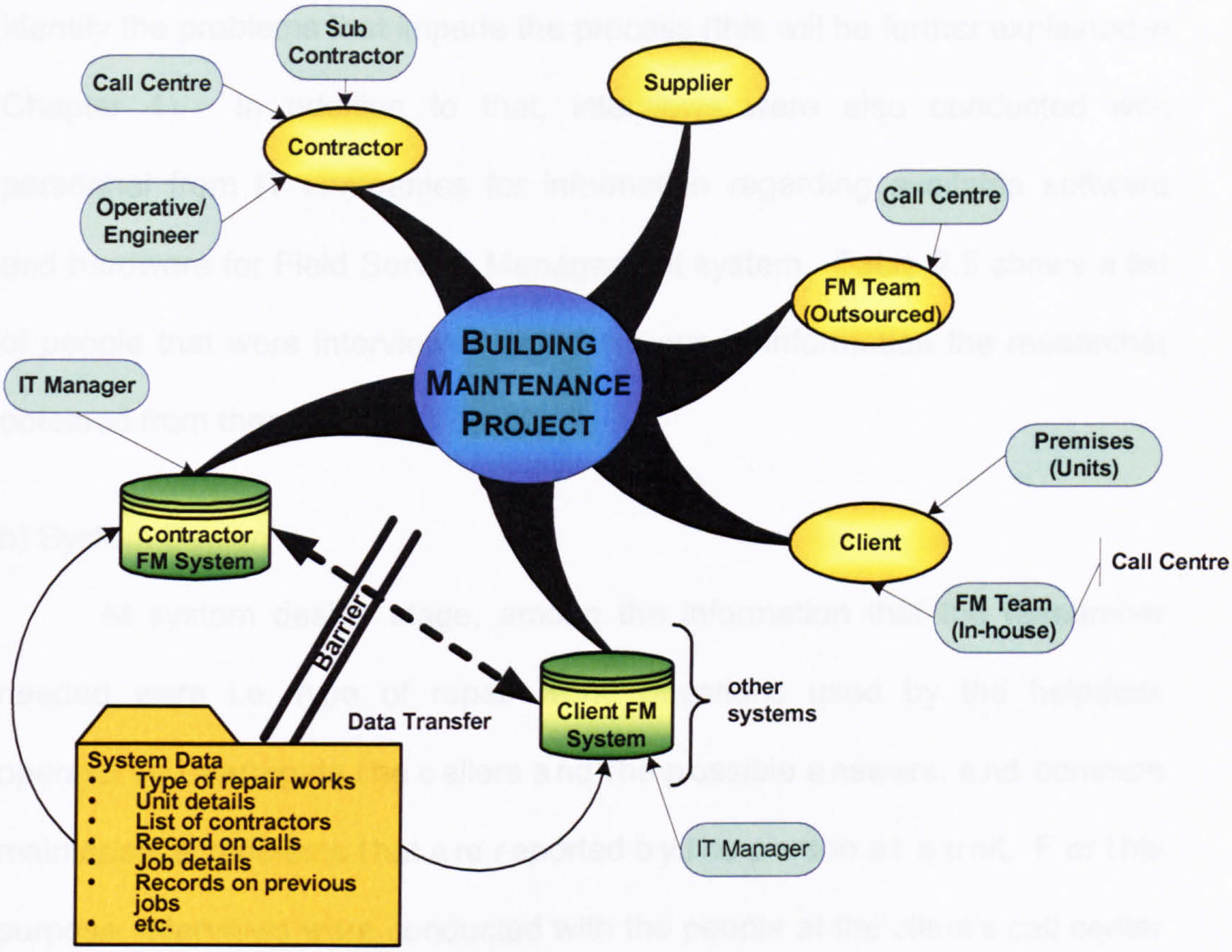


Figure 2.6: Bird's Eye View of Building Maintenance Project

stages i.e. process analysis stage and system design stage.

a) Process Analysis

At this stage interviews were held with all parties involved in the process such as Clients, Helpdesk Operators, Contractors, Facilities Manager, Suppliers, Operatives and IT Managers. The aim was to understand the actions taken in the process; the transfer of information among the parties; the dynamics of tacit and explicit knowledge in the process and the type of related IT system being used. A generic business process was an outcome of the interview and the researcher has managed to identify the problems that impede the process (this will be further explained in Chapter 4). In addition to that, interviews were also conducted with personnel from IT companies for information regarding available software and hardware for Field Service Management system. Table 2.5 shows a list of people that were interviewed and the types of information the researcher obtained from them.

b) System Design

At system design stage, among the information that the researcher needed were i.e. type of repair work; questions used by the helpdesk operator to interrogate the callers and the possible answers; and common maintenance problems that are reported by the person at a unit. For this purpose, interviews were conducted with the people at the client's call center such as the helpdesk operators and their coordinators/ supervisors; and also some IT personnel. For classification of repair work, interviews were conducted with people that are familiar with facilities management such as Professor Keith Alexander and David Baldry from Centre of Facilities Management; or divisions/departments that are responsible for the maintenance of buildings and their infrastructure such as Estate Divisions of University of Salford and Property Division of Manchester City Council.

In order to understand how questions and answers flow between the Helpdesk Operator and the callers, a direct observation was made where the researcher sat down with some Helpdesk Operators at their Call Centre. This has enabled the researcher to get a better view on how maintenance

Table 2.5: Samples Selected for the Data Collection (Number of persons is for both stages, i.e. Process Analysis and System Design)

PARTICIPANTS	NO OF PERSONS INTERVIEWED	TYPE OF INFORMATION
CLIENT	6	• Business process (Process scenario, problems) • Facilities Management System • Evaluation of prototype
FM TEAM (OUTSOURCED AND IN-HOUSE)	6	• Business process (Process scenario, problems) • Facilities Management System • Classification of Repair Work • Evaluation of prototype
CONTRACTOR	4	• Business process (Process scenario, problems) • Facilities Management System • Technology device used (e.g. Vehicle Tracking) • Classification of Repair Work • Evaluation of prototype
CALL CENTRE (CLIENT, FM AND CONTRACTOR)	9	• Business process (Process scenario, problems) • Call Handlings and the Problems • Classification of Repair Work • Testing of prototype
SUPPLIER	1	• Business process (Process scenario, problems)
OPERATIVE	2	• Business process (Process scenario, problems)
UNIT MANAGER	1	• Business process (Process scenario, problems)
IT TEAM	4 (more)	• Client and Contractor Facilities Management system (database, structure, function) • Other Field Service Management System • Hardware Technologies (Wireless device, PDAs and etc.) • Evaluation of prototype

problems are being reported and the types of common repair work that occur in the clients' premises.

2.3.2 Secondary Data

Library- and internet-based publications were the main sources of secondary data for literature purposes such as books, journal, articles from magazines, conference and seminar papers. Apart from that, related written documents from the organizations were also gathered, such as procedures for call centre training; classifications of repair work and system manuals. This was part of the knowledge that needs to be captured for the development of the proposed system. Unfortunately none of the call centres record their every day incoming and outgoing calls, which could have been very useful to the development of the prototype if the natural conversation could be captured. Classification of repair work was also retained from books. A documented flowchart of the business process was perceived from the client. Samples of various standard forms such as jobs instruction (fax format) and unit feedbacks form; were collected to help the understanding of the type of information/ knowledge that was required in the maintenance process.

Other than the above-mentioned data, information regarding IT (be it the hardware or software) were gathered from sources such as; field service management magazines, IT magazines, Internet websites, and FM expo/ exhibition or talk seminars. Some IT firms were contacted for further information about their off-the-shelf FM system. The researcher also had the opportunity to study the structure in both client and contractor's FM system i.e. bespoke or off-the-shelf system especially Call Log - the facilities management's IT system.

2.4 DATA ANALYSIS

All information that has been gathered was put together and analysis was made by comparing the data from the different sources and categorized into criterions based on the objectives. Data analysis could also be divided into two stages: i.e. process analysis stage and system design stage.

a) Process Analysis

A comparison has been made between the documented flowchart of the business process and the data gathered from the interview. To ensure no essential actions in the process are missing, a generic process flowchart was produced. This flowchart was sent back to the process owner i.e. major parties, for them to check the validity of the business process. Eventually, problems that impede the flow of the business process were identified and discussed further with the participants.

b) System Design

At system design stage, there are two types of data that were gathered: i.e. classification of repair work and questions script.

a) Classification of Repair Work

From the interview, it was discovered that there is no standard classification of repair work. However, each property management organisation has their own design classification that suits their need. These classifications, together with the one published in a book (Lee, 1987), were compared to each other and a generic classification has been deduced to become a standard classification of repair work that suits the case study in this research. For the development of the prototype purposes, this classification has been narrowed down into the most common repair work due to the time constraint that limits the researcher to cover all of them.

b) Questions Script

The documented question scripts in the Call Centre manual book are very rigid. From the observation, most of the Helpdesk Operators do not refer to the script (not even the newly trained operators). Unfortunately, all calls are not recorded. In a group interview that was held with the operators and their supervisors, the researcher has used a tape recorder to record the discussion and try to capture their experience as much as possible. These questions were then analysed and arranged in a decision tree structure. This is important for the development of the system.

c) Other Data

The client and contractor's FM systems are laden with various types of data. This data was gathered and classified for system development purposes. For technology review (as per second objectives), comparisons were made among the information and categorised them into hardware and software.

2.5 CONCLUSION

This chapter discussed the methodology adopted for the research and its implementation in the path to achieve the overall aim and objectives. The objective of this study being to examine the existing management process and review some IT system in minor construction project has led the researcher to employ qualitative case study approach for an in-depth investigation to the subject in the research. Data was mostly collected from parties that were involved in the maintenance process such as client, contractor, facilities manager, suppliers and helpdesk operator; using various techniques i.e. open-ended interview (recorded or non-recorded), observation and document analysis. They were analyzed by comparing one source of data to another.

The next chapter will discuss knowledge management in building maintenance projects.

CHAPTER 3

KNOWLEDGE MANAGEMENT IN BUILDING MAINTENANCE

3.0 INTRODUCTION

Building maintenance is a big business (Wordsworth, 2001). Historically, maintenance activities have been regarded as a necessary evil by the various management functions in an organisation (Tsang, 1995 and Ikhwan & Burney, 1994). In the construction industry, besides always being seen as the "Cinderella" (Allen, 1993), it has become a very important part of the industry around the world.

Repair and maintenance work is not only important because of its great contribution to total construction output but also because it comprises the largest number of individual items of work (Headley and Griffith, 1997). Examples of maintenance works would include the design and construction of new roofs or internal structural arrangements, with any associated with M&E equipment, right down to remedying minor problems such as electrical failures, plumbing leaks and building fabric/ equipment failures.

Owing to the relatively small size of maintenance works, the sector has received little attention in the field of published literature (Allen, 1993; Headley and Griffith, 1997).

This chapter comprises the definition and categorisation of building maintenance, its significance to the construction industry as a whole, issues relating to the management of building maintenance and perspective of knowledge management in building maintenance.

3.1 BUILDING MAINTENANCE

3.1.1 Definition and types of maintenance

BS 3811 defined maintenance as 'A combination of any actions carried out to retain an item in, or restore it to an acceptable condition'. The definition highlights two main processes: 'retaining' – work carried out in anticipation of failure or preventative and 'restoring' work carried out after failure or also known as corrective maintenance; 'to an acceptable condition', implying the work standard is acceptable to the persons carrying out the works, paying for the works, and/or the users of the building, though the acceptability standard may vary from one person to another (Wordsworth, 2001). According to CIOB, maintenance entails work undertaken in order to keep, restore or improve facility (involving every part of a building, its services and surrounds) to an agreed standard, determined by the balance between need and available resources.

Wordsworth (2001) and Chanter & Swallow (1996) discussed at length regarding the definite definition of maintenance. Both arguments concluded that maintenance requires effective strategic management approach as the bottom line is to ensure that the buildings continue to efficiently perform the functions for which it was initially designed. It is the aim of maintenance to preserve a building in its initial state, as far as practicable, so that it effectively serves its purpose (Seeley, 1976) besides retaining value of investment and presenting good appearances. Maintenance work is necessary: 1] to maintain the safety of persons; 2] to keep property habitable (hygiene, security, electrical and water supply); 3] to keep building operable; and 4] for the appearance of the property, the provision or upkeep of non-essential services or facilities (Shen, 1997).

According to Headley and Griffith (1997) minor maintenance or small works comprise of (Figure 3.1):

- Any item of work, either improving, maintaining or
- Any item of work, either improving, maintaining or altering a part of an existing building
- Any small-scale new-build operation.
- Any item of maintenance work from any of the categories of

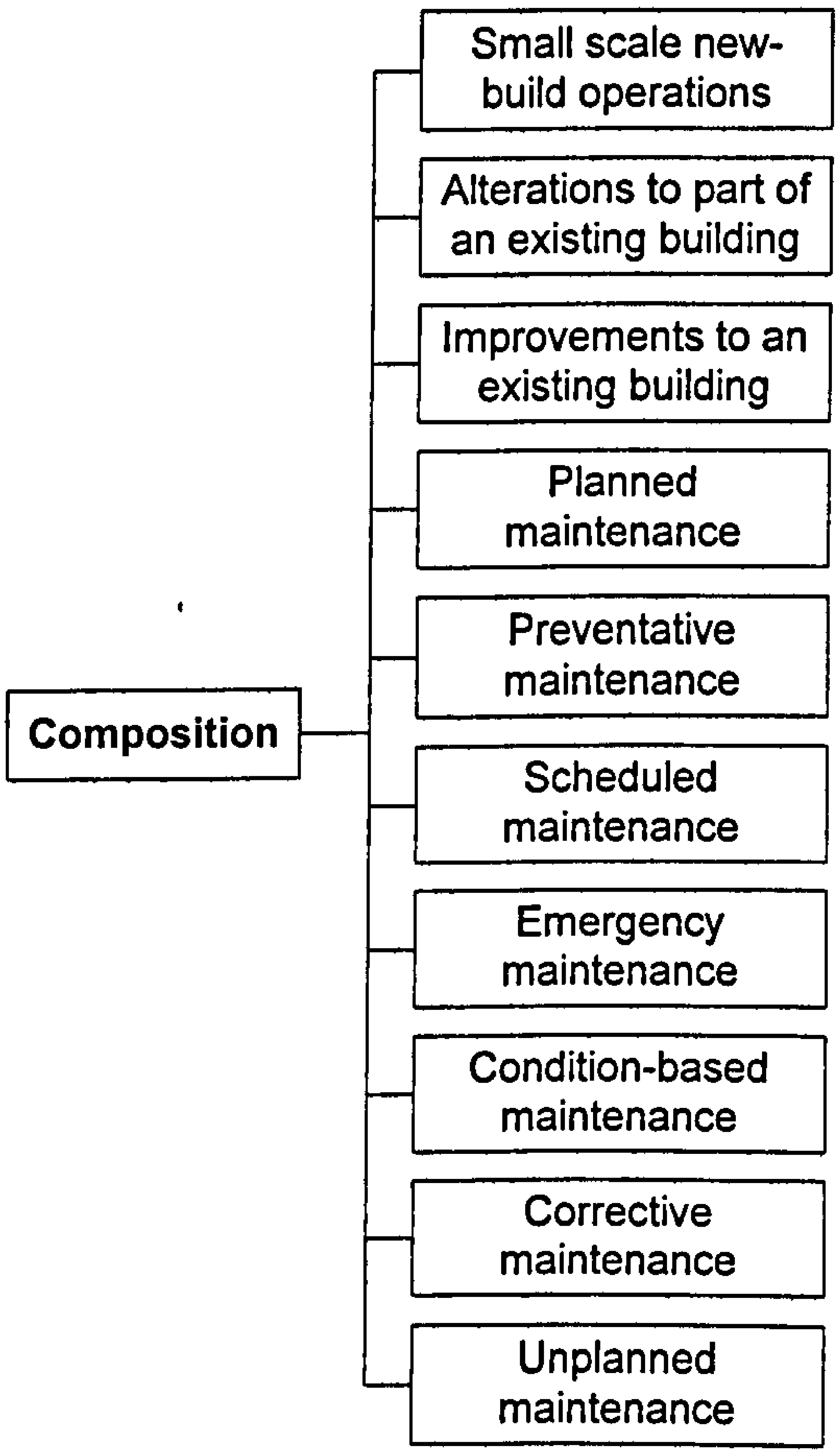


Figure 3.1: The Composition of Small Works (Headley & Griffith, 1997)

maintenance work specified in BS 3811:1

a. *Planned maintenance.* This is maintenance organised and carried out with forethought, control and the use of records to a pre-determined plan.
b. *Unplanned maintenance.* Maintenance carried out to no pre-determined plan or work resulting from unforeseen breakdowns or damage due to external causes.
c. *Preventive maintenance.* Maintenance carried out at pre-determined intervals within the expected life of the facility to ensure its continued operation, or corresponding to prescribed criteria, and intended to reduce the probability of failure (prevention of failure).
d. *Corrective maintenance.* Maintenance carried out after a failure has occurred, and intended to restore an item to a state in which it can perform its required function, or to an acceptable standard.
e. *Emergency maintenance.* Maintenance, which it is necessary to take action immediately to avoid serious consequences.
f. *Condition-based maintenance.* Preventive maintenance initiated as a result of knowledge of the condition of an item from routine or continuous monitoring.
g. *Scheduled maintenance.* Preventive maintenance carried out to pre-determined interval of time, number of operations, mileage etc.

A simple chart (Figure 3.2) from Chanter and Swallow (1996) categorising the maintenance works into planned and unplanned maintenance thread. This is further explained in another chart (Figure 3.3) of how to recognise a type of maintenance by first determining whether the work required is a planned or unplanned maintenance (also in Chudley, 1981). In practice, planned and unplanned maintenance are also widely known as proactive and reactive maintenance. The term reactive maintenance is used throughout the thesis that refers to any work that requires immediate attention.

Maintenance can also be classified into two generic types i.e. 1] Strategic; and 2] Tactical (Audit Commission as mentioned in Chanter & Swallow, 1996; Pintelon, Du Preez & Puyvelde, 1999 and Headley & Griffith, 1997). Strategic repairs and maintenance would include both planned and unplanned maintenances operations that require the long-term preservation of an asset. It involves maintenance of the building fabric (decorating and

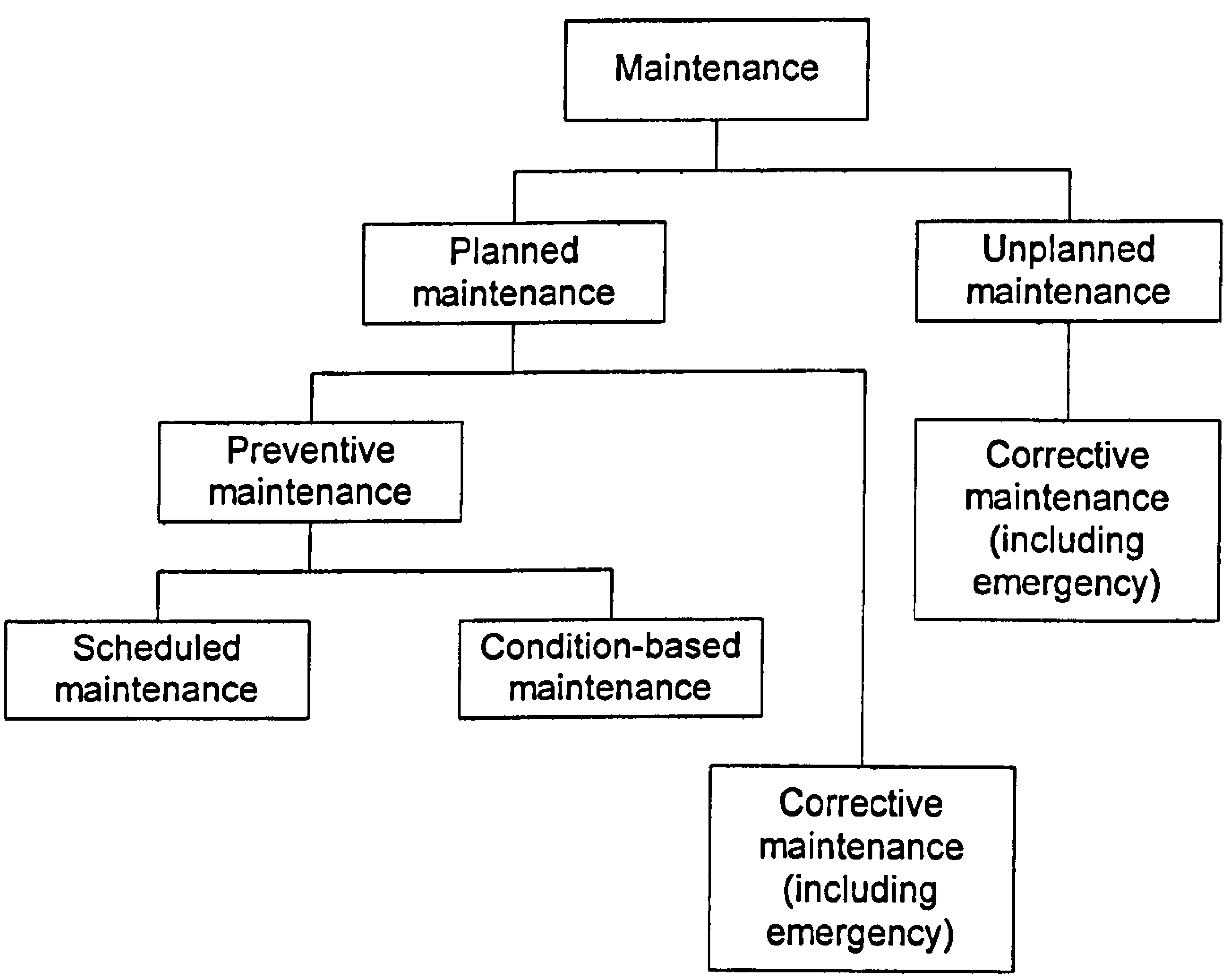


Figure 3.2: Types of Maintenance (Chanter and Swallow, 1996)

routine replacement), maintenance of engineering services installations and major structural repair work, such as re-roofing.

Tactical repair and maintenance is restricted to the day-to-day repair work, in response to immediate need such as a broken window. Tactical includes unplanned maintenance, corrective maintenance and emergency maintenance (Chanter & Swallow, 1996). According to Daren Murphy of Willmott Dixon (2000), this type of reactive maintenance work covers two third of the overall maintenance, being 80,000 out of 120,000 of total works are basically reactive maintenance work. Due to the unexpected nature of these types of faults, they are more disruptive to normal business and require immediate repairs (In the manufacturing industry, about half of maintenance time is spent on this type of maintenance (Johnsson, 1997))

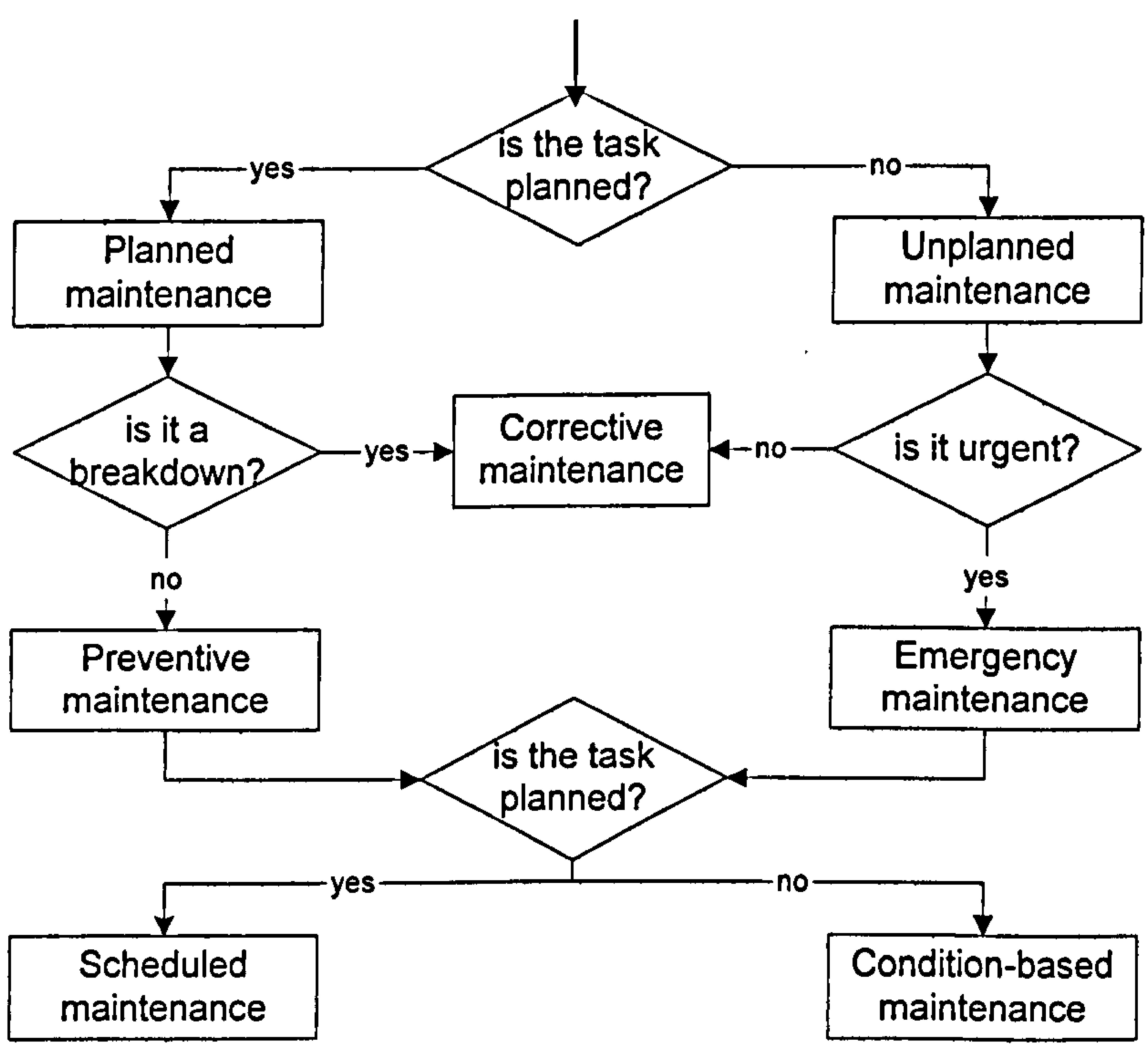


Figure 3.3: Decision Based Types of Maintenance (Chudley, 1981 and Chanter & Swallow , 1996)

However, some tactical work might be of strategic importance – for example a collapsed roof requires an immediate response (which is tactical) but is clearly of a strategic nature.

3.1.2 Significance of Maintenance

In most countries, the construction industry amounts to 10%-20% of GNP, making it the largest economic sector employing the largest amount of manual workers with the total value of US$2 trillion worldwide (Albert & Chan, 2002). In the USA, 35% of the overall turnover in the construction sector consists of renovation and modification projects (Mitropoulous and Howell, 2002). In Canada the value of maintenance activities (US$104billion) is greater than the new construction projects which is US$100 billion (Vanier, 2001). In a research on maintenance of hospital buildings in Israel, the annual maintenance expenditure (AME) constitutes 68.7% of the annual budget for optimal maintenance (Shohet and Bar-on, 2003). In Lisbon, the maintenance department of the Municipality of Lisbon claims that it frequently receives requests from tenant asking for repair works and this imposes a yearly financial burden that clearly exceeds the available budget (Costa and Oliveira, 2002). Hong Kong's overall maintenance expenditure on public buildings for the year of 1990/91 only, involved US$1000 million and the total number of work orders was around 200,000 per year (Shen, 1997).

The UK's expenditure on maintenance, repair and refurbishment, covers more than 50% of all annual construction activities (DETR, 2000; Baldry, 2002; Olubodun, 1996; Torrance, 1997; and Sun, 2003b) compare this to the period between 1970-1980 where from there on, the share of maintenance steadily increased until now. It has always been well over 40% since late 70's and early 80's (Chanter & Swallow, 1996). These types of works are carried out by firms with less than 20 employees that constitute 84% of the industry (DTI, 2000).

Each of the three large client organisations involved in this research (Whitbread Plc, Lloyds TSB and Boots the Chemist), are responsible for about 1000 to 9000 properties and issues between 50,000 to 300,000 maintenance instructions annually, at a cost of £5,000,000 to £50,000,000 on both planned and reactive maintenance (Ali et al, 2002). A facilities management consultant - WS Atkins Facilities Management, plays a significant role as it maintains a property portfolio of over 100,000, representing about 2 million work requests valued in the excess of £100 million per annum. The sheer volume of work often caused disruption to business activities, and reactive maintenance, due to its unexpected nature, is particularly troublesome.

Another example stated in Headley & Griffith (1997) is the workload of a local authority maintenance department, which involved around 200 contracts, and in excess of 60,000 works orders a year. This type of activity maintains a considerable asset value of the country's property stock equivalent to over half the nation's total wealth (Wordsworth, 2001).

3.1.3 The Issues in Maintenance

Views that the level of expenditure on maintenance is too high have been frequently expressed (Shen, 1997; Wordsworth, 2001). This serves to illustrate the magnitude of the problem in many cases. Wordsworth (2001) points out that because building maintenance is a diffuse operation, taking place incrementally through time, in many locations, and by many different organisations, the scale and importance of building maintenance work is frequently undervalued in comparison with higher-profile and more visible new construction.

Key characteristics of small work that differentiate the maintenance works from larger building works are related to certain issues i.e. risk, cost, scale, complexity, duration, technology and documentation (Figure 3.4) (Headley and Griffith, 1997).

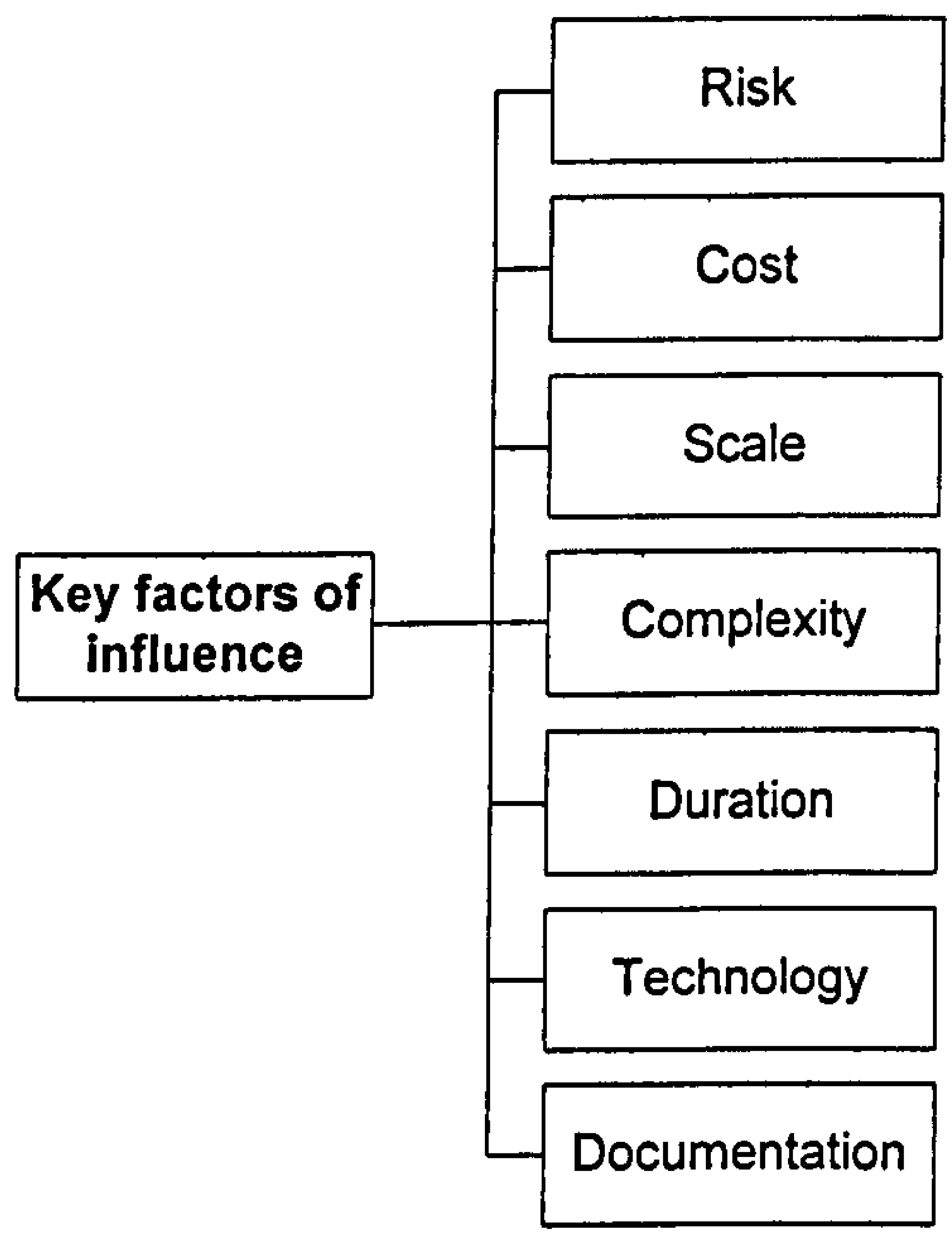


Figure 3.4: The Key Factors of influence in Small Works (Headley and Griffith, 1997)

The alteration and improvement nature of maintenance works compared to new work, demand a rapid response when variations occur. Although the works are much less complex (e.g. changing of light bulb) than higher value building work, this has resulted in a reduced requirement for consultant input, thus less documentation. In terms of duration, small work is much shorter than higher value work. Since much of the works take place in occupied buildings, consideration on disturbance and health and safety are very important.

The cost of administration and management of the small works is much greater than it would be for building work. Nevertheless, it usually involves small quantities of material, with reduced discount from suppliers and a low number of labour tasks. It is well noted that it is often difficult to specify the extent of the work due to the uncertainty of the nature of the work, which sometimes require more than one visit by the contractor.

Due to the relatively few different labour tasks involved, a subcontractor is less common in small work than building work. There is always a contractor that is able to cater for various types of repair works, unless in work involving special elements or components such as glazing work.

It is not a strange fact that the total workload of maintenance works for a typical organisation is much greater than larger or higher value type of work. Although the cost of average small works is relatively low, the total amount often exceeds the expenditure on major works. For example, the average value of maintenance work often amounts to less than a few hundred pounds but the total figure of thousands of pounds is always expected in many organisations. This smaller scale of individual items often serves to disguise the true significance of maintenance works in the context of large property maintenance.

This is due to the high frequency of these small-scale jobs, which not only cause financial burden to an organisation but also can lead to many management difficulties. An ineffective and expensive management approach can contribute to unnecessary cost especially when mistakes (often expensive and unavoidable) occur along the process. The amount of management time spent administering the small works workload may be disproportionate to the costs of the work itself. For example, in the large organisational context, contractor approved lists can easily run into hundreds likewise works orders and invoices into thousands annually. This is a situation in which inefficiencies can easily arise.

The existing maintenance management system has generated a large amount of paperwork, which made it both unwieldy to operate and tedious for those persons in-charged (Headley and Griffith, 1997). They highlight that new strategies to overcome the large amount of paperwork are by placing the workload in the hands of outsourced management contracting or facilities management organisation (also in Jones, 2000). But this would only solve the clients' workload, as outsourced management will also face the same amount of paperwork. In addition to that, it creates another chain of communication into the maintenance process. Being responsible to not only one client but also several other large clients, outsourced management, at a certain stage, will take turn in seeking ways to reduce the paperwork.

Any reduction in resources applied to building maintenance will have a visible effect on the national economy. Allen (1993) suggests that one objective in maintenance management should be to reduce the levels of manning and building maintenance. Some clients seek to reduce headcount in the maintenance department, this in corresponds with the pressure to seek greater efficiency in the organisation. The facilities management organisation in this research operates in excess of 20 Property Helpdesks providing over 100 helpdesk workstations. They are willing to look for ways to reduce the number of helpdesk operators in their call centre and have more control in their expenditure.

The reasonableness of maintenance can be considered in three factors (Wordsworth, 2001):

a. whether the amount spent is excessive in relation to the work done
b. whether the work which is done is necessary and unavoidable
c. whether it would be advantageous to carry out more work

The first point is related to the view that maintenance expenditure is too high and suggested better management and work planning would result in a more economic use of resources and a corresponding reduction in total costs. The second point is cases where maintenance works could have been avoided by better design, and the choice of more suitable materials. The third point concerning the limited resources in construction and the objective should be to achieve the optimum allocation of manpower, materials and capital between the maintenance and the construction of new buildings. It would be advantageous if replacement could be delayed by spending the resources on arresting decay and thereby defers expenditure on new construction.

Commonly client's critical success factor will usually be based on time, cost and quality. In maintenance works these factors are as below (Headley and Griffith, 1997)

1. Time
    a. Requiring minimum delay in responding to identified work
    b. Rapid response and commencement on site
    c. Certainty of finish date
    d. 24-hour and 365-day cover for certain work.

2. Cost
    a. Price competitive
    b. Price certainty
    c. Attainment of value for money
    d. Minimise cost of mistakes
    e. Minimise staff resource costs
    f. Minimise direct cost of work
    g. Minimise indirect costs of work.

3. Quality
    a. Different standards for front of shop/behind the scenes
    b. Appropriate for purpose
    c. Guarantee for client.

The quality and efficiency of a building maintenance operation depends on how this information is collected and used, i.e. 1] the condition of the building 2] the needs of the users and 3] the works carried out (Allen, 1993). Other factors which are equally important are 1] health and safety – since maintenance works take place in occupied buildings; 2] flexibility due to the uncertainty of the nature of the repair work required; 3] ease of data gathering – the high amount of information of maintenance works sometimes are made abandoned; 4] security – security of the occupiers of the building and minimum disruption to ongoing activities within the organisation and; 5] accountability for decision makers.

Many organisations have either recently carried out, or are currently conducting, an examination of the effectiveness of their current maintenance management policies. This suggests that there has been widespread internal recognition of inefficiencies in the ways that many large organisations procure their small works. This trend has resulted in many organisations carrying out re-engineering and new policy implementation exercises in an attempt to improve their services. As with many other organisation these days, the issues of retaining the most valuable asset i.e. knowledge has been seen as a way to gain competitive advantage.

3.2 KNOWLEDGE MANAGEMENT AS SOLUTION

Newman (online) in his Knowledge Management Forum has gathered various definitions and descriptions of knowledge management, which can be summarised here as a collection of processes that create, acquire, organise, share and use knowledge within an organisation.

It is pertinent to note that it is increasingly being recognised that knowledge is a valuable asset, which needs to be managed. The discipline of Artificial Intelligence has been striving to formalise and apply knowledge to a wide range of problem solving tasks. However, it is only in recent years that it has been widely recognised that knowledge management is more than the encoding of knowledge as rules in an expert system or the training of neural network to recognise some pattern. Knowledge management is a management process that embraces the entire system within which the technology operates. This includes people, processes, strategy and the culture of the organisation for the enhanced management and leverage of human knowledge and learning in the organisation (Figure 3.5) (Ahmed et al, 2002). The interactions between these elements will allow an organisation to manage knowledge effectively and sustain competitive advantage (Bhatt, 2001). Organisations are required to reconsider and analyse the balance between the technological and social facet of the organisation and not to address one side of the components of knowledge (i.e. use of information technology to increase the circulation of information) (Mc Dermott, 1999; Lang, 2001).

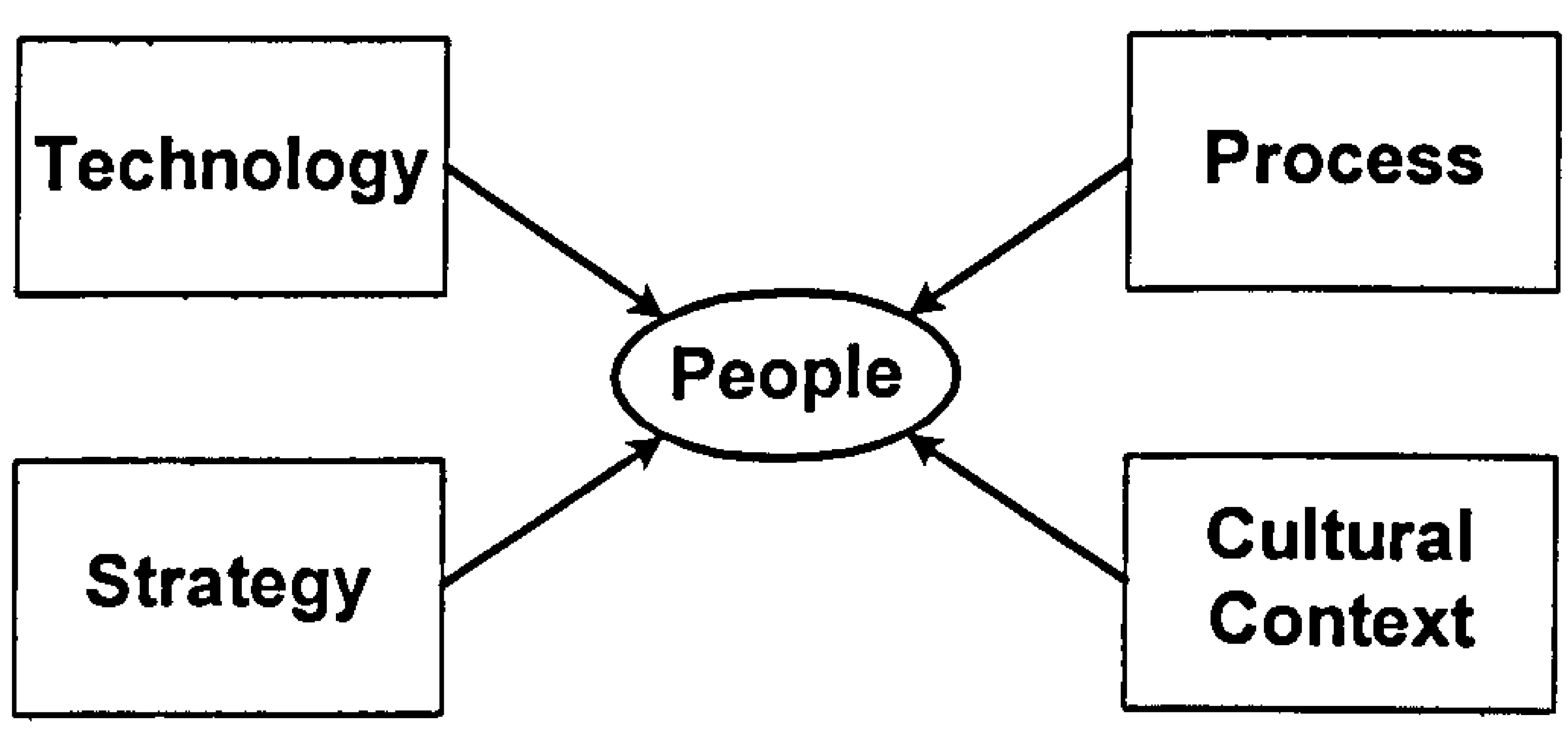


Figure 3.5 Key Elements of Knowledge Management (Ahmed et al, 2002)

Current knowledge management thinking is that organisations should create flexible technological infrastructures that do not attempt to formalise all problem solving knowledge into rules but rather they create more informal environments that encourage employees to share knowledge, to collaborate and learn. This new knowledge coincides with the explosion in availability of Internet access, a huge cost of establishing Intranets, Extranets and secures Virtual Private Networks and the increasing "web-awareness" of common desktop productivity tools such as Microsoft Office and Microsoft Project.

Many companies began to develop more structured ways for managing knowledge that has led them to see the management of knowledge and learning as a core competency, fundamental to sustaining competitive advantage. Among the potential benefits materialised from successful knowledge management programme are (Ahmed et al, 2002):

1. Improved innovation (improve product and service)
2. Improved decision making
3. Quicker problem solving and fewer mistakes
4. Reduced product development time
5. Improved customer service and satisfaction
6. Reduced research and development

The emergence of knowledge management in business organisations to leverage knowledge to enhance business success can be considered as fairly new. To the best of the researcher's knowledge, little literature relating to knowledge management in building maintenance exists. Nonetheless, the importance of knowledge management especially with the use of information technology as an enabler has begun to be seen as a potential area in the facilities management area – the “umbrella” industry of building maintenance (Nutt, 2000; McLennan, 2000; Barrett, 2003).

3.3 KNOWLEDGE MANAGEMENT IN BUILDING MAINTENANCE

Like other sectors in the construction industry, each building maintenance project involves various parties which individually possess certain types of knowledge. Unlike physical assets, a human employee is an asset that moves from one place to another and carries along the most valuable asset an organization could have ever g ot, to sustain competitive advantage, which is knowledge.

Not only that, a maintenance project involves plenty of information and requires some stages of decision-making, it also demands an efficient level of communication. The various parties involved in a maintenance project mean it entails a long chain of communication, and information needs to be communicated from one party to another in the minimum time possible to avoid a job being delayed. Occasionally this type of maintenance work still requires a longer time than it was supposed to be since the contractor has to revisit the site.

Some examples of building maintenance information are the nature of repair work, priority response time, building location, contractors' and suppliers' details, status of work progress, feedback on contractor's performance and maintenance cost. Management is overloaded with paperwork and some information is abandoned, as they are not available to be shared or reused.

Health and safety is very important considering the maintenance work has to be taken in occupied building. This issue is sometimes overlooked due to the nature of the work which seems small and trivial. For example, the dampness on the ceiling in a restaurant/ pub can spread infectious fungi on foods or "slippery floor" when plumbing is broken. Health and Safety information should not only be for the occupiers of the building but also for the safety of the people who come to repair the problem i.e. the contractor (Chudley, 1981).

3.3.1 Information Technology in Building Maintenance

Due to the high proportion of building maintenance in the construction industry, problems and difficulties with regards to the management of maintenance have brought many researchers into various aspects of building maintenance, which are mostly aimed at minimizing building maintenance cost. For example a study on prediction of maintenance costs (Underwood and Al-shawi, 1999); study on factors of maintenance requirements (Olubudon, 1996; Engelhardt et al, 2002) or factors affecting the maintenance costs (El-Haram & Horner et al, 2002); and also research on the strategic management of the maintenance (Horner et al, 1997; Griffith and Phillips, 2001; Leibovich and Shohet, 2002). One area of the research is related to the optimisation of preventative maintenance schedules and maintenance policy using statistical models (Madu, 1990, Dekker, 1998). The focus of these studies is on the accurate prediction of costs for different maintenance schedules.

Research on the application of IT in construction has gained the interest of many researchers for many years (e.g. GALLICON (Aouad et al, 2001); WISPER (Faraj & Al Shawi, 1999); OSCON (Aouad, 1997); INSITE (Sulaiman, 1997)). IT has contributed in other field service management in other industries such as manufacturing (e.g. Tsang, 1995), retail (e.g. ClickSoftware, online) or mining (e.g. Lewis & Steinberg, 2001). In the building maintenance industry, there are several researches on the use of IT (e.g. Watson & Brandon, 1992; Perera, 1997). Wang and Xie (2002) adduced a system that integrates building management systems and facilities management systems using Internet/Intranet. Finch (2000) presented an overview of the impact of the Internet on the facilities management business.

In addition to research initiatives, there have been many commercial software packages of Computer Aided Facilities Management (CAFM) and Building Management System (BMS). These systems have components for all areas of FM, such as space management, property and lease management, furniture and equipment management, telecommunications and cable management. However not all of them have a reactive maintenance component.

There is also a group of systems called Field Service Management systems, which are for the control of information when people are being sent out to locations to repair problems. These systems are a level above CAFM, as they are more generic as they can be used for facilities management or in other industries, such as laser printer servicing etc.

Some companies will have developed their own system in-house (bespoke system). However, the existing FM systems do not provide a cost effective solution for the particular problem of big client organisations managing a large number of small maintenance jobs (Sun et al 2003).

A large number of studies have illustrated the benefits of using IT in the construction industry (Torrance, 1997; Barret, 1997; Betts, 1999). IT as an enabler plays a major role in achieving major improvements in the construction industry (Aouad et al, 1999; Smith, 2001). Aouad et al (1999) emphasise the importance of addressing the business process when investing in IT. IT approach (strategy) prior to that was perceived/ seen as a driver (Allen, 1993), which unfortunately has frustrated the industry. Many firms were disappointed with the investment they made in IT as, in the first place, they had neglected the actual business needs.

IT can be described as "the integration of telecommunication, data processing and office automation (Karake (1994) cited in Pintelon et al, 1999). It consists of hardware and software components, data communications equipment and data base management systems. Davenport and Short (1990, also cited in Pintel et al, 1999) listed several functions that an IT system has.

1. Transactional – transforming unstructured processes into routine transactions
2. Geographical – making fast communications over long distances possible
3. Automational – reducing human labour

4. Analytical – using complex analytic methods
5. Informational – processing large amount of information
6. Sequential – allowing work on multiple tasks
7. Knowledge Management – capturing and disseminating knowledge and expertise to improve process
8. Tracking – allowing detailed follow-up on task status, inputs and outputs
9. Disintermediation – directly connecting two parties that would otherwise communicate through an intermediary

The growth and accessibility of the World Wide Web (WWW) has been instrumental in catalysing opportunities for knowledge sharing (Ahmed et al, 2002). The role of web-based technology system improves inter-organisational communication, reductions of time delays and information flows (Mohamed, 2003). Network technology, with its available information can be accessed at any time and anywhere.

3.3.2 Cultural Barriers

Knowledge is becoming a sustainable competitive advantage for an entity in today's society. It must be protected, cultivated and shared among the entity's member. This is where knowledge management plays its role.

A learning process must occur in an organisation to ensure the organisation's knowledge stays and grows. In order to learn, knowledge has to be shared. With the development of current IT, knowledge can be shared faster, and be more accurate and reliable. However, sharing knowledge is what some people are reluctant to do. Although this has become a typical cultural barrier in many organisations, it is something that will bring greater impact to an organisation if the barrier is brought down.

It is easier to transform explicit knowledge into tacit knowledge when people cooperate, trust each other and willingly contribute their own valuable knowledge resources (Smith, 2001). These can occur when people who add to and use databases are appropriately recognised and rewarded for sharing their special form of knowledge. Since individual expertise in an organisation is a valuable asset to an organisation, management should create an environment that encourages its employees to collaborate (Bhatt, 2002). With this, it enhances employee's knowledge and creats organisation knowledge through individual interactions. IT tools is an enabler for sharing knowledge (McDermott and O'Dell, 2001). It acts as a catalyst for knowledge management (McDermott, 1999). A review on knowledge management literature (Swan et al, 1999) suggested that knowledge management literature is biased towards a technological agenda and concluded that soft issues (social and behavioural factors) from wider organisational perspective have been ignored.

Many recent researches argued that technology alone could not deliver knowledge management and emphasise the importance of balancing the cultural and technological issues (McDermott, 1999; McDermott and O'Dell, 2001; Bhatt, 2001, 2002; Davenport and Prusak, 1998a; Lang, 2001; Hendriks, 2001). Nevertheless, after all these years, IT has proven its reliability in storing and disseminating knowledge especially with the robust development of the World Wide Web which has significantly improved the level of communications in daily life. Every IT strategy comes along with some changes in the business process and the most affected are the individuals in the organisation i.e. the way they work and behave. To change them is not an overnight task. It requires consistent motivational support e.g. incentives and rewards (Bhatt, 2001 and McDermott and O'Dell, 2001) to get people willingly involved in the process to achieve the business goals.

The sections that follow review the importance of knowledge management in organisations, the theory of knowledge, tacit versus explicit knowledge, the conversion of knowledge, and information and communication technology (ICT) in knowledge management.

3.4 THE IMPORTANCE OF KNOWLEDGE MANAGEMENT IN AN ORGANISATION

In order to gain an optimum outcome of knowledge management, Bhatt (2001) refers to knowledge management as a process of knowledge creation, validation, presentation, distribution and application (as depicted in figure 3.6) which requires coordination of these phrases. Knowledge

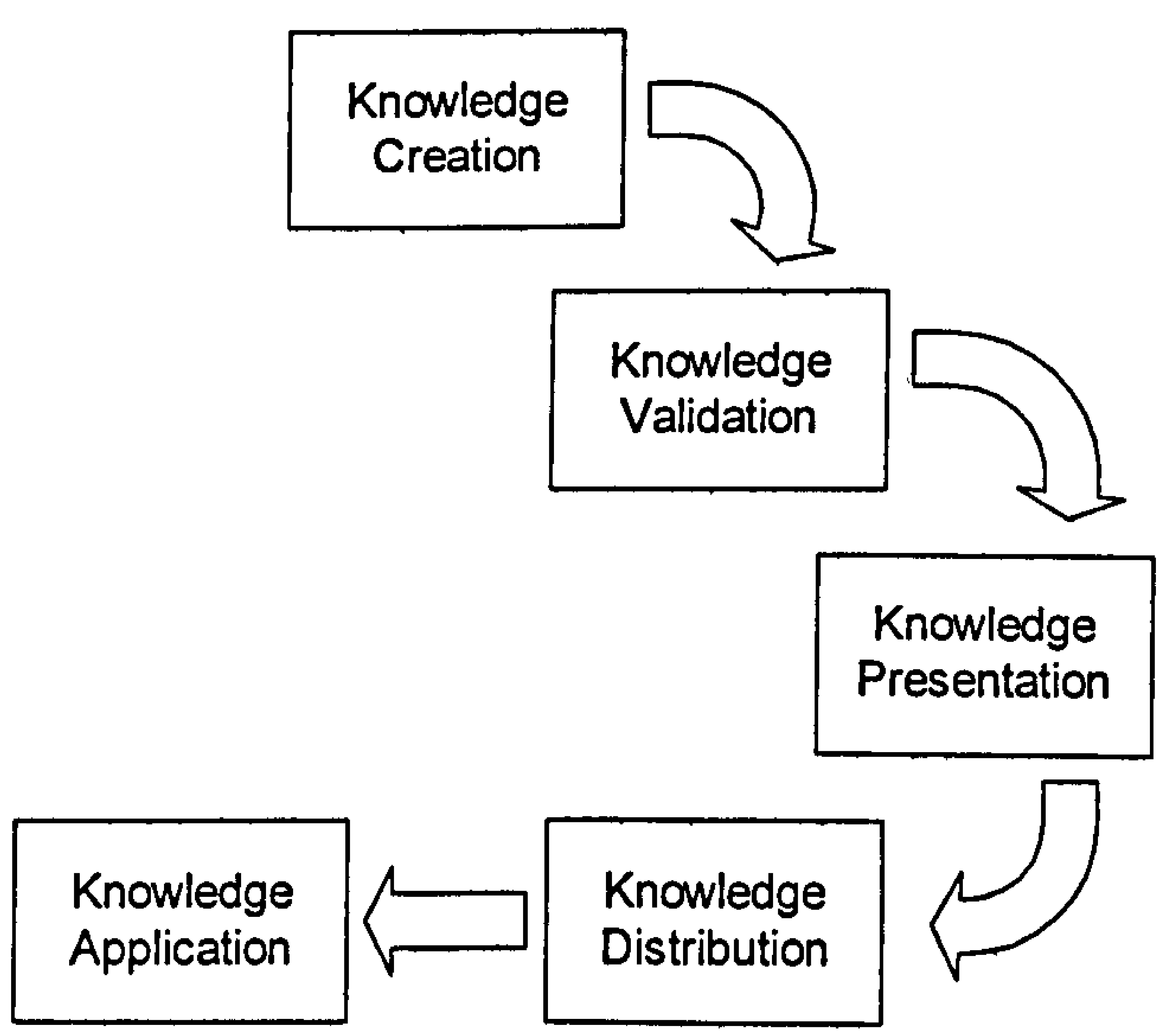


Figure 3.6: Knowledge Management Process Activities (Bhatt, 2001)

management, with the right tools, is probably the most profound way to change an organisation and gain a strong competitive edge. By effectively creating, capturing, sharing and utilising the company's wide knowledge, successful knowledge management is also contributing in many environments to enhance team performance, customer service, corporate culture, management roles and employee relations (Seeman, 1997).

Knowledge management helps an organisation to gain insight and understanding from its own experience. The activities in knowledge management will also help the organisation in problem solving, dynamic learning, strategic planning and decision-making (Ahmed et al, 2002). Besides the knowledge management process of capturing, structuring, utilising and disseminating, knowledge can protect intellectual assets from decay, adding to firm intelligence and increased flexibility. It is more readily transferred and made accessible to individuals throughout the organisation. In today's environment, knowledge must be accessible when needed and where needed. This is where information technology can provide effective and efficient tools to enable the facets of knowledge management from capturing knowledge, to sharing and applying it.

Knowledge management is there to make an organisation more productive, more effective and more successful. It is introduced to enhance collaboration, to improve productivity, to enable and encourage innovation, and to coup with information overload and deliver only the essentials (Srikantaiah, 2000). Knowledge management at Ernst & Young has led to a 44 percent increase in revenues and they are planning to extend it into their other practices and geographies (Davenport, 1997b). Microsoft and Hewlett

Packard have proved that the knowledge management that they implemented in their organisation has increased the advantage margin over their competition, encouraging communication among employees besides increasing the knowledge in other areas such as competition, marketing, product development and customer services (Davenport, 1996 & 1997a).

There are some factors that make knowledge management fundamental in today's organisation (Skyrme, online):

1. The value of an organisation's wealth is increasingly in its intangible assets - its people, know-how, brands, patents, licences, customer relationships etc.
2. Knowledge can command a premium price in the market - applied know-how can enhance the value of products and services.
3. As suppliers and consumers get more globally connected (e.g. through the Internet), access to critical knowledge becomes easier and more cost effective.
4. As organisations become more efficient at what they do, they need to apply new learning and talent to help them differentiate themselves in the marketplace.
5. By retaining knowledge as organisations downsize or restructure, organisations can save costly mistakes and prevent "reinventing the wheel".

Organisational knowledge does not replace individual knowledge; it complements individual knowledge, making it stronger and broader. Thus the full utilisation of knowledge, coupled with the potential of individual skills, competencies, thoughts, innovations and ideas will enable a company to compete more effectively in the future.

3.5 THE THEORY OF KNOWLEDGE

Data can be in the form of numbers, text, letters or graphic and is the means through which information and knowledge is stored and transferred (Ahmed et al, 2002). When data is interpreted, put in context and given a meaning, it becomes information. For a human being, the element of thinking and reasoning when utilising the information is called knowledge. For instance, 100 will remain a number form of data unless it is related to a circumstance such as 100 degrees Celsius of boiling water, which means it is very hot – thus, this is now information. Hence, a person approaching a kettle of boiling hot water, has to apply reasoning and thinking before he touches it especially if the kettle is made of stainless steel as he knows it will hurt his finger and that he will have to apply extra care. He might only touch it with his fingertip to confirm the information. This person uses his knowledge that "boiling hot water can burn skin" to avoid getting hurt.

Not only that, he also has information that "stainless steel is a material with a low melting point" and "polymer material melting point is very high". He reasons with "stainless steel is better heat conductor than polymer material" to decide whether to touch a kettle or not. Since his aim is to make a cup of coffee, once he knows the state of the water, he now can decide what to do next. He has to put the kettle on if it is cold or use the water to make the drink if it is already hot. Information combined with experience, context, interpretation, reflection and perspective (Davenport et al, 1998b; Kerchner, 1997) is knowledge that helps us to make decisions.

How does a man gain knowledge? Knowledge is absorbed into the brain and transformed into action via sense organs as the medium (eyes, ear, nose, tongue and skin - five human senses i.e. vision, hearing, smelling, tasting and touching) and motor organs (the limbs, the arms, the throat etc.), meant for performing specific work. Frequent actions will develop skills and one can become expert when skills and knowledge come hand in hand. They are many ways to gain knowledge. It is either finding it through documents, learning from surroundings or learning from other people. The first requires one to gain the knowledge from printed/published materials either in electronic or conventional (paper) form. As in the above example, the man could have read about temperature of boiling water from books and then applied it to his daily life. The second is experience gained when one has to go through a situation by himself e.g. one might have an experience with skin burn suffered from a domestic accident while playing in the kitchen when he was small which taught him about the danger of hot boiling water. The third is by mixing around with other people and sharing one's knowledge with others' e.g. this person might have learn from his friends who shared their experiences or knowledge related to hot boiling water. Knowledge involves an individual combining his or her experience, skills, intuition, ideas, judgements, context, motivations and interpretation. Information has little value and will not become knowledge until it is processed by human mind and that knowledge involves the processing, creation or use of information in the mind of the individuals (Ash 1998; Kirchner, 1997). It involves integrating elements of both thinking and feeling (Ahmed et al, 2002).

Learning is an important element in gaining knowledge Argyris & Schon, 1996). Learning new knowledge, learning from mistakes, learning from surroundings, learning from one individual to another individual and etc. are important to help people in making a decision in their daily life. All living creatures learn from each other but humans can absorb more knowledge compared to others given the bigger size of our brain that explains the human's ability. This unique human capability of making meaning out of information is deemed very important to knowledge (Miller, 1999).

3.5.1 Tacit versus Explicit Knowledge

Theory of knowledge can be traced back hundreds of years ago to philosophical epoch during Aristotle and Plato where knowledge at that time was believe to be a set of common sense (Popper, 1979 & Cornford, 1935). Merriam-Webster Collegiate Dictionary (online) defines knowledge as the fact or condition of knowing something with familiarity gained through experience or association. It applies to facts or ideas acquired by study, investigation, observation, or experience (Merriam-Webster, online). An alternative view given by Baker and Barker (1997) is that knowledge is created when information, which is the raw material for knowledge, is applied in a particular context. Knowledge can be classified into 1] descriptive: know what 2] Procedural: know how 3] Reasoning: know why. Nevertheless, before considering the management of knowledge in an organisation, it is necessary to distinguish between two types of knowledge, which is tacit and explicit knowledge.

Knowledge can be conceptualised into two types i.e. tacit and explicit. Polanyi (1958 a & b, 1967) first distinguished between tacit and explicit knowledge. According to him, explicit knowledge is set out in written words or maps or mathematical formulae and tacit knowledge is an unformulated knowledge such as something that we are use to doing it and find it very difficult to describe or express (Ahmed et al, 2002). Polanyi (1967) again emphasised on the important of tacit knowledge by saying that tacit knowledge is the dominant principle of all knowledge, and that its rejection would, therefore, automatically involve the rejection of any knowledge whatever.

In a very simple term, Koenig and Srikantaiah (2000) construe tacit knowledge as knowledge that is in people's hands or in their own files, as distinguished from explicit knowledge, which exists in documents or database. Tacit knowledge is usually transferred by demonstration rather than description, encompasses skills (Ahmed et al, 2002) and associated with common sense (ElAshaheb & Aouad, 2003). It also described as a personal knowledge embedded in individual and involves intangibles factors such as personal belief, perspective and value (Patel et al,2000; Court, 1997). Nonaka and Takeuchi (1995) give further definition to differentiate both types of knowledge. Tacit knowledge, according to them, is usually in the domain of subjective, cognitive, and experiential learning. It is non-articulated; embedded in contexts and actions; very personal and hard to verbalise or communicate (Nonaka, Reinmoller and Senoo, 2000). Explicit knowledge deals with more objectives, rational and technical knowledge that is typically well documented, accessible and easily shared. Explicit knowledge can be codified and therefore, can be stored and shared, whereas tacit knowledge remains in someone's head and cannot be codified (Saharasbudhe, 2000). Sharing tacit knowledge can only occur through networking among those people in possession of tacit knowledge. Nonetheless, the interaction of tacit and explicit knowledge often create new knowledge and innovation (Ingirige et al, 2002)

3.5.2 Types of Tacit Knowledge

Scharmer (2000) has divided tacit knowledge into two by addressing two questions i.e. how does a company become aware of and utilise its "imagination"? And what kinds of knowledge do companies need in order to sense, perceive, actualise and exploit the emerging markets and opportunities? He distinguished between two types of tacit knowledge i.e. embodied tacit knowledge and not-yet-embodied tacit knowledge or 'self-transcending' knowledge in order to answer the questions.

He illustrates that [1] Embodied-tacit knowledge is based on action experience, whereas not-yet-embodied knowledge is based on aesthetic experience. [2] Embodied tacit knowledge needs a different kind of managerial infrastructure from that needed by not-yet-embodied tacit knowledge and [3] The capacity to tap into the sources of not-yet-embodied-tacit knowledge is the only sustainable source for competitive advantage in a highly competitive age.

He further explains these three forms of knowledge; explicit, tacit-embodied knowledge and tacit-not-yet-embodied knowledge from a different point of view. Explicit knowledge relates to the reality that it emanates *from outside*. For example, a person's knowledge about 'the world tallest twin tower building is located in Kuala Lumpur' does not enable him to actually produce the thing that the knowledge signifies. He produces a statement about the 'known', but cannot bring it into existence. Knowledge, from this point of view, is a thing.

Embodied tacit knowledge relates to the reality that it signifies *from within*. Here the knower does not talk about the building, but actually builds and constructs it. This type of knowledge enables the knower to produce and bring into existence the 'known'. Knowledge here is not a thing but a living process. It is about doing things.

Not-yet-embodied tacit knowledge emerges to reality both *from within and from outside*. This knowledge is about the origins of doing things. Knowledge, from this point of view, is a field or place that gives rise to the process of enacting tacit knowledge in the first place.

To make knowledge management effective, bringing explicit knowledge and tacit knowledge together in an infrastructure is absolutely essential. Both types of knowledge have a symbiotic relationship (Srikantaiah, 2000) whereby tacit knowledge contributes to explicit knowledge and vice versa.

3.6 THE CONVERSION OF KNOWLEDGE

In today's world of business and information era, intellectual capital is something that a company has to take into consideration in order to sustain a competitive advantage. Since explicit knowledge can be verbalised and communicated among the customers and suppliers, companies can accumulate and utilise such knowledge. However, this knowledge is often a public knowledge, which is available to all competitors, and hardly becomes the basis for sustainable competitive advantage.

Tacit knowledge is rooted in an individual's action and experience as well as in the ideals or values he or she embraces. This intellectual asset, an intellectual capital for a company, can add great value to the company's daily operation. So it must be captured, stored, disseminated and utilised. The company might loose this valuable asset when the person leaves the company and offers his or her knowledge to its competitors (Smith, 2001). As a result, this will create a threat to the competitive advantage that they have already had.

Tacit knowledge can be articulated through observations even though those who have tacit knowledge are not able to express it. To make use of tacit knowledge for competitive advantage, it needs to be articulated and utilised by companies and their partners (Nonaka, Reinmoller and Senoo, 2000). Tacit knowledge needs to be converted into explicit knowledge in order for it to be shared and utilised by others. The conversions between these two kinds of knowledge are the essence to 'knowledge creation' (Nonaka & Takeuchi, 1995).

Nonaka and Takeuchi (1995) (also in Nonaka, Reinmoller and Senoo, 2000) describe the conversion of tacit to explicit, and vice versa, by categorising it into four type of conversions namely socialisation, externalisation, combination and intenalisation. This is depicted in SECI Model in Figure 3.7.

1. *Socialisation* is the process of sharing the tacit knowledge of individuals. Sharing is a key to understand others' way of thinking and feeling through observation, imitation or practice. This is tacit to tacit conversion.
2. *Externalisation* requires tacit knowledge to be transferred or recorded into forms, documents, database etc. where while doing this editing, summarising or arranging information into order is the key process. This is tacit to explicit conversion.
3. *Combination*, which is explicit to explicit conversion, involves the conversion of explicit knowledge into more complex sets of explicit knowledge. Here, the new knowledge transcends the group and is diffused or disseminated throughout the organisation.
4. *Internalisation* means a process of experiencing knowledge through an explicit source. The newly created explicit knowledge is converted into tacit knowledge of individuals. Practical training, exercise and learning by doing are important to embody explicit knowledge. One can combine the experience of reading a report with previous experiences.

The model in Figure 3.7 describes how individuals or groups go beyond their restricted knowledge to promote the dynamics of knowledge creation within an organisation. Also, organisations can transcend their boundaries by engaging in conversion process with their partners, such as customers and suppliers. The example below shows how this cycle applies to a Helpline customer service (Russel, online).

The cycle starts on the help desk with a call. The person in charge listens to the caller and tries to understand their problem, which through that,

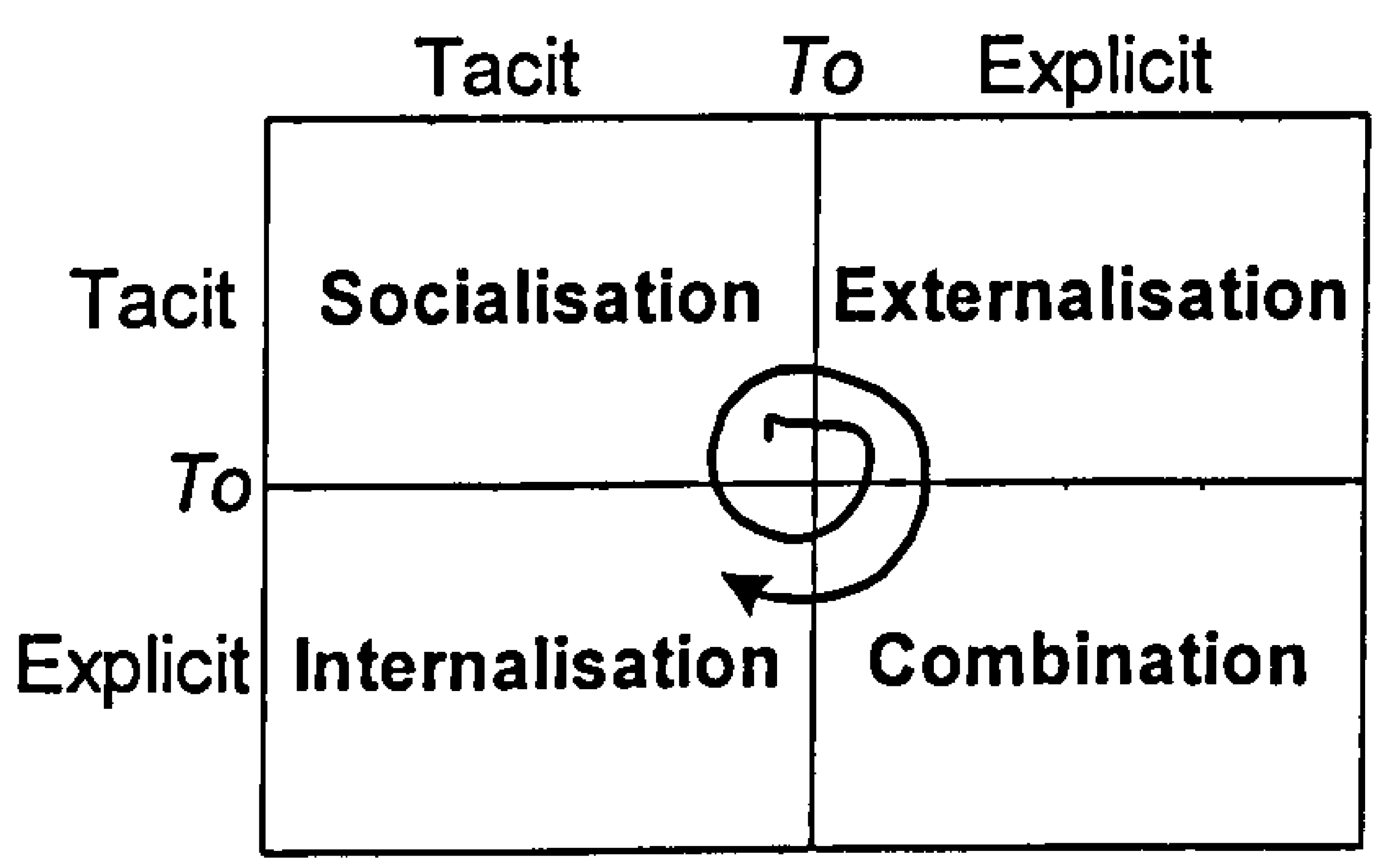


Figure 3.7: SECI as a Self-trancending Process (Nonaka, Reinmoller and Senoo, 2000)

the person is creating a new tacit knowledge. As he is successfully solving the problem, he may record his solution in his own database or notebook for his own use. Now, the tacit knowledge has become explicit. If the organisation has its own knowledge base that the help desk shares, he can upload this new knowledge into the database for others to use in the future. This knowledge base combines individual explicit knowledge into a shared explicit knowledge. This is where explicit to explicit conversion applies. Finally, the explicit knowledge is converted into tacit knowledge when other members of staff are accessing this knowledge and utilising it.

3.7 STAGES IN KNOWLEDGE MANAGEMENT PROCESS

Knowledge conversion is the key to the knowledge management process. Each conversion that knowledge flows through, provides a platform where knowledge management methodology and tools can be identified and developed. Ruggles (1997), when justifying about knowledge tools, has classified the knowledge management process into three general categories:

1. Knowledge generation

This is one of the keys to an organisation's long-term viability and competitiveness. It includes the creation of new ideas, the recognition of new patterns, the synthesis of separate discipline and the development of processes. Knowledge generation can be divided into acquisition, synthesis and creation of knowledge:

a. Acquisition

Getting 'new' knowledge from various resources e.g. primary resource (practical experience) or secondary resource (publications from the Internet or hardcopies materials).

b. Synthesis

Synthesis is about bringing ideas together, often from extremely diverse sources, and recombining them so that new ideas can emerge.

c. Creation

Creation of knowledge is usually limited to a person or group's creativity. However, with appropriate tools, people are able to create something that is beyond their creative mindset and would have been difficult to achieve from their own paradigms.

2. Knowledge codification

Knowledge codification is the representation of knowledge so that it can be accessed and transferred. The results need to be available for others, internally and often externally. It can be divided into 4 categories of knowledge:

a. Process knowledge

This knowledge is useful in optimising operations and increasing efficiency

b. Factual knowledge

Factual knowledge is knowledge that resides in people's head. It is low value-added information unless synthesised and contextualised.

c. Catalogue knowledge

Knowledge that resides in an individual of an organisation whom knows where to go for the right knowledge.

d. Cultural knowledge

This knowledge is about people whom know how things actually get done in an organisation. This relates to cultural issue that, at the moment, still appear as barriers to the implementation of knowledge management.

3. Knowledge transfer

Knowledge that has been acquired and codified or structured must be able to be transferred from among users or databases. The farther apart two people (groups) are on places, the more difficult it is to pass along true knowledge.

The knowledge management process involves many stages and addressing many different needs. Wiig (1997) describes four separate functions of knowledge management in handling knowledge. These functions are shown in Figure 3.8. They deal with how knowledge makes its way from where it originates (experts, R&D Programme, etc.) to where it finally can be used (thin line arrow). The broken arrow shows the information that is being reuse throughout the process. The last function is where the knowledge is being applied during delivery of product or services (thick line arrow). The details of each function are as follows:

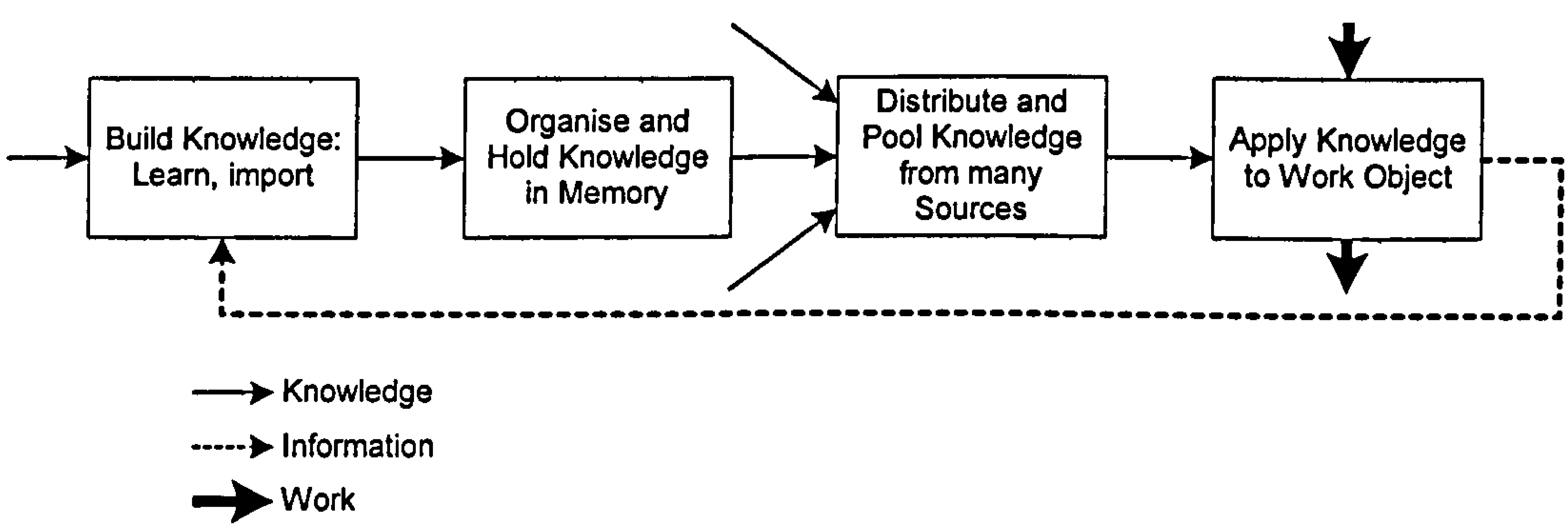


Figure 3.8: Four Stages of Knowledge Transition from source to Use (Wiig (1997)

1. Knowledge creation and sourcing - Build knowledge from innovation, learning and importation. Assemble knowledge from outside and internal experts, R&D, and lessons learned from programmes, books, articles and etc.
2. Knowledge compilation and transformation - Organise and hold knowledge in memory and remember. Reconstruct, validate, and inventory the obtained by organising it, weeding out outdated and wrong knowledge.
3. Knowledge dissemination - Distribute and pool knowledge from many sources and disseminate knowledge to where it is needed, either to people or embed it in systems.
4. Knowledge application and value realisation - Apply knowledge to work objects. Use knowledge to create and deliver products and services.

In analysing the different perspectives of stages in the knowledge management process, they appears to be certain noticeable similarity among the perspectives. The elements of knowledge gathering, storing, sharing and use are common among the perspectives. By using the SECI models as a platform, it can be concluded here that the main stages in knowledge management process are as below:

1. Knowledge Acquisition
2. Knowledge Organisation and Storage
3. Knowledge Distribution and Use

3.7.1 Knowledge Acquisition

Knowledge acquisition is driven by the types of information that an organisation need in their business process (Chun, 1998). Knowledge is pulled and captured from various sources either through first hand experience, sharing thoughts and feeling during socialisation or getting new knowledge from published materials in the Internet or books etc. In this process, knowledge is identified, created and gathered. As described earlier in this chapter, socialisation is where tacit to tacit conversion occurred. The SECI spiral has verified that explicit to tacit knowledge conversion (internalisation) is also applied during this stage as individual in the organisation starts using stored or recorded data.

3.7.2 Knowledge Organisation and Storage

Knowledge that has been gathered will be organised or structured in a way that it can be later easily found and retrieved, thus, utilised. The acquired information is edited, summarised or codified before it is stored in the knowledge base. Other processes that might be involved in this stage include cataloguing, indexing, filtering, refining or linking related information with each other.

Database is a space where information can be kept and retrieved from. Knowledge that has been organised will be stored in a database and updated when required.

At this stage, the process of organising the knowledge and later storing it in the database is where the externalisation conversion from SECI model applied. Tacit knowledge that is captured in the first stage is transferred into explicit documents.

In a knowledge database, the new knowledge is probably a totally new branch of knowledge or an updated knowledge to the existing ones. The combination of new explicit knowledge with the existing explicit knowledge will result in a more reliable database for the organisation. Again, SECI knowledge conversion model has provided a genuine platform for the knowledge management process.

3.7.3 Knowledge Distribution and Use

The goal of knowledge distribution is to increase the sharing of information. Knowledge sharing across the organisation is used as a strategic tool, to boost customer services, decrease product development times, and to share best practice. Computer systems that are networked across organisational boundaries can improve the flow of information and knowledge to meet business goals.

Knowledge use is for the creation and application of knowledge through the interpretive and decision-making process. In organisational learning, an individual uses information to create knowledge, not just in the sense of data and facts but in the form of representations that provide meaning and context for purposive action. The use of knowledge is unfolded through social interactions dispersed over space and time.

One of the ideas of knowledge management is to learn about something and use them. Knowledge is to be shared and utilised to improve competitive advantage. Besides, knowledge management makes people learn from the experiences that other people have gone through.

So, knowledge distribution and use is a stage where stored information is open to anybody in the organisation to utilise it. This process will not only increase the value of an individual's knowledge but also organisation as a whole.

When an individual uses and experiences the knowledge from the database, it means the explicit knowledge has become tacit. It will complete the conversion loop when other individual get the tacit knowledge from him or her and starts the process all over again.

3.8 INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN KNOWLEDGE MANAGEMENT

Nowadays, an organisation's response to the need of implementation of knowledge management has led them to the application of information and communication technology (ICT) (Egbu & Botterill, 2002). Managing knowledge creation requires getting individuals and teams to share information, experience and insight (Ahmed et al, 2002). Some new technologies currently available facilitate this process. Tools like email, Intranet, Internet have effectively been used. Apart from that, videoconferencing, document management, online information sources, performance support and decision support tools are also quite widely used in order to enable knowledge, be it tacit knowledge or explicit knowledge, to be transferred.

There are a lot of different ICT tools that support knowledge management. These tools relate to the stages in the knowledge management process. It implies a human interaction in gathering and sharing of knowledge. An organisation must identify its business process and needs, before adopting any types of ICT tools.

Skyrme (online) maps a framework that matches various ICT tools

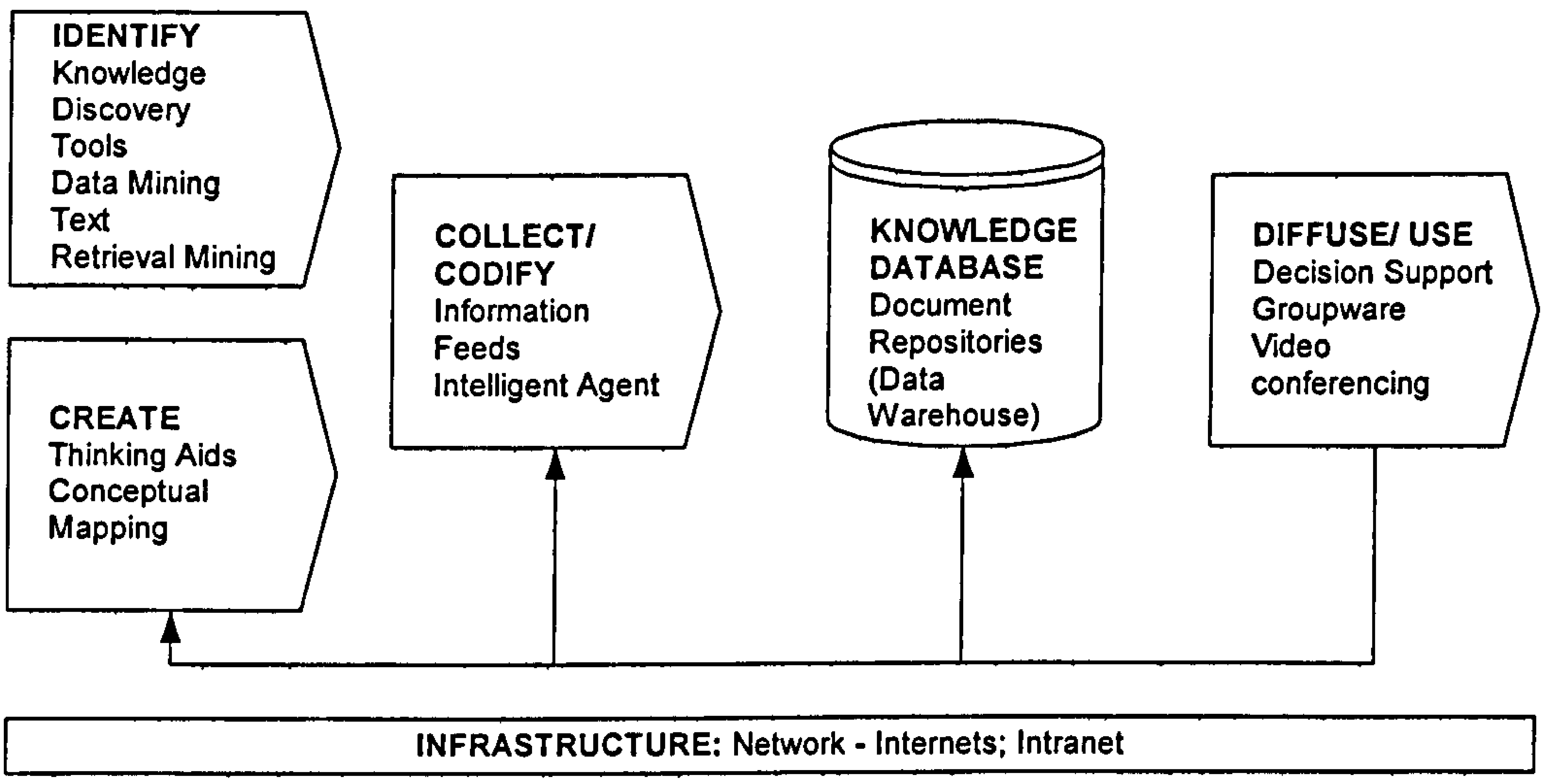


Figure 3.9: Representative Information Systems Solutions Mapped against the Knowledge Processes They Augment (Skyrme, online)

according to the knowledge process they enhance. A representative selection of ICT tools is mapped into different processes. Slightly similar with the stages of knowledge management process concluded before, Figure 3.9 shows a schematic of knowledge process whose left-hand categories are identifying existing knowledge and creating new knowledge. The knowledge flows from there until it is diffused and used by end-users. The whole process is networked via Internet or Intranet. This will allow users to access any information available to them, anywhere, at any time as the best information environments is where people can work together irrespective of geographic location and time (Ahmed et al, 2002).

Internet provides extensive pathways with worldwide coverage to share knowledge. Nowadays, it is important to be connected to Internet. Internet allows knowledge to flow faster to and from the user. The world becomes small as Internet makes communication a lot easier than before. Intranet is Internet used within an organisation, with restricted access from outside. Those within an organisation can access sites outside the Intranet, but access from outside an organisation to an Intranet is usually restricted. If the knowledge within Intranet is proprietary, the appropriate security measures must be implemented, e.g. firewall or login password.

3.8.1 IT Supports According to Types of Knowledge

Sahasrabudhe (2000) list the most common technologies that could be used according to types of knowledge i.e. tacit and explicit knowledge, which are discussed below.

3.8.1.1 Information Technology Support for Managing Explicit Knowledge

Saharasbudhe (2000) divides IT tools for managing explicit knowledge into three categories:

1. IT for Codification and Organisation of Explicit Knowledge

There are two types of system i.e. Relational Database Management Systems (RDBMS) and Document Management System. The former is a database that is organised and accessed according to relationships between data items through one common field. It could be used to obtain knowledge like worldwide weather or international trades. Document Management System supports production, storage, search of and retrieval of mixed-media documents.

2. IT for Accessing Explicit Knowledge

Examples for this are, Internet, Intranets, search engines, and work flow tools. Search engines allow the user to find all sort of knowledge from the Internet. Workflow tools allow documents and other forms of information to be routed among individuals and applications according to predefined processes.

3. IT for Using or Applying Knowledge

There are performance support systems, decision support systems, data mining and data warehousing. A performance support system is for assisting individuals to carry out specific tasks without requiring specific training because it incorporates techniques such as expert systems. A decision support system is used by management in making business decisions. Data mining is capable of searching data in a sophisticated way and data warehousing consolidates data from many sources and enables easy search and online analysis to present the results in specific formats.

3.8.1.2 Information Technology Support for Managing Tacit Knowledge

The choice of technology tools will depend upon the desired characteristics of the networking. Conventional methods of communicating require either parties to be available at the same time or at the same place, e.g. telephone or face-to-face meeting. Fax or letter has become too slow for today's needs. IT provides other tools to support management of tacit knowledge such as:

1. Emails - share knowledge by sending messages through internet
2. Video-Conferencing - share knowledge and have visual contact with each other
3. Electronic Workplace for Collaborative Work - enables members in an organisation to synchronise their activities more effectively. E.g. LotusNotes.

3.8.2 Knowledge Management System

Knowledge management system is meant to accomplish the main tasks in the knowledge management process as mentioned in section 3.7.1 – 3.7.3. It includes components to acquire, organise, store and use of knowledge. Its decision support reasoning or diagnostic engines provides the user with ability to make critical and fast decisions. The decision support reasoning comes in several types such as decision tree, rule-based, simulation-based, model-based and case-based or integrated method of any two, for example the integration of model-based and case-based reasoning

(ClickSoftware, online). As knowledge based systems are often used for decision support, the knowledge has to be stored using a structure that allows retrieval. For example, rules can be used in the form: if state X is true then Y is true. Decision trees are another way of linking knowledge. The sophistication of this component determines how intelligent a knowledge management system is.

The more the knowledge is shared, the more valuable the knowledge becomes. The knowledge management system improves in intelligence and efficiency over time when more users share their knowledge and becomes useful for other users. The commercial knowledge management system comes with friendly user interface and is often used at Call Centre for answering customers' needs e.g. Autonomy (online) and Hyperknowledge (online), as well as in field service management for remote diagnostics through the World Wide Web (WWW) (ClickSoftware, online). The latter enables local self-help over the Web rather than sending out Field Service Engineers to carry out on-site fault-finding.

There is also a knowledge base authoring tool which allows users to easily build and maintain complete and consistent knowledge bases for acquiring knowledge e.g. Acquired (online), XpertRule KBS(rule-based) (Attar, online) and Assistum (online) and ReCall (case-based reasoning) (Isoft, online). Other knowledge acquiring tools are natural language input using text (Natural Language Processing) or speech using voice recognition technology.

3.8.3 Communication Hardware

In term of communication, there are many advanced mobile devices available in the market. Mobile phones, handheld devices, mobile digital camera, internet TV or email telephone are among the devices that allow the convenient communication and transfer of data and information. Many of these devices now are equipped with wireless facilities for data transfer such as Infrared Data Association (IrDA), General Packet Radio Service and Bluetooth (online). The operating systems of many handheld devices such as Windows CE, Palm or EPOC are becoming more PC compatible for synchronising data. Most handheld computers accept handwritten input. Its handwritten-abled screen allows normal signatures to be captured and stored. There are two type of handheld i.e. Personal Data Assistant (PDA) and handhelds for business uses. The former is more for organising personal data and information e.g. Pocket PC and Palm Pilot while the latter is used especially for field service engineers (TBS, 2000) such as Voyager (TouchStar, online) and Husky (Handheld, online).

Nowadays, Internet can be accessed from almost any handheld, Wireless Application Protocol (WAP)-abled mobile phone or Internet-ready TV. The rapid changing of today's communication technology contributes to the efficiency of knowledge sharing in organisations and this is a good sign for better communication and knowledge management.

3.9 CONCLUSION

The building maintenance industry, as with the construction industry itself, is fragmented and rife with problems. The high frequency of small and simple maintenance work (especially reactive maintenance work) has caused some management difficulties and often raised some concern regarding the total maintenance cost amounted every year.

Each maintenance project is laden with valuable information and involves people whose knowledge and skills has been built over time along the process. Knowledge assets have recently gained attention from organisations in many industries. As much as they realised the fact of how important knowledge asset is to an organisation these days, they seek ways to implement knowledge management in order to comprehend their position in the industry. Knowledge management involves people, processes, technology, techniques (strategy) and culture. Although it is not *a simple question of capturing, storing and transferring information* due to the cultural barrier (Bhatt, 2001), it is an area worth looking into in order to increase the efficiency of the people and enhance the information flow within the organisation especially with the current rapid development in information and communication technology.

This chapter deduced that the management of an organisation's knowledge (tacit and explicit) is becoming indispensable to today's competitive business. Some of the advantages identified by the researcher accruable to organisations for adequate management of their knowledge resources are that they can:

1. Encourage disclosure of knowledge to be achieved, so that all employees in an organisation can use that knowledge in the proper context;

2. Ensure that knowledge is available at the location where it is most crucial for decision making process (e.g. the front-office, on the Internet);
3. Ensure that knowledge is available when it is needed for the business process (e.g. 24 hours a day);
4. Ensure that new knowledge is distributed to the people in the organisation that perform activities on the basis of this knowledge (e.g. distribution of lesson learned);
5. Ensure consistency of knowledge;
6. Ensure that everybody in the organisation 'knows' where knowledge is located within the organisation or network of organisations;
7. Ensure quick problem solving and reduced expertise cost;

Email, Internet and Intranet are some of the knowledge management tools widely used today (Derrington et al, 2000). These are supported by devices for videoconferencing, document management, online information sources, performance support and decision support. However the adoption of knowledge management tools is conditioned by an organisation's business process.

As process is one of the elements in knowledge management, the next chapter will look into the business process of reactive maintenance projects, discussion on the problems along the process and some requirements to improve the process.

CHAPTER 4

THE OPERATION OF BUILDING MAINTENANCE

4.0 INTRODUCTION

Business must be reviewed not in terms of functions, divisions, or products but of key processes (Davenport, 1993). In an ever increasingly competitive and challenging business environment, organisations begin to recognise the growing importance of the role of process in business management. Many organisations look back into their business process for improvement opportunities especially with the growing (rapid) development in information and communication technology (ICT) and how ICT could enhance their business process (Betts, 1999).

This chapter presents the analysis of the existing business process in reactive maintenance projects, concentrating on the information and communication technology that supports the process. All information reported in this chapter is mainly primary data gathered from interviews with the parties that are involved in the process.

The analysis consists of identification of the parties involved, understanding the business process, understanding the information and communication technology used in the process, identification of problems within the process and ways to improve them.

4.1 MAINTENANCE ORGANISATION - PARTIES INVOLVED IN THE REACTIVE MAINTENANCE PROCESS

Maintenance operation for a small firm can be under the responsibility of a member of staff in addition to his core duties. In a large firm it would usually be undertaken by a separate organisation solely responsible for maintenance (Wordsworth, 2001), either independent consultants to advise on a particular problem or a maintenance contractor who carries out the repair work.

Deciding between employing in-house consultants directly or engaging an independent consultant/ contractor has to be based on the feasibility of cost, quality and convenience. Among the advantages of in-house maintenance staff are:

1. Quicker response to emergencies as the allocation of work must not have to pass through the consultant or contractor;
2. In-house operative is very familiar with the user's requirement and any constraint to carry out the work. Hence, simplify the communication of job information;
3. Better control of quality of work through direct supervision;
4. More effective cost control as it is possible to gain first hand knowledge of the factors which influence the output and also to carry out controlled experiments with different methods in order to achieve the same standard at a lower cost;
5. Tender procedure is not necessary;

6. Where work involves a security risk, in-house staff are more trusted than outsiders. Organisations such as a financial institution demand a high level of security. Hence an in-house consultant or contractor is understandably essential to prevent unnecessary risk. One of the clients in this research is a bank by function and the only one that does not have outsourced Facilities Management. However, due to its size, outsourced contractors seem necessary and practical.

Above all the advantages, to a large company, employing a direct labour force could cause a high overhead cost (Wordsworth, 2001). However, there are some factors which influence the decision for a client to engage an outsourced consultant/ contractor or otherwise. i.e. (Wordsworth, 2001):

1. Nature of work

Work required according to skills required to execute the work i.e. traditional craft skills, specialist skills and unskilled or semiskilled work.

2. Volume of work

Depending on the size of the business, the more branches it has, the more volume of work it will be expected to cover.

3. Response time

Work according to the degree or urgency of work such as [1] emergency work e.g. breakdown which involve security and health risk to the occupant or contents (high response time – 24 hours); [2] urgent work e.g. defect that may become a more serious fault if left unattended (e.g. 1 week or 2 days response time) [3] Normal work which does not effect the occupants and its contents.

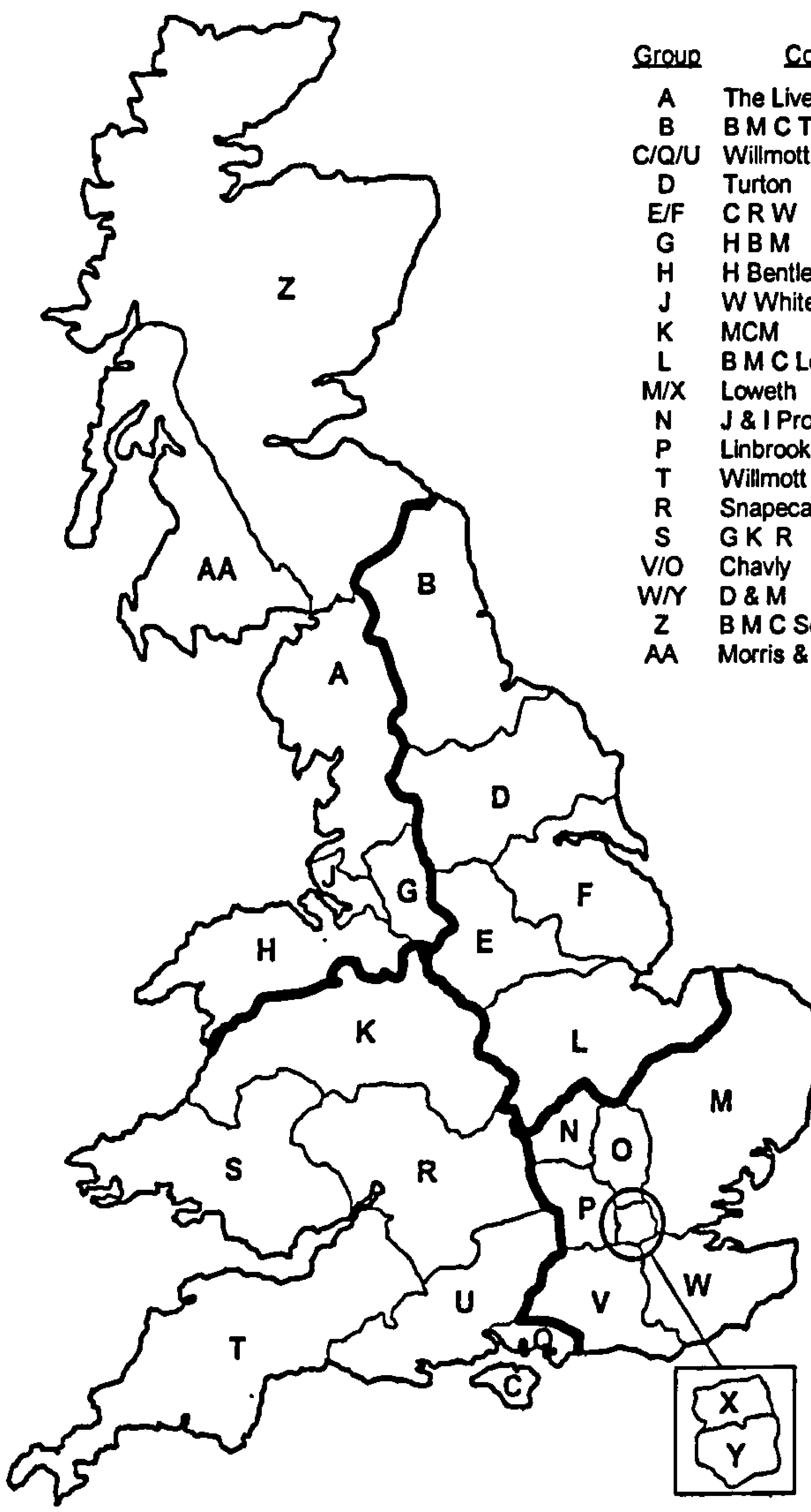
4. Location

In this research, contractors are responsible for maintaining the clients' premises throughout the nation. Thus, they are categorised geographically according to the premises' location. Figure 4.1 s hows the designation for one of the clients in this research.

Other than the above mentioned factor, availability of space, market condition and cash flow also have to be considered.

Investigation on the case study and intensive reading on literature material have identified three main parties involved with the building maintenance work i.e. client, Facilities Management (FM) Team and contractors. The client is the organisation who owns the property and is ultimately responsible for paying for any repairs. The contractor is responsible for carrying out the repair work. The FM team, either an in-house department or an outsourced managing agent, manages the contract between the client and Contractors. Suppliers are involved in providing the necessary parts for repair work. This is as depicted in Chapter 2 (Figure 2.3). In brief, the client's branch or Unit reports to the Facilities Management's Helpdesk about a repair work and then passes it to the Contractor. The Contractor informs his Operative or Subcontractor to go and repair the work at the Unit. The Facilities Manager is consulted if the work needs to be authorised. Figure 2.4 in Chapter 2 shows the relationship among the people that are involved in the process and their roles are further

Group	Area	Postcode
A	1	CA, LA
	2	FY, PR, WN, BB
B	3	NE, DH, SR, TS, DL
C	36	PO
D	5	BD, HG, HX, HD
	7	LS, WF, YO
E	8	S (Part), DE, NG
	9	S (Part)
F	10	DN, LN, HU, PE (Part)
G	11	M, OL, BL, SK
H	13	CH, LL, L (Part), CW
J	14	L (Part), WA
K	15	B, DY, WS, WV, ST, TF, SY
	17	CV
L	16	LE, PE (Part), NN
M	19	CB
	20	NR, IP
	21	CO, CM, IG, RM, SS
N	18	MK
	23	LU
O	22	SG, AL, EN
P	24	HP, WD
	25	HA, UB, TW, SL
Q	37	PO
R	27	WR, GL (Part)
	28	GL (Part) OX, SN
	29	HR
S	30	SA
	31	CF, NP, LD
T	32	BS, BA, TA
	33	EX, TQ, PL, TR
U	26	RG
	34	BH, SP, DT
	35	SO
V	38	CR, SM, KT, GU
	39	BN, RH
W	40	TN
	41	BR, DA, ME
	42	CT
X	43	NE
	44	W, NW
	47	WC, EC
Y	45	SW
	46	SE
Z	48	TD, EH, FK, KY, PH, DD, AB, IV, KW
AA	49	G, PA, KA, ML, DG



Group	Contractor
A	The Livesey Group
B	B M C T & W
C/Q/U	Willmott Dixon
D	Turton
E/F	C R W
G	H B M
H	H Bentley
J	W Whiteside
K	MCM
L	B M C Leicester
M/X	Loweth
N	J & I Property
P	Linbrook Services
T	Willmott Dixon
R	Snapecall
S	G K R
V/O	Chavly
W/Y	D & M
Z	B M C Scotland
AA	Morris & Spottiswood

Figure 4.1: Designation of Contractors for client Whitbread Plc

discussed below.

4.1.1 client

The client is the main player in the construction industry. The three companies in this case study are responsible for about 1000 to 9000 properties with a large number of group companies and estates in the UK.

The client organisation is the lead and major company in building maintenance, with each of the three companies in this case study responsible for between 1000 and 9000 units. Looking at the high number of properties, they issue between 50,000 and 300,000 maintenance instructions that cover from £5m to £50m a year of planned and minor construction work. The client's unit will report the reactive maintenance job to start the whole reactive maintenance process, and will then finish the process with a payment to the contractor for the repairs after the FM agent accepts a contractor's invoice.

It is the client's main concern to ensure the performance of its consultants and contractors are up to the standard required to support the business environment in terms of cost and quality of work.

4.1.1.1 Unit

"Unit" in this study refers to the client's properties, a company's or sub-company's branch. There are various kinds of properties, such as hotels, pubs, restaurants, pharmacists and banks.

The Unit Manager reports problem tasks to the client mainly by phone, rarely fax or email for any type of building repair works that is required. Reports can be made during or outside of office hours depending on how essential it is to the Unit. The person at the Unit describes the type of problem that has occurred in their property and chooses the response time required for the problems to be solved. They will be informed by the Helpdesk when the job has been forwarded to the Contractor. After the Operative has completed a job, then the Unit Manager fills in a worksheet with feedback on the quality of work done.

The Unit Manager is responsible for the premise both physically and financially. There is some budget limit to every Unit on how much they could spend for maintenance repair. To avoid excess cost, it is important for the Unit to ensure that the budget is spent on necessary repair work essential to their premises.

4.1.2 Facilities Management Team

Facilities Management is defined by Barrett and Baldry (2003) as;

> *"An integrated approach to maintaining, improving and adapting the buildings of an organisation in order to create an environment that strongly supports the primary objectives of that organisation."*

FM organisation ensures its building, system and services support their core business and processes, which covers all aspects of property, space, environmental control, health and safety and support services (Alexander, 1996). In short, managing every aspect related to the property is the main aim of facilities management.

Some clients have the FM agent as an internal part of their own organization to manage their properties or otherwise, outsourcing the service to a managing agent company. They select qualified Contractors and arrange the term of the contract for work done on behalf of the client. It is quite common for an FM agent to have a Facilities Management System (FMS) to increase the productivity and efficiency in their service. This system helps them to monitor the work reported by the Units, the Contractors' progress and cost controlling. This system will be further explained later in this chapter.

In a reactive maintenance context, the FM agent/organisation has to handle the acceptance of the jobs reported by the client's units, and then the forwarding of this information on to the selected contractor, all of which is accomplished by a client specific call centre. The FM agent also checks completed work and authorises payments via their FM managing agents who visit a certain number of jobs per year to check on the reactive maintenance work.

4.1.2.1 Facilities Manager

The Facilities Managers in this case study are the people that manage the maintenance work. They are responsible not only to the occupants, but to employees, the public, customers and the out-sourced services (Allen, 1993). For reactive maintenance work in particular, besides arranging contracts with qualified contractors for work required by the clients, their job also includes authorising work that is over the budget limit, monitoring the contractors' progress, site evaluation of work when finished, certifying payments and analysing of project records. Facilities Managers will prepare Tender Documents for the tendering process and also Contract Document to be signed by the client and successful contractor. Although some clients use other terminology e.g. Property Manager, Area Manager or State Area Manager, the nature of the works is very similar. Facilities Managers are normally from a Quantity Surveyor or Architects background. They are capable of handling the construction process with their skills and knowledge in construction.

Authorisation for some work is given on jobs that must be done due to [1] A store's trading being affected [2] Health and Safety [3] Security. The Facilities Manager will discuss over the phone with the contractor if the work is very essential and needs to be done without delay, and/or the total cost is just slightly above budget limit. Otherwise, the contractor has to send in a quotation, complete with cost breakdown of the work and wait for the authorisation from the Facilities Manager.

The Facilities Manager 'desk checks' or 'audits' the description of every building maintenance job sent from a helpdesk with every report on the work done sent in by the contractor. The Facilities Manager checks the invoice submitted by the contractor upon completion of the work to ensure that the cost limits on jobs have not been exceeded and the charges are at the agreed cost.

Site evaluations are chosen at random with the Facilities Managers choosing between 5% and 10% of any site from the total works. The Facilities Manager then certifies the payment for work done by the contractor. While the outsourced Facilities Management issues a Certificate of Payment to the contractor upon approval of that invoice, in-house Facilities Management teams give an instruction to an internal account division to pay the contractor.

In short FM agent's main tasks in reactive maintenance work are to monitor the contractor's work performance and the Unit's performance; managing the financial aspect of the reactive maintenance project and managing the Call Centre.

4.1.2.2 Helpdesk

The Helpdesk is an intermediary between Units, contractors and Facilities Managers. They are the frontline of building maintenance work that links the communication between client and contractor. Equipped with telephone devices, facsimile machine and computer system, the Helpdesk operator receives a job from the Unit and then sends the job to the contractor which is identified by the system. The FMS (Facilities Management System) choose contractors according to the type of maintenance work they are responsible for and location of the Unit with the problem. The Helpdesk operator gets a detailed description of the problem from the persons at the Unit by asking them technically related questions in order to avoid the system choosing the wrong contractor. At times the Helpdesk operator would pass a call that cannot be responded to, immediately to another operator. Consequently, this will cause delay to the caller (Bruton, 2002).

In view of the fact that most Helpdesk operators, especially the new recruits, are not from a building maintenance background, this task is quite tricky. However, this could be overcome by giving them full training and with the experience they gradually gain over time. Not all FM agents in this research provide question scripts and guidelines to their Helpdesk. But to those who have, the script does not cover all reactive maintenance work. In addition, they are more like procedures or guidelines rather than a complete script, as depicted in Table 4.1 - an example of the procedure obtained from an FM Call Centre in this research. This procedure is intensively used during the first few weeks of the training (or days for experience new recruit). Although experience in customer service line or Call Centre environment might help some already experienced recruits, technical knowledge on maintenance and repair work is something that they have to learn and gain as an FM helpdesk operator. Nevertheless the knowledge that has been built up by the operators over time will be lost when they leave the company.

Many Call Centres have a problem finding and keeping the right staff (Bruton, 2002). An effective Helpdesk operative must need some technical competence, computer literacy, considerable patience and ability to handle certain situations with diplomacy. The nature of the job, low salaries and pressure could cause staff to burn out and leave (Bruton, 2002). As a result, they have to look for new staff and this means that the training has to start all over again.

Table 4.1: Example of Helpdesk Procedures – Lifts

	OPERATOR	ACTION/RESPONSE
1	Receipt of call from Store	Log store number and contact name
2	Ask what type of Lift Passenger Lift Goods Lift Disabled Lift Dock Levellers Conveyor	Log of Appliance type Continue call go to (3) Continue call go to (3) Continue call go to (3) Continue call go to (3) Continue call go to (3)

3	Ask what the problem is? Ask for location? Ask for Reference (Lift No.) Ask if person stuck in Lift?	Log progress description, If problem relates to Sun Alliance Defect Go to (8) Log Appliance location Log if reference is available Ensure Top priority callout Continue (4)
4	Ask if ongoing/recurring problem?	Check store log and notes for existing problems. If existing Job Instruction (JI) in hand chase contractor and report to store. If new call continue (5).
5	Log call as a JI and establish priority and other advice to contractor	If Customer/Goods Lifts, contractor should attend as per contract. If any other lift should be U.K. Lifts. Establish if contractor will be allowed to work in store between11.00am-2.00pm.
6	Advise on contractor callout (if asked for)	Within 4 hours, but contractor will be advised of call out immediately. Advise store of time if persons in Lift
7	Place call with appropriate contractor	Ring contractor and offer all information. Fax contractor JI and information.
8	If call is associated with Sun Alliance(Insurance Inspector)	If Section 5A or 6A type defect. Pass call to Helpdesk Supervisor. Go to (9). If Section 5B or 6B place call repeat process (3 to 7) and let Helpdesk Supervisor know and she will fax information regarding call to Helpdesk Manager.
9	Section 5A or 6A response	Repeat process (3 to 7) to log call information. Request Immediate response to call. Record JI on 24 hour job chase log, record store, and contact name. Telephone and Fax information to Helpdesk Manager.
10	Job Progress/Completion Section 5A and 6A jobs only	Telephone store contact and request job position. If complete - sign off. If not complete continue (11).
11	Job Progress (Chase)	Telephone contractor; ask for service area tel. no. if req. ask for job update. If advised of further work, ask for completion information, and advise store contact. If quote requires authorisation inform Helpdesk Coordinator
12	Job Progress/Completion	Continue steps (10) & (11) until job complete.
13	Job Completion	Sign Job off
	*Note Response Times for UK Lifts	Disabled Lifts - 4 hours Scissor Lifts - 8 hours Goods/Customer Lifts- 2 hours Entrapment – half and hour

Occasionally, a caller from the Unit would contact the Helpdesk to find out about the status of work done they reported earlier. If the status is not yet in the system, the Helpdesk has to check with the contractor and update the system for others.

On average the number of helpdesk operators working at the same time is less than ten. The number of calls a day is on average between 100 and 300 a day with approximately two thirds leading to work being undertaken. The other calls are abandoned. Abandoned calls consist of those calls made to the wrong helpline and of calls repeat reporting jobs. The wrong calls get through to the helpline and are asking for unrelated services such as computer support.

Bad weather and festive seasons can increase the calls by 50% a day. One of the client's Facilities Management team's helplines has a small electronic scoreboard that shows information about the helpline's performance. For example, 'CIQ - 6' which shows that there are 6 Calls In Queue. Call Scan from AMC, Cable & Wireless is the software used for call handling. None of the Call Centres in this research records their incoming or outgoing calls, neither for training nor security purposes.

4.1.3 Contractor

The maintenance contractor is selected based on the clients' need, the contractors' performance, their financial background and previous projects handled. Maintenance contractors can provide all levels of services ranging from caretaker maintenance for unoccupied buildings, to a fully comprehensive contract which allow for the provision of consumable items (e.g. lamps, filters etc.), spare parts and repairs (Sidney, 1992). Contractors are responsible for all jobs and are subject to the terms of the contract between them and clients. Large contractors usually have their own Helpdesk which connects the link between the client's helpdesk, their other branches (National Area Branch) and their operatives (in-house or sub-contractors). Small contractors responsible for rather less coverage of work area compared to large contractor.

The contractor assigns, via a regional branch for a nationwide contractor, one of their operatives/field engineers to the unit requiring reactive maintenance work. The operative visits the client's unit and tries to complete the repairs for the reactive maintenance job, with authorisation sought from the FM agent when the quote for the job is above a certain pre-designated cost limit.

Contractors usually have their own operatives or engineers to do the repair work. Some contractors engage Subcontractors to do certain trades such as glazing, drainage, roofing or air-conditioning systems. Whenever they need equipment the contractor will get it from a Supplier.

A contractor should seek authorisation from the Facilities Manager for jobs that are over the budget limit by either discussing it over the phone or by sending in a quotation of the expected cost for the work and then waiting for the Facilities Manager to authorise it. To claim payment from the client, the contractor submits an invoice together with a cost breakdown of work performed. The job reference number given by the Helpdesk must be stated for payment and checking purposes.

Some clients have no time limit on when the contractor must have made a payment claim. However, in this case study, one client gives contractors two months to submit their invoices. After that period, the jobs will be taken off the system and the contractor will not get paid. Payment will be issued once FM certifies their claim.

4.1.3.1 Operative

The Operative is the contractor's field engineer whom does the maintenance work. A contractor receives a job from the Helpdesk by phone or fax and then informs the best-suited Operative about the new job by phone. One contractor in this study equipped its Operatives' vans with a Vehicle Tracking System to enable the contractor's Helpdesk to easily track the nearest Operative to the Unit. The Vehicle Tracking System can prevent the Operatives from finishing work early and it stores all the travelling information for a van.

Before the Operative proceeds with any repair work, he has to estimate the cost of the maintenance that will occur. If it is slightly over budget limit, he will have to report to the contractor with the estimated cost and the contractor will then call the Facilities Management directly to discuss it.

For over budget jobs, the Operative goes back to the Unit to resume the work upon authorisation. After the job has been completed, the Operative fills in a worksheet. The Unit Manager fills a feedback form on the operative's quality of work and signs off the job.

When an Operative goes to the Unit and checks the condition of work, he decides the type of equipment required for the work. Normally, an Operative is given a fully stocked van with necessary spare parts and will top it up when required on their way to a job, from the Supplier. There is an asset register with a history of parts used and this can be checked against what is found in the van.

4.1.3.2 Subcontractor

For certain specialist work such as glazing or air-conditioning, a contractor will engage a Subcontractor to do the maintenance work. The process taken by the Subcontractor is identical with the Operative. However, some Subcontractors who are not aware of the authorisation process and budget limit will proceed with work without permission. This will effect the contractor's payment, as the client may not pay for such work.

4.1.4 Supplier

The supplier is needed to provide the necessary parts for the contractor to do the reactive maintenance work.

4.2 UNDERSTANDING THE BUSINESS PROCESS

Process is basically an activity to convert (deliver) input into output (product/services). Harrington (1991) defined process as *any activity or group of activities that takes an input, adds value to it and provides an output to an internal or external customer.* People in an organisation work together on the activity to achieve some desired outcome (Ould, 1995). An organisation can be *any group, company, corporation, division, department, plant, sales office etc.* (Harrington, 1991). There are a few important elements in the notion of business process i.e. people in the organisation, machines, activity or group of activities, goal or objectives (Ould, 1995) and resources (Harrington, 1991).

Modelling the business process could help visualised these elements in such a way that could be quickly understood by the team. In other words, it makes work visible and with increased visibility it helps to improve communication and understanding (Damelio, 1996). It allows the visualisation and understanding of interfunctional processes and their individual effects on each other (Belmiro and Pina, 2001) and shows how activities of relationship with external clients and suppliers can affect the overall organisational system (Davenport, 1993).

In a situation where the existing business process is being questioned, process modelling is used to identify improvement opportunities in order to do work better, quicker and with fewer resources by clarifying the requirements for inputs and output, especially if many different functions or parts of business are involved in producing the final output (Damelio, 1996).

Damelio (1996) highlights that the more cross functional boundaries inputs and outputs that present, the greater the opportunities for improvement. He also suggests that improvement opportunities show up in the form of reducing the clutter of the process model by simplifying a process or by eliminating redundancies or non-value-added steps, etc. These non-value-added steps are part of the 80% of the repetitive processes occurring daily in most businesses (Harrington, 1991).

Greenwood (as cited in Ould, 1995) gave three reasons for modelling process i.e. to describe, analyse and enact a process. Modelling to describe a process is carried out in order to define a process, communicate it to others, share it across a group of people or negotiate around it (Ould, 1995). Therefore it is important to model the process in a way which people can clearly read and easily understand it. Processes are usually analysed prior to carrying out improvement. These improvements may be carried out by changing the order of activities, the responsibilities for activities/ decisions, or scheduling mechanism; increasing or decreasing the amount of parallel activity; removing (or inserting) buffers or stores for materials between steps in a process; or restructuring functions to align them better with the process (Ould, 1995). Lastly, processes are modelled to support groups of people in organisations in enacting those processes.

4.2.1 Process Modelling Techniques

In Business Process Re-engineering (BPR), process modelling is a major element to study a business process. As to explain how to model a process, they are many techniques in process modelling. It differs from four different perspectives; 1] functional 2] behavioural 3] organisational or 4] informational (Huckvale & Ould, 1998). The selection of one technique will be based on the aim and objectivity of reviewing the "As-Is" process. At any cases, these techniques are the enabler to a more important end (Galloway, 1994) which is improvement opportunity in business and in establishing the "To-Be" process.

Some modelling techniques used to mapping process are Data Flow

Diagram (DFD), Integration Definition Function (IDEFx) family, Process Map, Action Workflow, Role Activity Diagram (RAD)/ Role Interaction Nets (RIN) and Entity Relationship Attribute (ERA) Modelling (Huckvale & Ould, 1995). Process Modelling techniques such as DFD and IDEFx provide largely on functional views of the process representing what activities are being performed and the dataflow which connects them (Huckvale & Ould, 1995; Gichuiri, 2002). On top of that, IDEFx includes some elements of behavioural and organisational perspective (as it covers decision making and representing where, and by whom, activities are performed (Huckvale & Ould, 1995)).

Process Map or traditional flowchart addresses the organisational and functional aspect of a process. It has always been claimed as a technique that is easy to understand by an "ordinary" reader (Huckvale & Ould, 1995) as it shows the sequence of tasks/ steps that make up a process (Galloway, 1994 & Damelio, 1996).

RAD and RIN model functional, behavioural and organisational view processes, capturing roles and interactions (Huckvale & Ould, 1995). ERA modelling addresses mainly the informational perspective as do other techniques such as Object Oriented (Martin & Odell, 1998). These techniques provide structural views as they capture objects (documents, data, artefacts or products) manipulated and used by a process (Martin & Odell, 1998; Huckvale and Ould, 1995; Nagarur & Kaewplang, 1999; Yu & Wright, 1997).

The process modelling technique adopted for this study is a technique suitable to illustrate activities in the organisations involved, the interaction between them, the rules and procedures and the information flows. It is also important that the tool could describe the process in a way that it is easy for the process owner to understand. Ould (1994, 1995) highlights that process modelling should be intuitively familiar, easy for readers to grasp, unambiguous for analysing and enacting the process, and able to describe what people do rather than how they do it. With that notion in mind, this research has adopted process mapping/ flowchart technique to model the business process of reactive maintenance projects.

4.2.2 Process Map

Process maps or flowcharts, which graphically represents the activities that make up a process, was used in this research to identify weaknesses in the organisation structure and business processes. It provides the basis for reengineering or improving these processes and the enacting of the process of which the models could be used to map out the "To-Be" models and to test the effect of various scenarios on the organisation (Nelson & Baldry, 2000; Harrington, 1991). There are four different types of flowchart (Harrington, 1991) i.e.:

1. Block diagram which provides a quick overview of a process
2. The American National Standard Institute (ANSI) standard flowchart which analyses the detailed interrelationships of a process
3. Functional flowcharts, which depict the process flow between organisation or areas
4. Geographic flowcharts, which illustrate the process flow between locations

Block diagram flowchart is used in this study to describe the business process because its simplicity makes it easily understood by "ordinary" people.

4.2.3 The Process Modelling Process

A series of one-on-one interviews, group interview, site visits and observation at Call Centres have enabled the researcher to model the process. Every process was taken back to the process owners and reviewed for the final generic process map. Eventually the model was presented to the representative of the organisations involved in this research for their comments and feedback.

Ould (1995) suggests that there are *no hard and fast rules for procedures... that should be followed* (page 182) to model a process, but recommended some steps which the researcher has adopted in this study with some modifications to suit the needs requested to design the models. The route to model a generic process map in this study was as follows:

1. Started by getting an overall picture of the process particularly on who are involve in a reactive maintenance work and identifying the major processes. This was done by interviewing senior people (e.g. Heads of Facilities Management or Maintenance Division) in the organisations which led to many other groups and individuals.
2. Interview groups about how they collaborate in the process and the interactions that take place.

3. Interview individuals (such as the Facilities Manager, helpdesk operators, operatives on the move, unit manager and supplier) about their individual roles in the process so as to refine the models. Interviews were also conducted with IT managers in the clients, Facilities Management and contractors' organisation to understand the IT aspect of the process. One of the FM system was actually installed on the researcher's server to enabled the structure of their system to be studied.
4. Collecting the necessary documents to ensure minute details of understanding the process.
5. Observing and experiencing the Helpdesk's scope of work at the Call Centre.
6. Reviewing and revising the draft of the process model by taking it back to the process owners before they could eventually validate the generic model.
7. Analyse the process model. This was done throughout the modelling process where problems and potential solutions emerge to be recognised and taken into consideration. Most clients participated in the research documented their business process which allowed the researcher to carry out a comparative analysis and come out with a generic process flowchart of the business process.

With this flowchart, the feedbacks from industrial partners were very positive. A number of them did not realise that this was the way things were being carried out and agreed to the problems that had been discovered. In addition to that, they managed to point out (from the flowchart) the drawbacks they have to put up with in the existing process.

In the next section and onwards, some flowchart standard rules for modelling the process are briefly explained followed by the business process of the reactive maintenance projects and also the outcome of the analysis.

4.2.4 Flowcharting Symbols

Harrington (1991) defined flowcharting technique as *a method of graphically describing an existing process or proposed new process by using simple symbols, lines, and words to display pictorially the activities and sequence in the process* (page 86). He listed a range of standard flowchart symbols. Figure 4.2 depicts only the symbols used in this study.

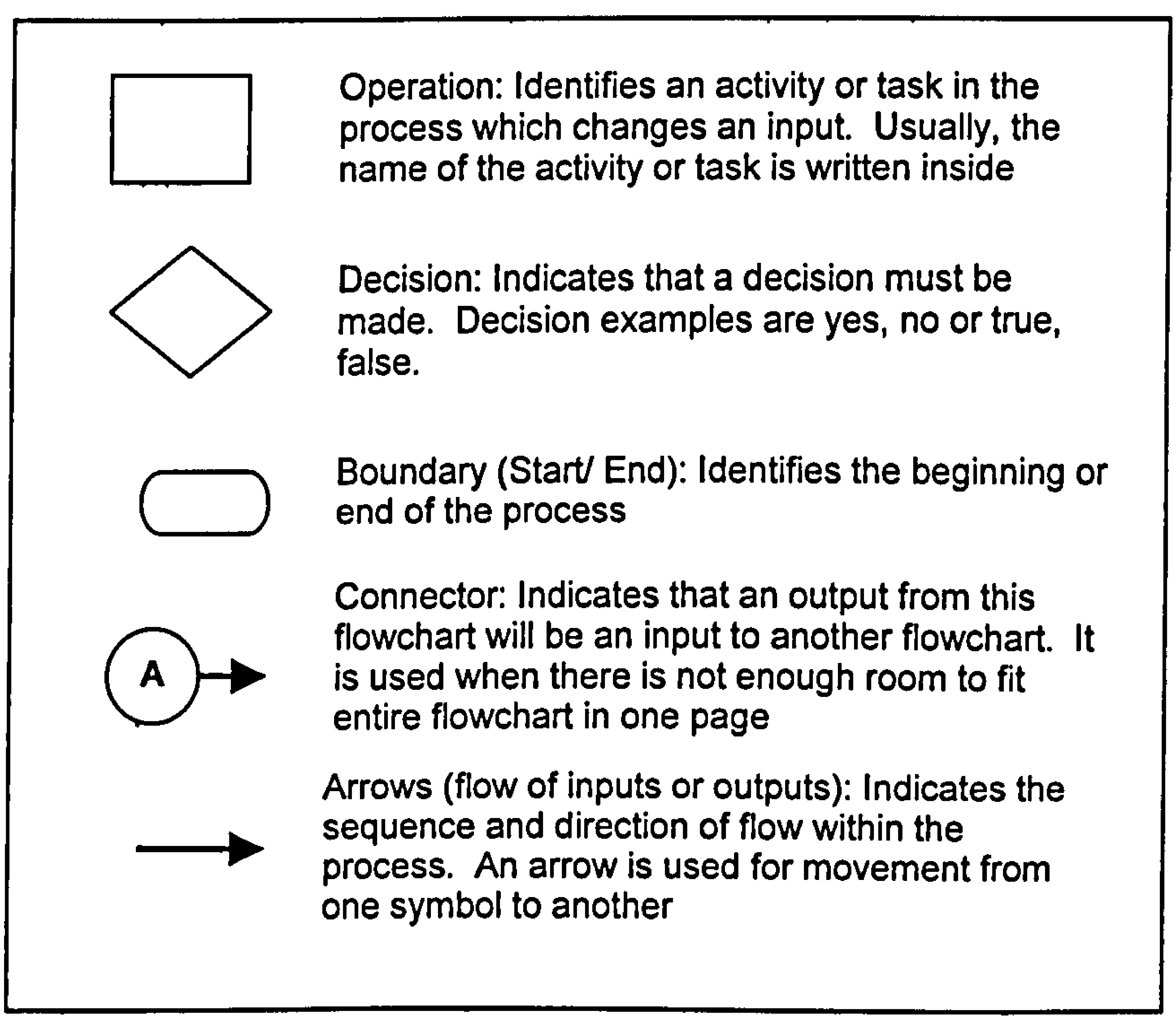


Figure 4.2: Flowchart Symbols (Harrington, 1991 and Damelio, 1996)

4.2.5 Reactive Maintenance Projects – The Business Process

The process model for reactive maintenance was developed. Figure 4.3 shows the interactions involved between the four different organisations: the client, the FM agent, the contractor and the suppliers with every party is indicated with different colours. It shows a high level representation of the reactive maintenance business process, with the links between the main parties and their roles. The process basically starts when someone at the client's premises raises a problem by calling the helpdesk, and the description of the work is forwarded to the contractor. The contractor ensures an operative is assigned to deal with the problem. When the repair

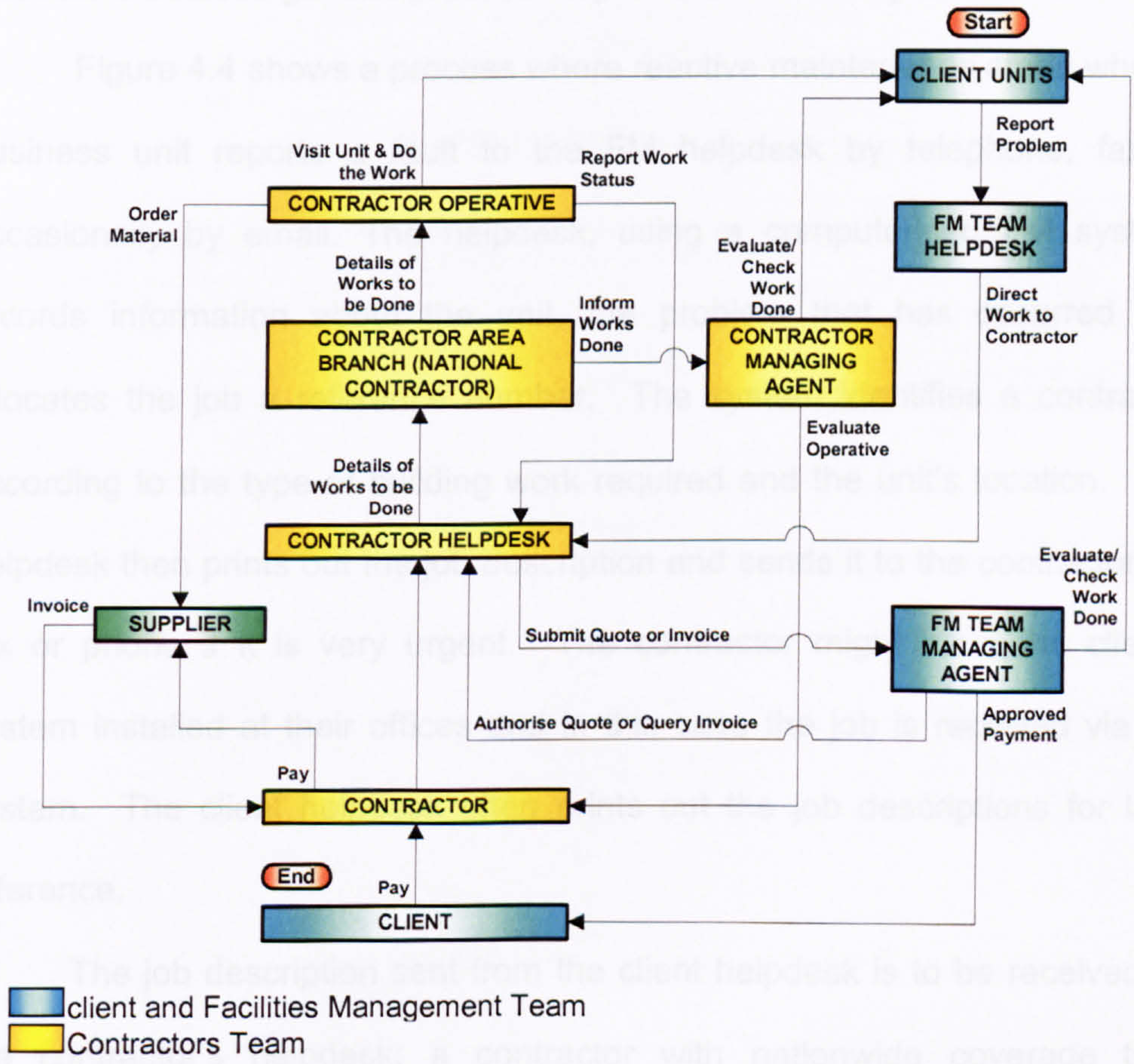


Figure 4.3: Reactive Maintenance Project – High Level Business Process

work is completed, the contractor will prepare an invoice for payment purposes. In any case where a job needs the Facilities Manager's authorisation, a quotation of the said work is submitted for the FM's approval before the Operative could proceed.

Flowchart process modelling was employed in this study to map out and analyse the actions taken in the processes. Information from the interviews with targeted personnel involved in the reactive maintenance process, and paper document evidences were further analysed. This section outlines the whole process in detail. Some more detailed process diagrams based on Figure 4.3 are shown in Figures 4.4, 4.5 and 4.6. These figures illustrate a detailed generic process map for the case study of this research.

Figure 4.4 shows a process where reactive maintenance starts when a business unit reports a fault to the FM helpdesk by telephone, fax or occasionally by email. The helpdesk, using a computerised FM system, records information about the unit, the problem that has occurred and allocates the job a reference number. The system identifies a contractor according to the type of building work required and the unit's location. The helpdesk then prints out the job description and sends it to the contractor, by fax or phone if it is very urgent. The contractor might have the client's system installed at their offices and in this case the job is received via the system. The client helpdesk often prints out the job descriptions for later reference.

The job description sent from the client helpdesk is to be received by the contractor's helpdesk; a contractor with nationwide coverage then forwards this onto the area branch. Based on the description, the contractor area branch or contractor helpdesk allocates the job to an operative (in-house engineer or subcontractor) and informs them via their mobile phone to attend the problem. The operative is selected by location, availability and the maintenance skills required for the job; if none match then a sub-contractor would be given the job.

The operative visits the unit when they are available, normally when they have finished their current job. The first thing that the operative does is

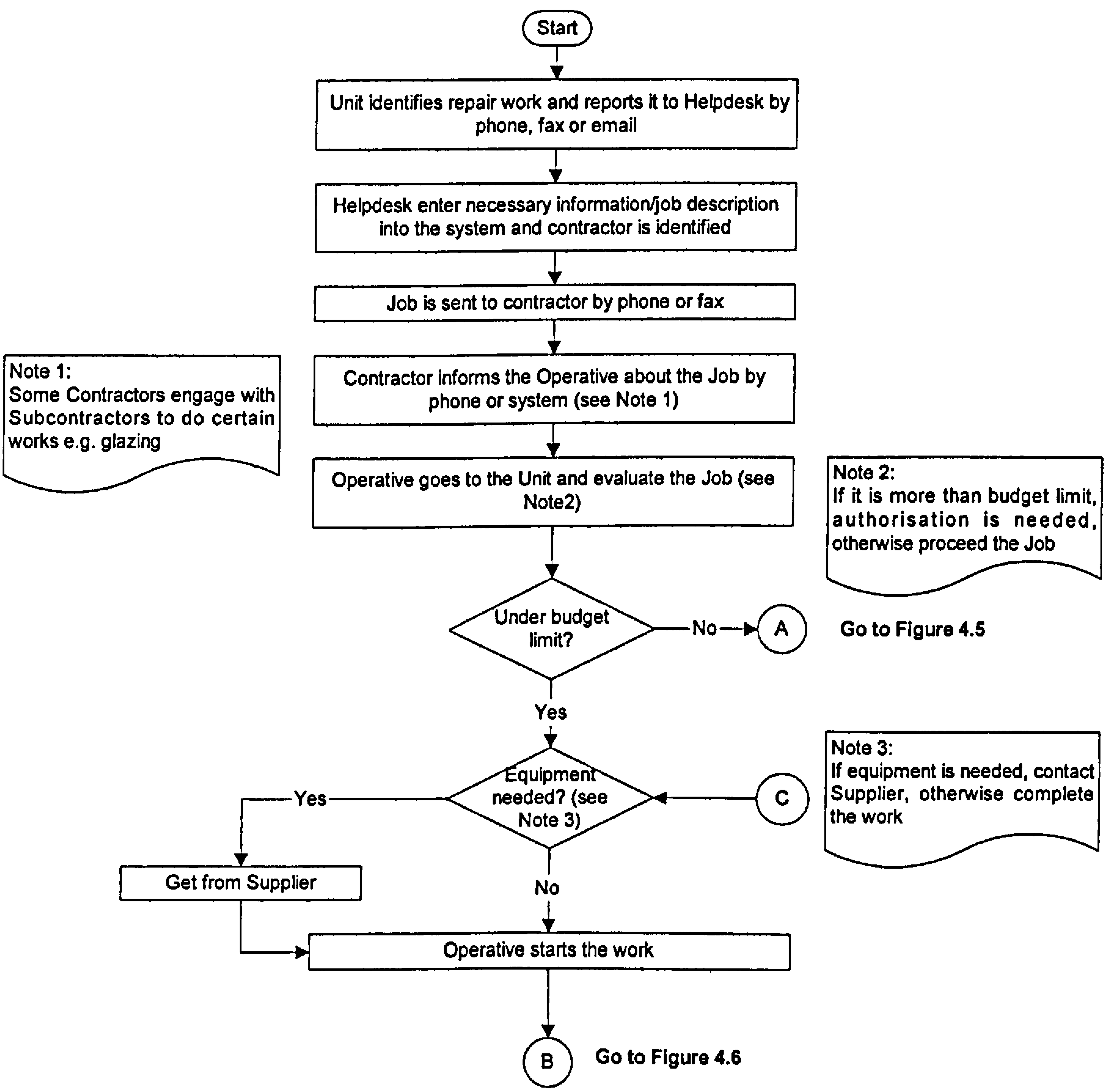


Figure 4.4: Generic Reactive Maintenance Actions

to estimate the cost of fixing the problem. If it is over the budget limit for a reactive job then the operative provides the contractor with an estimated cost for authorisation purposes. Otherwise, they check whether any equipment or spare parts are needed from a supplier and then start the repair work.

For repairs over the budget limit (Figure 4.5), the contractor needs to request for authorisation by calling the facilities manager; except in cases where the work is urgent and essential, in which case the work can proceed without explicit authorisation. Urgent and essential work refers to problems which affect health and safety, security, or the unit's business, in which further damage would be caused without immediate attention. When an authorisation request is received, the facility manager evaluates the estimated cost and decides whether the problem is worth repairing. Meanwhile, the operative waits at the unit for the authorisation to go ahead with the work.

If the over budget work is non-essential, then the contractor prepares a quotation with a breakdown of the expected costs for the work, and sends it by fax to the helpdesk. In this instance, the operative leaves for their next job and will only return when the contractor has got an approval from the facilities manager.

The facilities manager evaluates the quotation and may ask the contractor to resubmit the quotation. This continues until they agree on an acceptable cost for the job. After the job is authorised, the contractor informs an operative who will return to the unit and start the work. Jobs that fail to get authorisation will be abandoned, and if an operative proceeds with a job without permission then the contractor might not get paid. However, this authorisation rule can be ignored when the job occurs outside of office hours and needs to be completed.

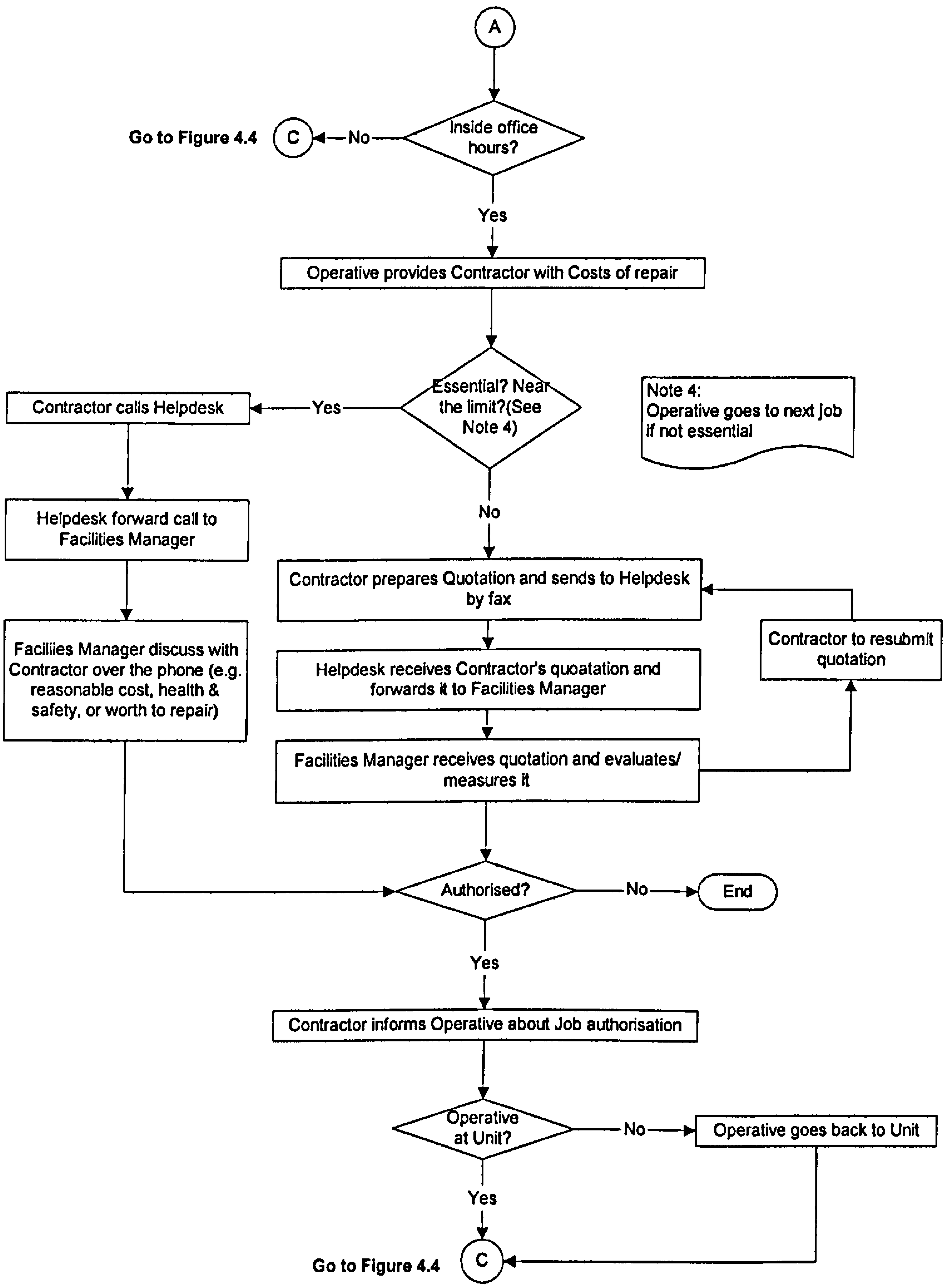


Figure 4.5: Generic Reactive Maintenance Actions

Upon completion of the job (Figure 4.6), the operative gets feedback from the unit on the quality of the work, and this is sent to the contractor. The normal procedure is for these worksheets to be handed in once a week in person by the operative to the contractor's area branch. The helpdesk is also informed about the completed work. The contractor then prepares measurements and invoices for claiming purposes and submits it to the FM team. The facilities manager checks the measurements and invoices for any discrepancies. If necessary the facilities manager will discuss any problems

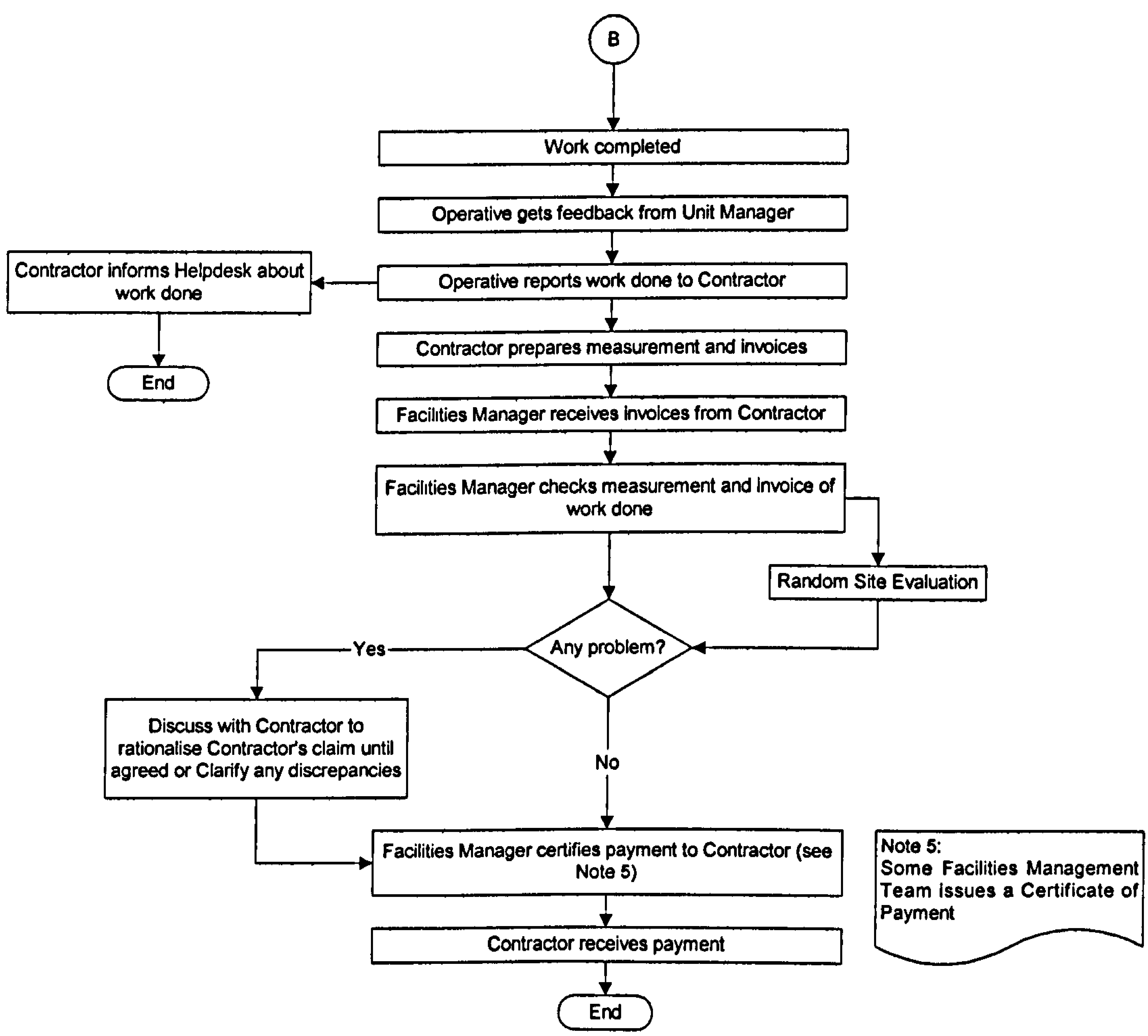


Figure 4.6: Generic Reactive Maintenance Actions

with the contractor until both parties agree a final cost. The Facilities Managers choose sites at random for Site Evaluation. This is done but to varying degrees.

The facilities manager certifies payment to the contractor upon approval of acceptable invoices. Once the managing agent certifies a payment, then the contractor can apply to the client for payment; this is done once a month to limit the number of transactions and their associated costs. Outsourced FM teams issue a certificate of payment to the client in order to get payment, while an in-house team issues an instruction of payment to their internal account division to pay the contractor. The settlement of the payment indicates the completion of that particular reactive maintenance job.

4.3 INFORMATION AND COMMUNICATION TECHNOLOGY SUPPORT IN THE EXISTING PROCESS

During the study, it was revealed that all the FM helpdesks (in-house or out-sourced) use IT systems to manage the reactive maintenance jobs. However, the age and sophistication of the IT systems in use varied from ten-year old DOS-based programs, to the latest MS Windows-based ones. Some of these IT systems were off-the-shelf commercial packages and others were bespoke systems developed in-house.

These systems allow the helpdesk to quickly and easily enter the information about the repair work reported by a unit. They automatically select the contractor from the type of repair work and the location of the unit. Some of the systems then automatically fax the job to the chosen contractor.

On the contractor side, most companies had computers, but the systems varied from a basic database system, to a specifically developed system to support their business operation, depending on the size of the company.

4.3.1 The Systems

There are a number of systems used by the clients to support their business process. The systems are:

1. MEMO - in-house MS-DOS based package
2. CALL LOG and HEADERS - FM consultants Windows based in-house system
3. QFM-SERVICE WORK - a configurable off-the-shelf Windows based software (QFM, online).

CALL LOG and HEADERS are Windows-based system, which are operated by outsourced Facilities Management; DOS based MEMO is a client's system used by outsourced Facilities Management; and QFM - SERVICE WORK, is also a Windows-based system operated by the in-house Facilities Management of a client.

The client with the MEMO system (client A) engages an outsourced FM which already has CALL LOG and HEADERS in operation for maintenance projects. Hence every job logged in CALL LOG will also have to do the same for MEMO as required by this client (Figure 4.7). Meanwhile, other clients without any FM system (client B) managed by the same outsourced FM will rely on CALL LOG and HEADERS, as shown here in Figure 4.8. Figure 4.9 depicts QFM-SERVICE WORKS used by in-house FM for client C. All of these systems have a quite similar functionality, which is discussed in the next sections.

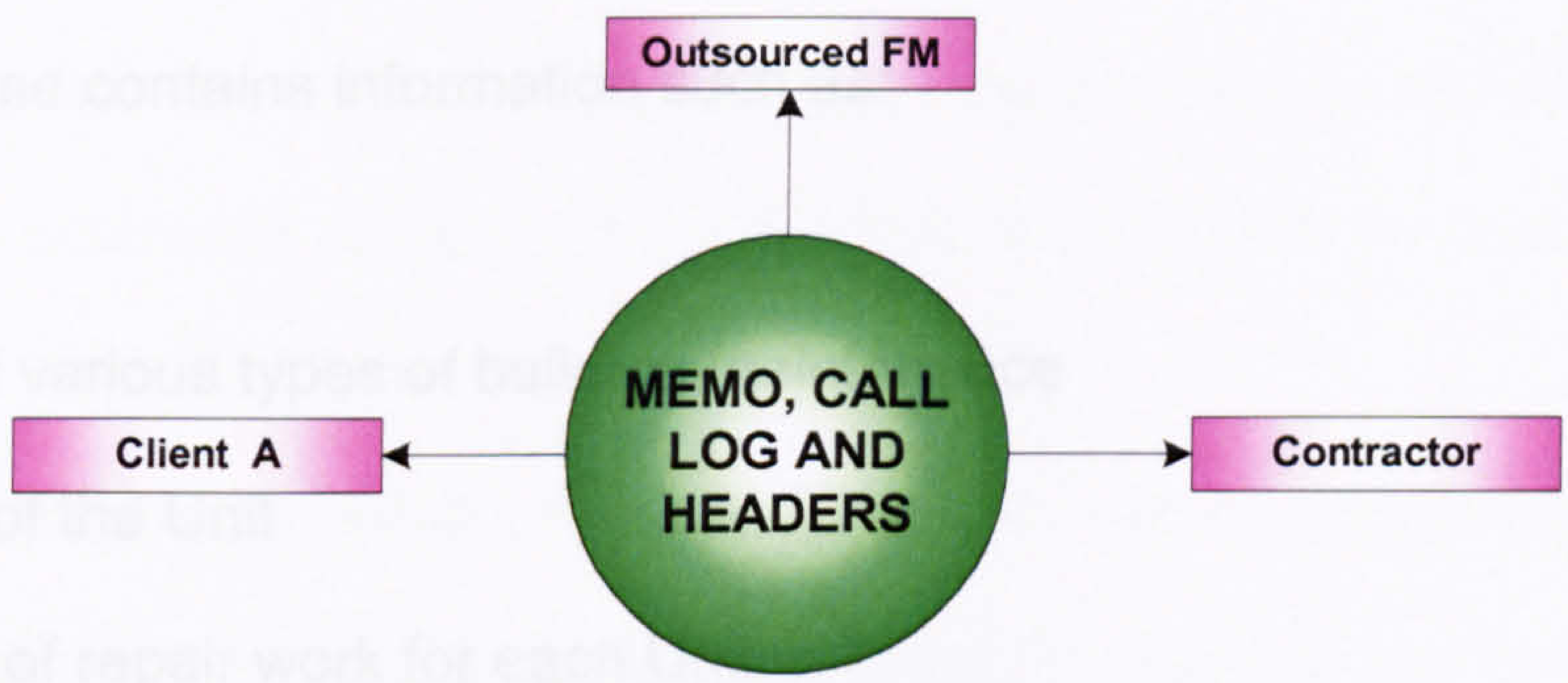


Figure 4.7: IT Systems that Link client A, Outsourced FM and Contractor

Figure 4.8: IT Systems that Link client B, Outsourced FM and Contractor

Figure 4.9: IT Systems that Link client C's In-house FM and Contractor

4.3.1.1 CALL LOG

This is a Windows based system set up for used by the Helpdesk. The Facilities Management team, as an intermediary between the client and contractor, provides this system to monitor calls regarding any repair work from the client's Unit or the contractor. The system is able to choose a contractor geographically and according to the type of repair work reported. Its database contains information such as:

1. A list of various types of building maintenance
2. Profile of the Unit
3. History of repair work for each Unit
4. List of contractors engaged with the client
5. List of Facilities Managers

A Helpdesk operator is assigned to handle calls, facsimile or emails that come in from both the Unit Manager or the contractor in-charge of the repair work. The information listed below is very important for the system to identify which contractor should be contacted and assigned the work.

1. Location of the Unit and contact number
2. Name of the person reporting the repair work
3. Type of building maintenance work
4. Response rate i.e. 2 hours, 4 hours, Same day, 24 hours or nominated
5. A detailed and accurate job description

Other information includes the budget limit and time and date of the call made. Questions are asked to Unit about the problem to ensure the correct type of contractor is chosen. For example, when a fridge is not working, questions must be asked to distinguish whether the problem is caused by an electrical failure or a fridge fault, i.e. it has run out of cooling gas. A wrong description may lead to a wrong entry into the system. Therefore, the contractor chosen by CALL LOG may not be the right one and the repair work gets delayed. Not only that, the Unit will be charged by the contractor for this mistake.

If a planned contract or guarantee does not cover the job, it will be given a Job Instruction (JI) number. Without this number the contractor will not be able to claim any payment. The majority of jobs are given a JI number.

After CALL LOG has chosen a contractor to do the work, the Helpdesk operator will print out the details and fax them to the contractor. For the client with the MEMO system, the information saved in CALL LOG will later be transferred into the MEMO system.

4.3.1.2 HEADERS

This is also a Windows-based system that is set up and used by the Facilities Management team to check the work done by contractors. It stores all the detailed information about the building maintenance job assigned to the contractors. The information fields in HEADERS are similar to the information stored in CALL LOG.

HEADERS is installed at every contractors and they must enter every job they do into this software. Contractors enter their costs into HEADERS, which the Facilities Manager will then check to see that the contractors are charging the agreed cost. A work record sheet is kept for each month and is updated for each new job with the cost. Facilities Managers will check the information in HEADERS matches the records on CALL LOG and the work record sheet.

4.3.1.3 MEMO

MEMO is a DOS based bespoke system owned by one of the clients and is used in the Helpdesks for the clients with an outsourced Facilities Management team. MEMO is also installed in the contractor's office. It basically link both the client and the contractors frontline. MEMO has the same main functions as both CALL LOG and HEADER, which are:

1. Storing the jobs that are sent to contractors

The information includes job description with reference number, location of Unit, response rate etc.

2. Sending messages to contractors

This function, however, is not always used now as it is outdated by email. Besides it can not handle attachment the way email does.

3. Receiving invoices from contractors

contractors send in their invoices to claim for payment.

Since the FM team has their own Facilities Management System (FMS), i.e. the Windows based CALL LOG and HEADERS, any building maintenance job that has been entered into CALL LOG must be manually entered into MEMO. The Helpdesk operator has to repeat the manual entry of the information on the job and a new job number is entered in MEMO. Later after the job has been performed, the job information in MEMO has to be exported into HEADERS for payment claim purposes.

4.3.1.4 QFM - SERVICE WORK

QFM - SERVICE WORK is off-the-shelf software used by the in-house Facilities Management team and Helpdesk operators for one client. This system is equivalent to CALL LOG and MEMO, where again information about any repair work reported by a Unit is entered and then faxed to the contractor chosen by the system. Listed below is the information needed from the Unit:

1. Name of the person reporting the repair work
2. Location of the Unit
3. Type of building maintenance work
4. Job Description
5. Response rate i.e. emergency, 2 hours, 4 hours, 8 hours, 4 days, 1 week and 2 weeks

Other information that is entered into this system includes reports on the progress of the work, date of completion and invoice number. Every job will be given a reference number for payment purposes, and an estimated cost (which is a standard amount and is independent of the type of job).

QFM - SERVICE WORK automatically selects the contractor based on the type of building work required, location and the contractors' previous performance. Contractors that have been problematic or have not always performed well can be rejected in the system. Sometimes the system does not function automatically and the Helpdesk operator has to manually select the most capable contractor for the outstanding work. Deciding upon the correct Contractor requires a decision on the work type from the detailed description supplied about the repair work. This will hopefully avoid the wrong Contractor being assigned to the wrong job.

4.3.2 The Systems in the Reactive Maintenance Process

In general, this process involves phones (landlines and mobiles), facsimiles, IT systems (Windows and DOS operating system), paper, hand delivery, email and post. Figure 4.10 is a block diagram flowchart that depicts the movement of information between the systems.

The vast majority of reactive maintenance jobs start with a landline phone call from the unit to the FM agent's reactive maintenance call centre – very occasionally it is emailed. At this point the call centre operative listens to the caller from the unit and enters the information into the client's IT system if the call centre is in-house (QFM – SERVICE WORKS) or the FM's IT system if outsourced to an external FM agent (CALL LOG or MEMO). The system then generates a unique job code for the job and selects a contractor using the location of the unit and the repair type selected by the call centre operative. The job details are then either sent by an automatic facsimile (in CALL LOG and QFM-SERVICE WORK), or via the client's IT system (client's MEMO) with the job appearing on a computer installed by the client at the contractor's offices.

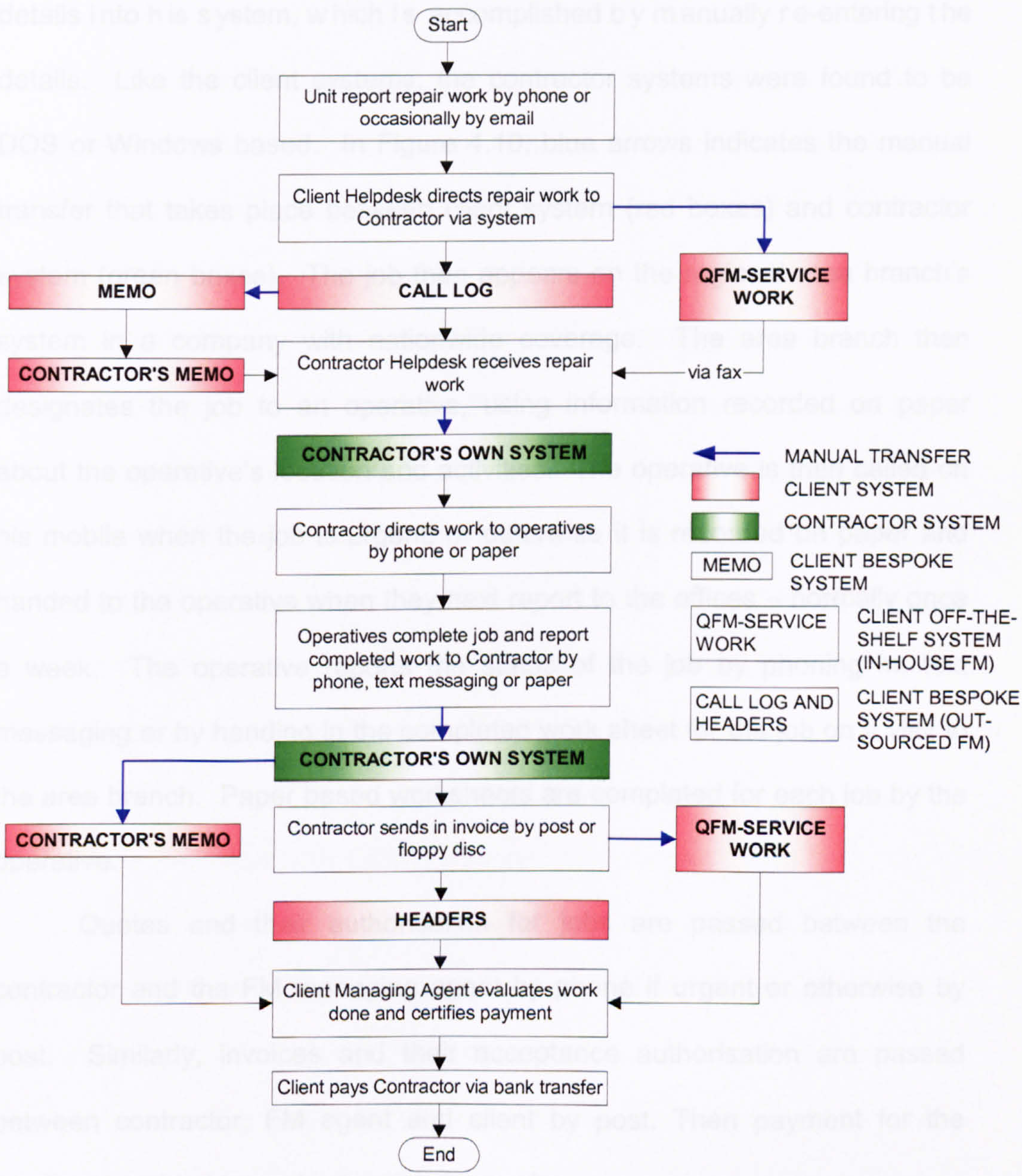


Figure 4.10: IT in the Existing Business Process

The client IT systems consist of a user interface, which varied from a DOS based text only interface to a more modern looking Windows based graphical user interface. This is then linked to a database that stores the jobs entered. Some of the systems have the capability to generate reports on the information stored and display this to the client's management.

Once the Job Instruction is received, the contractor enters the job details into his system, which is accomplished by manually re-entering the details. Like the client systems, the contractor systems were found to be DOS or Windows based. In Figure 4.10, blue arrows indicates the manual transfer that takes place between client system (red boxes) and contractor system (green boxes). The job then appears on the regional area branch's system in a company with nationwide coverage. The area branch then designates the job to an operative, using information recorded on paper about the operative's location and activities. The operative is then called on his mobile when the job is urgent, or otherwise it is recorded on paper and handed to the operative when they next report to the offices – normally once a week. The operative reports the status of the job by phoning in, text messaging or by handing in the completed work sheet for the job on a visit to the area branch. Paper based worksheets are completed for each job by the operative.

Quotes and their authorisation for jobs are passed between the contractor and the FM managing agent by phone if urgent or otherwise by post. Similarly, invoices and their acceptance authorisation are passed between contractor, FM agent and client by post. Then payment for the services provided is made via a bank transfer.

The Contractor generates a claim using their system and sends the invoice by post to client's FM. They also have to generate using HEADER and send in a copy of the invoice in a diskette. The client's FM checks this claim in their HEADER. The same invoice is also entered into Contractor's MEMO which is recorded and completed in the client's MEMO. For in-house FM, status of claim and completion of work is recorded in Q FM-SERVICE WORK.

The communication between the contractor and supplier is via the phone when checking if the parts are in stock, and in person to collect the parts. The billing and payment is by post.

There is no way for the person at the Unit to know if the job reported has been attended as required except to call the client/ FM Helpdesk. The status of work progress will not be in the system unless the Helpdesk checks with the contractor. Hence, in most cases where the unit calls the helpdesk for work status, the helpdesk does not have them on record.

Although the whole process involved is depicted in one flow chart (Figure 4.10), the process can be divided into two flows i.e. the process with MEMO system and the process without MEMO system.

4.3.2.1 Process with MEMO System

This is the process for the client who owns the MEMO system. A Unit reports problem to the Helpdesk by phone, fax or sometimes email and this is then entered into CALL LOG. Helpdesk then has to repeat manually the entry of the information into the client's MEMO system which then sends the job to the Contractor's MEMO system. For Contractors with their own information management system, another step is required as the information is transferred manually from Memo into their system.

The Operative is informed about the new job by phone. Only one Contractor of three visited uses a Vehicle Tracking system for allocating the Operative that is nearest to the Unit. If authorisation is needed then the Contractor sends a quotation to the Facilities Manager by fax or discusses over the phone if the job is essential.

When the work is completed, the Contractor prepares measurement and invoice in their system and repeats the entry into the MEMO system before being transferred into HEADERS. Finally the job is checked and analysed in the Facilities Manager's HEADERS for the cancelling of payment, work or related debt etc.

4.3.2.2 Process without MEMO System

Generally the whole process is very similar except that no MEMO system is involved in the process. The Helpdesk prints out the job description from CALL LOG and faxes it to the Contractor. When the work is completed, the Contractor prepares the invoice and measurement in HEADERS and sends them to the Facilities Manager to claim their payment.

The in-house Facilities Management team use QFM - SERVICE WORK to receive and store any works reported by Units. However, upon completion, Contractors send in their invoices and measurements by fax to the Helpdesk.

4.4 EXISTING DEFFICIENCIES

The problems identified from the visits and process analysis are listed in this section. The problems have been grouped together under three categories to clarify the major issues. Firstly, the knowledge management, storage and use of data; secondly, the problems in the procedures used during the reactive maintenance process; and finally, the inadequacies of the current systems.

4.4.1 Data Management

There are problems with the management of the information generated in reactive maintenance projects, for example the storage and utilisation of data has major inadequacies. The following knowledge management problems were found:

a. Error Prone Data Acquisition

The helpdesk operator has to define what type of problem is occurring at the unit, they are given a list of possible problem types and then have to select one option. However, the operator with little maintenance knowledge has to decide which questions to ask the caller to determine the problem type, and with no guidelines.

b. Manual Data Entry

Databases could be used to provide the information required, such as when entering the unit address details. Instead the user has to manually enter the address every time. Also, when information is passed between client and contractor a manual re-entry (double handling) is required to get the data from one system to the other.

c. Lack of Industry Data Protocol

If a standard data format for the data stored in the reactive maintenance process was used, then the clients and contractors' systems would be more compatible.

d. Incomplete Data

Databases are not complete and are not updated with new information.

e. Non-existent Data

Some useful information is not known or stored

f. Data Stored on Paper

Some information is recorded on paper and is not entered into the IT system.

g. No Archiving of Data

With records kept for years and the massive databases of jobs that evolve, the non-archiving of these jobs slows down the system.

4.4.2 Procedures

Some of the procedures in the reactive maintenance process are not well defined or followed by the users, these are listed below:

a. Wrong Telephone Numbers Called

Some of the calls received by the client's helpdesks are from unit staffs who have phoned the wrong help desk. One helpdesk said that wrong numbers received was as high as 20% of incoming calls.

Also, helpdesks are missed out of the communication chain. For example, calls go straight from the client helpdesk to the contractor area branch, when all jobs should go through the contractor's central helpdesk.

b. Conventional Communication Methods

Information is sent via telephones, mobile telephones, facsimile machines, post and paper forms (such as client specific worksheets and job reports). This requires the operative to write down information that has already been entered into the system, the helpdesks to manually enter the data recorded on paper into the system, and the transfer of information between contractor and client involves the re-entering of information – 'a manual switch interface'. The use of paper forms means that recent job details are not in the system and are not available to be checked via the computer.

c. Lack of Adherence to Job Criteria

A client specifies that only jobs meeting certain criteria are performed, such as affecting store trading, but other types of jobs are still actioned. This is possible due to the vague criteria laid down, and the reporting of jobs out of hours.

d. Longer Time Taken in Job Authorisation Procedure

Often resulted in a re-visit by an operative as this involves a long communication chain of operative to contractor agent branch to contractor helpdesk to client helpdesk to client managing agent and then all the way back again.

e. Information Not Passed to Sub-contractor

The contractor does not always pass the job quote limit for a client on to the sub-contractor when they are used for specialist jobs.

f. Uncontrolled Provision of Parts

Parts required for the repairs are not in the operative's van and a trip is made to the supplier. Purchasing agreements exists between the client and suppliers, but are not used by the operatives when at the suppliers. When a part is used from the van it will cost the amount the contractor bought it for (as much as 30% of parts bought from a supplier are not at the agreement price).

g. Capability Consuming Assessment of Completed Jobs

Involves a lot of travelling, costs and takes up a lot of time.

h. Inefficient Payment Procedure

Involves too much paper, such as posted certificates of payment, and too many communication steps.

4.4.3 Overall System

The current systems used were discovered to have the following problems:

a. IT Systems Require Rejuvenation

Developed by clients years ago, run on early age operating systems which are not compatible with other parties' modern systems and machines, and lack modern features. Also, very fixed in design and so cannot be reconfigured to handle new types of information that could be used, such as email addresses.

b. Stand Alone Systems

Exporting of data for transfer of information to external systems, such the as contractor's, is impossible.

c. Unfriendly interfaces

The current interface is DOS based and therefore does not utilize the easier to use and graphical Windows-based interface.

d. Poor Data Analysis

Data analysis reports are not fully available, and the information that is stored is not easily manipulated.

4.5 EXISTING DEFICIENCIES – FURTHER ANALYSIS

The abovementioned deficiencies can be elaborated from a different perspective as explained below:

4.5.1 Inadequate Knowledge Support

One of the main functions of the helpdesk IT system is to help to identify the right contractor for a job. The helpdesk operators are responsible for choosing the type of work from a list on the system while the person reports the fault. It is important that the type of work entered into the IT system matches exactly what the unit needs, because it is the key criterion for choosing contractors. If the proper questions are not asked, misunderstanding of the problem can occur which will lead the wrong repair type being selected, and the wrong contractor being sent. Furthermore, if an inadequate job description is recorded, the contractor could send out a wrongly skilled or equipped operative.

The system's ability in choosing the Contractor according to type of building work and location of the Unit is undeniable and so far has helped expedite the response to repair work reported by Units. Helpdesk operators depend so much on the types of building maintenance work that are listed in the system. They have to choose the type of work as the person at the Units describes it. Their main task is to ensure that the type of work they chose is exactly what the Units need. This is because the system will choose a Contractor according to that specific criterion. Therefore, Units have to be asked for detail about the repair work, and with the answer the Helpdesk operators get from the Units they describe the work into the system using plain English.

There are conditions where the problems could be solved on-site. If the right questions were asked, the person at the Unit would probably discover that the problem does not require a Contractor to attend. An example for this would be; if an automatic door could not close because the eye beam was blocked by large box placed near to the door. This can be solved by removing the box away from the door and it will work like normal again. It is important to highlight that the Contractor will charge the Unit regardless of the need to repair the problem.

Very often, novice helpdesk operators have no technical background and little knowledge about maintenance work. They are given a standard script for handling calls from the unit managers. They gain experience through:

1. Training given by the company in charge of the helpdesk
2. Day by day experience
3. Other colleagues

Once they have gained some experience, they were found to no longer need the standard script or guidelines.

The helpdesk operators build up tacit knowledge over time with their experience and knowledge gained from the job. However, because this is not explicitly captured and codified, this knowledge is lost to the organisation when an operator leaves. For a new operator to become similarly skilled will require either lengthy working experience or costly training. If the knowledge can be captured and disseminated, it will help in the training of new as well as experienced helpdesk operators.

The over reliance on human interaction between the unit managers and the helpdesk operators also requires a large number of operators to be employed at call centres. Knowledge Management techniques can be used to automate some of the interaction and reduce the need to speak to a human operator when a fault is reported. The clients involved in this study identified this as a potential cost saving area.

4.5.2 Double Handling of Data Entry

MEMO is a DOS based system that is not compatible with a Windows based system. As a result, there are two categories of IT systems in the reactive maintenance business process, one on the client side and the other on the contractor side. Unfortunately, the lack of compatibility between the two systems causes major inefficiencies. Data has to be entered twice because it cannot be transferred electronically. This 'double handling' is an unnecessary process that makes the work tedious. At present, there is no widely recognised data standard for the building maintenance domain. This makes the integration between different maintenance systems particularly challenging.

Figure 4.11 shows the events where 'double handling' occurs. Processes to and from a different colour indicate the "double handling" – where data has to be re entered.

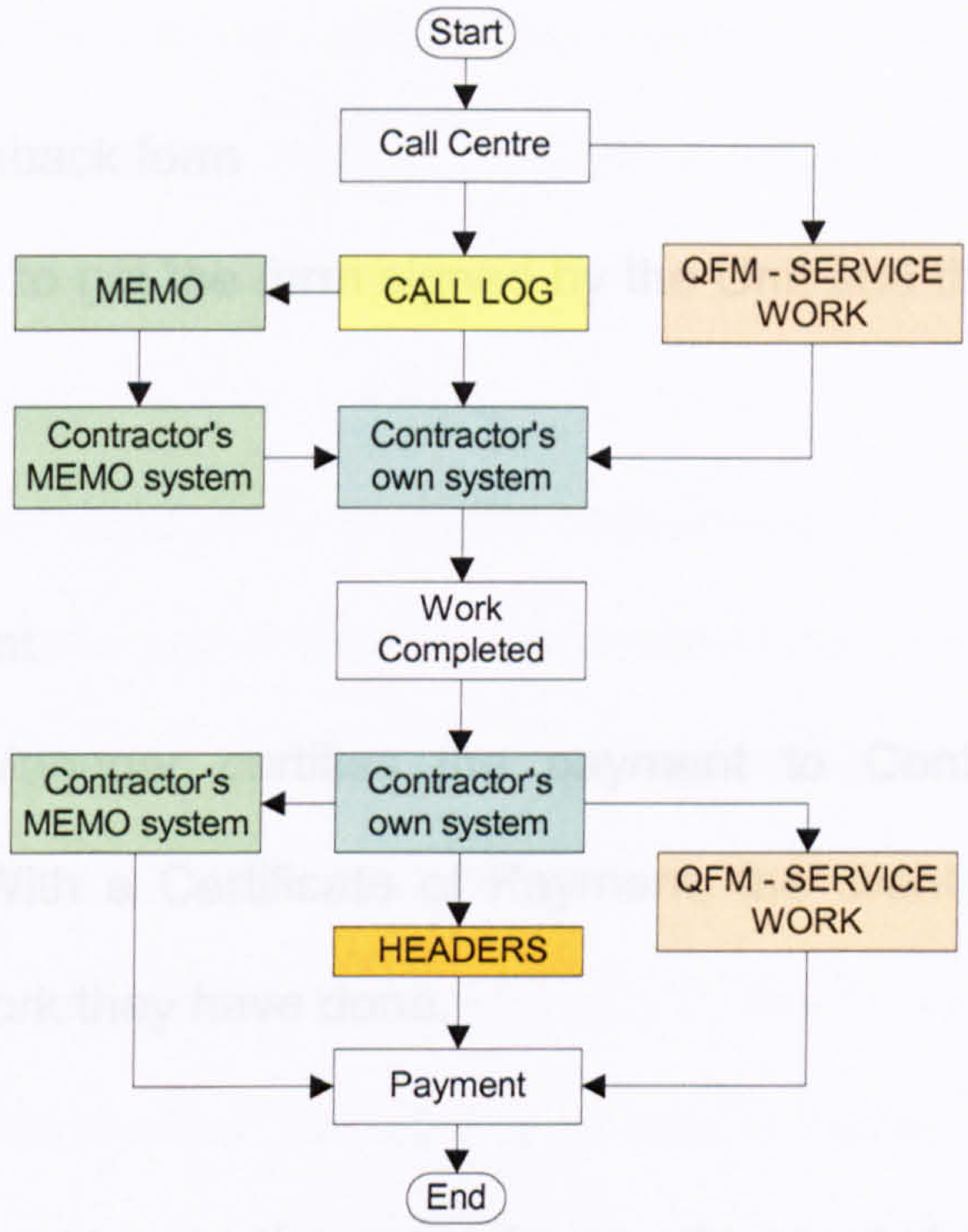


Figure 4.11: Double Handling in Data Entry

4.5.3 Poor Communication Medium

Due to the lack of integration, paper is still widely used for data transfer between clients and contractors in the forms of faxes, memo messages, quotations, forms, reports and certificates. The parts of the process that still use paper are:

1. Job description

The Helpdesk operator prints out the job description from the system that is to be sent to the Contractors.

2. Quotation for authorisation

Contractor sends quotation to the Helpdesk for authorisation by the Facilities Manager.

3. Worksheet and Feedback form

Operatives have to get the form signed by the Unit and their quality of work is assessed.

4. Certificate of Payment

The Facilities Manager certifies the payment to Contractor upon approval of invoice. With a Certificate of Payment, the client will pay the Contractor for on the work they have done.

The facsimile machine is the most frequently used device for the transfer of information. The Internet was not very popular among the companies in the survey, especially the contractors. Besides the facsimile machine, some paper documents are also sent via post or handed in to the office by the operative once a week. The use of paper in this way causes delays in the entry of recent job details, as the user must wait for the paper forms' arrival before the information can be entered into the system. Therefore, the status of current jobs cannot be checked on the computer if queries are made from the unit. In addition, the job authorisation procedure involves a long communication chain from the operative - to contractor's regional agent branch - to contractor helpdesk – to client's helpdesk – to client's managing agent and then all the way back again. Where approval is required, operatives have to revisit the unit after the arrival of the managing agent's approval, instead of carrying out the repair instantly.

The use of paper slows down the speed in which reactive maintenance work is handled. Hence, creates management difficulties. Moreover, it creates additional problems for "double handling" as data needs to be transferred from paper into the system.

The filing of paper documents is space consuming, and certain levels of information detail recorded on the paper documents are abandoned. For example, the unit manager's comments in the feedback part of the worksheet are seldom used to assess the contractor's performance for payment approval, because they are not entered into any of the IT systems. The forms are filed and forgotten about, unless a complaint is made.

4.6 IMPROVING THE REACTIVE MAINTENANCE PROCESS

Based on the analysis of the identified problems, this study proposed the following improvement to the reactive maintenance business process as explained below:

1. *Knowledge capture* – the use of IT tools to capture and update a knowledge base providing a central repository for both explicit and tacit knowledge for managing reactive maintenance projects.
2. *Electronic storage of information - provides easy retrieval for users* - for example, job feedback information is entered into the system and then used to assess a contractor's performance.
3. *Improving communication* – communication and information flow can be improved by making full use of the Internet and other Information

Communication Technology. This will in turn lead to a reduction in the use of paper, and associated delays.

4. *Easy-to-use interface* – provide an easy–to-use interface suitable for non-technical users, such as a person at the unit who is reporting a problem over the internet.
5. *Controlled accessibility* – a client and server configuration system and web interface, which can be accessed by all parties from wherever they are situated, but with their access capabilities controlled by job responsibilities.
6. *Automated data entry system* – for example, the transfer of information from one system to another should be done electronically. Because all parties have access to the same central data repository, it eliminates a certain need for information exchange using paper.

One of the main objectives of the MoPMIT research project was to develop a system, which allows the reusability of tacit knowledge and data sharing among the helpdesk operators, FM managers, client and the contractors. The more knowledge it captures, the more accurate the system will be at identifying the type of repair work needed. It can help to reduce wastage resulting from sending the wrong contractor or operative to a job. Furthermore, with better information collected about the reported problem, the operative will have a clearer view of what to expect at the unit on their arrival, especially with regards to Health and Safety issues. They will also arrive with the right tools and equipment for that particular repair work.

With the documented tacit knowledge and an appropriate user interface, the system should be able to help a non-expert user in describing the problem or identifying the types of repair work required. The unit managers will interact with the system by answering a series of non-technical questions, which are similar to what a helpdesk operator would have asked or should have asked. The adoption of such a system will also help to reduce the number of helpdesk operators and training time required.

The unnecessary process of double handling of data should be eliminated by the system. This can be achieved with a Standard Transfer Protocol (STP). Comma Separated Variables (CSV) and, the currently fashionable protocol, eXtensible Markup Language (XML) (Cover, 1998) are two examples of standard transfer protocols for exporting data from one system to another.

4.7 CONCLUSION

This chapter has given an insight into the business process of reactive maintenance projects in the UK. The flowchart technique used to mapping the whole process has made it visible enough to be analysed. The problems highlighted were agreed by the parties involved in this research which can be summarised as [1] poor communication among different parties in the process; [2] lack of knowledge sharing; and [3] poor quality of information. This has consequently opened up the opportunities for improvement particularly in the area of knowledge management, knowledge management system, communication and data sharing. In the light of the existing business process in minor construction projects and the identified inherent problems the client needs a system that has the following criteria in order to improve the process:

1. Intelligent enough to capture new knowledge with easy updating tools.
2. Can reuse information and avoid the abandonment of it. For example, information on feedback can be used to assess the Contractor's performance.
3. Improve communication by reducing the use of paper and make full use of the Internet.
4. Easy-to-use interface and suitable for non-technical user. In this case, a person at the Unit that has computer with connection to the Internet can report the problem. This can also reduce cost and time for training the Helpdesk operator.
5. Can be accessed by all parties with a certain level of access control
6. Eliminate unnecessary routine i.e. manual transfer information from one system to another

Knowledge management is seen as the key tool for realising the above criteria. Knowledge has to be captured, codified, shared and distributed in order to make the information available anywhere and at any time. The next chapter discusses the development of a knowledge management prototype system for the business process of reactive maintenance projects based on the problems and the requirements discovered (discussed in this chapter) to help improve the process.

CHAPTER 5

MoPMIT: A PROTOTYPE ONLINE KNOWLEDGE MANAGEMENT SYSTEM

5.0 INTRODUCTION

This chapter covers the development of a prototype system for reactive maintenance projects. It is an online knowledge management system named MoPMIT (More Productive Minor Construction Project through Information Technology) that seeks to address the identified problems which were highlighted or emerged in the previous chapter.

The system focuses on the improvement of communication between the key players involved in reactive maintenance work. It does not try to duplicate what is already widely available in commercial reactive maintenance systems, but to explore the application of IT techniques that have not been tried in the existing facility management systems. It aims to provide support during fault reporting, contractor allocation, job approval and performance evaluation using a knowledge-based system (MoPMIT), that guides the user through the decision making process. It seeks to enable not only the prediction of the spare parts required, but also the cost of a job by examining previous jobs of a similar nature and contractor's performance, hence assisting the managing agent in authorising jobs above the budget limit. By improving the communication between the unit managers, the contractors and facilities managers, it enables repair work to be carried out more quickly.

5.1 SYSTEM REQUIREMENT

The proposals for an improved reactive maintenance system are discussed in this section. These proposals were developed after considering the process analysis and the identified problems. The goal is to reduce the problematic components, and therefore increase the work efficiency in terms of time and cost during the reactive maintenance process. The advancements in information and communication technology are seen as the trigger to help in facilitating this improvement in this business process. The system should apply IT techniques currently absent from reactive maintenance systems. The system requirements are split into the same three parts as found in the previous process analysis problems section in Chapter 4.

5.1.1 Knowledge Management

The knowledge management part of the system has two components; firstly, a tool for supporting the decisions of staff members at the unit, or the call centre operative, takes when entering the details for a new reactive maintenance job. Secondly, the other knowledge management component of the system aims at improving the data storage and the resulting utilization and presentation of the data.

a. Decision Support Systems (DSS)

DSS are a specific class of computerized information system that support decision-making activities. DSS are interactive computer-based systems intended to help decision makers use data, documents, knowledge and models to identify and solve problems and make decisions. The DSS required for the MoPMIT system is needed to help the user with the decisions they make while entering information on a new reactive maintenance job. The DSS should be knowledge driven, with a Knowledge Based System (KBS) guiding the user through the decision making process as they enter the reactive maintenance job details, with the knowledge stored within the KBS. Therefore, the DSS removes the need for a lot of the phone calls between unit and call centre, while preventing data entry errors.

The knowledge for the KBS has to be stored using a structure that allows its retrieval. For example, rules can be used in the form: if states X_1, X_2, X_3, etc... are true, then state Y is true. Decision trees are another way of linking the knowledge, with every possible decision, or set of decisions, that can be taken linked to another required decision - a set of possible options with one required to be selected. The interface to the DSS should ask the user questions that identify the type of problem at the unit. The DSS is required as the member of staff in the unit or call centre is normally have little or no background in the technical aspects of reactive maintenance. It is vital that the user chooses the correct reactive maintenance repair type otherwise the system will send the wrong contractor to check the problem. The system should ask a series of non-technical questions and then use the answers to select the reactive maintenance job repair type.

An alternative is to use *Natural Language Processing (NLP)*, a type of IT technology that analyses, understands, and generates language that humans use naturally (Matthews, 1998). This option would allow the user to type the information for the reactive maintenance problem in a similar style as currently happens while contacting the call centre using natural language. The system then takes this entry and adapts it as required, generating further questions when some information is missing. Therefore, the user does not have to learn the system's syntax, or a programming language. NLP in the reactive maintenance process would involve the unit reporting the problem by entering a couple of paragraphs of information about the problem. Then the sentences entered are processed to select a repair type or generate the necessary questions to extract any important information that is missing.

b. Data Storage

The database is a major part of knowledge management, with the aim of the system's database to store all the information and then provide the user with access to these records. The querying and editing of the records by the user is allowed, but with the restrictions on the action they can perform, which are dependent on the requirements and responsibilities of the user.

A database system has to be chosen that can handle the amount of data entered and the number of users accessing it simultaneously. Then the database structure has to be designed, and split into linked tables when the data is in a relational database. The links allow the reassembly of the data in different tables to create the required temporary table of data for output, but with no reorganisation of the existing database. The purpose of having the data split into smaller tables is to prevent repetition of information and is called *Normalisation*.

A database design is required for the reactive maintenance job data, which defines a structure for the tables, their links, and their field names, data types, and field properties. The database structure should probably need to be slightly re-configured for each client's different information fields, but there will be a large part of the design that is generic and reusable from client to client.

A document defining the design for the database structure needs to be created, which states all the settings for the field names, data types and field properties. The resulting design must be able to store all the required data, including all the new fields identified in the process analysis.

Finally, an archiving strategy for the database is required, with the removal of data from the current database. Otherwise, the database would become too large, and so slow down any actions taken in the database. An archiving of jobs over 12 months old would suffice.

c. Data Utilization

The final knowledge management issue is the utilization of the data records once they are stored. One option is the application of Case Based Reasoning (CBR), which looks at past experiences (i.e. the existing data records) and then uses them to help with new problems. The basic idea is simple; when faced with a new problem, look for a similar problem that has occurred in the past, and then reuse and adapt the solutions. CBR's similarity based methods allow it to overcome many problems associated with database search. In particular, database search is limited to exact matches between predefined descriptive terms.

CBR allows the prediction of the parts required and the cost of a job from looking at previous jobs of a similar nature, therefore improving the time taken over quotes, as the managing agent can be pre-warned, and the operatives can visit the supplier on the way to a call out. CBR is, of course, only possible when previous cases are available.

Also, the presentation of the information stored in the database is very important, especially with more data from the reactive maintenance process now being stored within the new database structure. For example, it may now be possible to retrieve the performance of a component for equipment used in a chain of units. The relevant type of user must be able to easily access this data through the system's reporting mechanism.

5.1.2 Procedures

One of the major aims of the new reactive maintenance system is to redesign the processes already found in reactive maintenance, with a resulting improvement in the time and cost of the process from start to finish. The system must handle the following processes: accept the reactive maintenance job from the unit, store the job details in the system, assign the contractor and inform them of the job's details, display and alter the job status during the job's life.

The major change is to make the user interface to the reactive maintenance system Web based, allowing better and faster communication during the whole reactive maintenance process via the easier access introduced. The actions that the different users of the system are allowed to perform are defined within the user interface that appears to them upon logging into the system. For example, the managing agent can see the performance of all contractors and units, whereas a unit operative can only see the information and performance of themselves. The web interface becomes the means of communication, and replaces the use of facsimiles, phones, emails, etc. Almost all of the communication between client and contractor should be via the system, with automatic emails to alert the receivers if necessary.

The web interface is viewable using a standard web browser using *HyperText Markup Language (HTML) or Wireless Markup Language (WML)* when using a *Wireless Application Protocol (WAP)* enabled mobile phone. The web interface is used to update the database with new information as provided or as data changes, and therefore the data is not abandoned but added to the database.

Security is important for preventing the entry of fake jobs and the interception of job details, especially with regard to unit access details. A system with a web-based interface allows access to anyone with Internet capabilities and an allocated username and password. The data that can be viewed upon entry to the system would depend on the defined role of the user that has logged in, and the provision of the correct access details of the user is required.

However, the unit staff will still need the previous way of interfacing with the system via telephoning the call centre as a backup system, due to the varying facilities found in units (for example, when no Internet connection is available in store), and to protect against the possibility of power failures. The unit staff should be given better guidance, with a clearer description of the telephone number to call, and some automated options that they select by using a touch-tone telephone. The Call Centre operative then enters the details into the system on behalf of the member of staff calling from the Unit.

The development of a data exchange standard for the transfer of information is vital. Even though the job details are entered by the client and then passed to the contractor via the system, the contractor then needs to transfer the data onto their system, and so a protocol needs to be defined with a standard structure for the data to be understood when transferred from one source to another. There are various options, such as *CSV (Comma-Separated Values)* files containing the values in a table as a series of ASCII text lines that are organized so that each column value is separated by a comma, and each row starts as a new line. Another option is *EDI (Electronic Data Interchange)*, a standard format for exchanging business data. However, the use of *XML (eXtensible Markup Language)*, is a flexible way to create common information formats and then share both the format and the data on the World Wide Web, intranets, and elsewhere. This can then be used between any individuals, or group of individuals, or companies that want to share information in a consistent way. The reactive maintenance client needs to agree on a standard or common way to describe the information about a reactive maintenance job (repair type, job status, unit's address and so forth) and then describe this information standard with XML.

There is a European *Building Construction XML (bcXML)* standard under development (E-construct, online). An *Architecture, Engineering and Construction XML (aecXML)* standard is also being developed in the USA.

This has a facilities management operations and maintenance work group (IAI-NA, online).

The interaction between contractor and supplier could be improved by the operative using the equivalent of a high street shop store card, but for use at the supplier's outlets. When the operative is purchasing equipment for a job for a client they hand over the card to the supplier and state the company. The client then gets the parts at the rate agreed with supplier, and the client can also access the records of parts bought from suppliers.

Finally, the FM's assessment of completed jobs would be improved if the operatives had digital cameras, which are used to take photos of their work, enabling them to send the photos instantly to the managing agent. Thus, allowing the managing agent to asses the work from the comfort of their own office.

5.1.3 Overall System

The system is developed to operate on a modern operating system. The Windows operating system was available at all of the companies visited in the reactive maintenance process during the MoPMIT project, and would therefore seem the best choice. The system also needs to be hosted on a server at the client side; a PC server with high specifications that should be powerful enough to handle the envisaged number of people using the system and the amount of data transferred. The servers used should be the client's IT administrators' final decision. The users should only require a device with an Internet connection and web browser installed.

The Graphical User Interface (GUI) to the system is a web interface with a user-friendlier look and feel than existing systems, including pull down menus, tick boxes, etc, for selecting options and using the Windows-Icon-Menu-Pointer (WIMP) model of operations. The vast majority of people are now experienced and comfortable with the Windows style of computer interface.

The interface is linked to the continuously changing database, and therefore requires data-driven web pages. Active Server Page (ASP) or Common Gateway Interface (CGI) are the standard development platform for web pages that pass a web user's request to an application program, and then return the retrieved data to the user via another web page.

5.2 SYSTEM DEVELOPMENT

In this section the MoPMIT system development issues are considered, and an outline provided of the resulting actions taken. The discussion is split into knowledge acquisition and utilization, database design, web enablement, system users and the transfer of data.

5.2.1 Knowledge Acquisition and Utilization

The first aim of the system is to replicate the call centre taking the call from the client's unit. This required the system to contain and implement the knowledge used by a call centre operative when ascertaining all the required information from the caller at the unit. The major role of the call centre involves the identification of the correct reactive maintenance classification (also known as the repair type), which with the location of the unit, makes up the selection criteria for the contractor assigned to the problem. Selecting the wrong repair type will, in most cases, result in the wrong contractor arriving at the unit. This meant that the acquisition of the repair type selection knowledge from the call centre operatives is vital. The structuring and utilization of the knowledge once captured is just as important. The aim is to capture as much of the reactive maintenance knowledge as possible, with an acceptable system being able to "handle the reactive maintenance classification for 80% of new reactive maintenance jobs". The system would also be of benefit when used by the call centre operatives to enter a new reactive maintenance job, because the knowledge stored within the system means the call centre operative can be less skilled and new operators require less training and experience as the system provides the required knowledge.

The knowledge acquisition process consisted of meetings with experienced reactive maintenance staff from the various participating industrial partners and a review of the available documentation. The first task at the knowledge acquisition is to decide on the important, most frequently used, and problematic (i.e. wrong repair type selected) maintenance types and then concentrate on them specifically. This involves several meetings, and checking of documents. In these documents the knowledge was split into the individual maintenance repair types, for example roller shutter doors, glazing etc. Then within these repair types the knowledge was structured as questions and the possible answers. The answer selected would then divert the system to the next question - in the form of decision tree ordering the knowledge (the questions asked). A number of iterations are performed to reach a level of acceptance on the questions structure.

The knowledge is split into two sections, knowledge generic to all repair types and those questions that are specific. Generic questions are about health and safety, identification, location, warranty etc, while the specific repair type questions would be of the type: "Has the lift door jammed?".

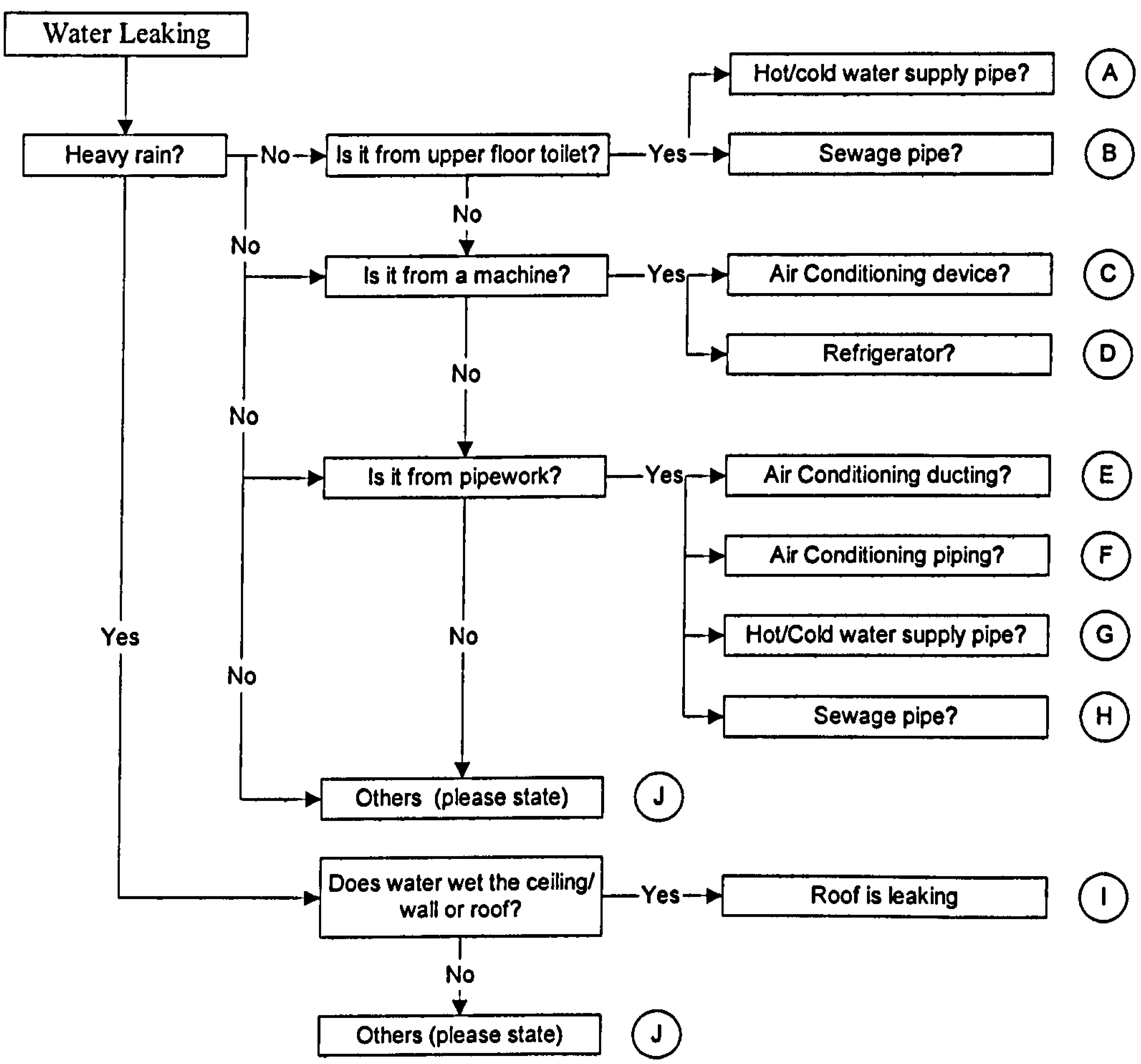


Figure 5.1: Knowledge Decision Tree

The last step is the utilisation of the knowledge within the reactive maintenance IT system. Various knowledge based system are trialed, such as XpertRule KBS (Attar, online). However, all the systems tried used Windows based interfaces and would not easily fit within a web enabled system, as discussed in section 5.2.3. Therefore, a decision was made to code the knowledge decision tree into the web pages of the system as in the example depicted in Figure 5.1. A question would appear on a web page and an answer will be selected by the user, the next web page would then appear with the content dependent on the answer passed to it from the previous page. Figure 5.1 shows the structure of the questions that break down the problem and identify the right Contractor to visit the Unit. From the example, Contractors that should be assigned for the works are as below:

A, G – Plumbing Contractor
B, H – Sewerage Contractor
C, E, F – Ventilation and Air Conditioning Contractor
D – Refrigeration Contractor
I – Roofing Contractor

If none in the list can describe what the problem is, the user may describe it as 'Others'. This will become a note for the system administrator to update the knowledge base.

5.2.2 Database Design

Firstly, the database software had to be chosen, with consideration given to the system usage. Once the type of database was selected, then a structure for the database is defined. Finally, the methods for the utilisation of the data stored in the database were developed.

5.2.2.1 Database Software

The database selected by a system developer will depend on the performance required, such as the speed when handling the number of fields used, or the number of records in the operational database. The number of calls taken by the client's call centre will provide the performance guideline for the system's database, with approximately 300 calls a day (with 200 calls reporting new jobs and 100 chasing up current jobs). There may be a case for an increase in the number of expected calls to the database once operational, because the new system allows the unit to check the status of a job more frequently.

A large and expensive *Relational DataBase Management Systems (RDBMS)* is required for web sites with a very high usage, for example, the Internet Movie Database (IMBd, online). However, the system would be viewed as a web site with small to medium operations, and therefore requires a standard database, such as MS Access. For complete performance assurance and higher capabilities then MS SQL database, Oracle or IBM DB2 databases are better suited.

In this study, the system was developed using MS Access. However, it was also assessed and checked that the system works with Oracle thereby allowing for an upgrade if required.

5.2.2.2 Database Structure

A database structure was developed, with the tables and contents recorded in a document. The knowledge that is required to be stored during a reactive maintenance job led the design of the structure. The normalisation of the various tables was checked, to avoid the multiple entries of data. The resulting structure and contents are discussed in more detail in section 5.3.2.

5.2.2.3 Database Utilization

The data stored in the database will be retrieved and displayed in reports via the web interface. The correct database structure will make this possible. Also, knowledge from previous reactive maintenance jobs can be used to aid in the entry of new jobs. For example, the average cost of a roller shutter job, or the average cost for a more specific problem within the roller shutter classification, can be displayed. This allows the managing agent to have an expectation for an imminent quote authorisation being sought for the reactive maintenance job. The retrieval of previous jobs of a similar nature can be achieved by using *Case Based Reasoning (CBR)*. However, previous reactive maintenance cases will be required to instigate the development of this part of the system.

5.2.3 Web Enablement

The system uses the World Wide Web to handle as much of the communication as possible. The first action was to select a Web server and install the system upon this server. A Microsoft IIS web server was available at the University of Salford and this was the chosen host for the system.

The server had to have certain software installed:

1. The database software - MS Access or Oracle.
2. Software for enabling access to the database - *Open DataBase Connectivity (ODBC).*
3. Script languages used by the Web pages - *ActiveX Data Objects (ADO),* JavaScript and VBScript.

The web server must have the database software used to store all the information generated during the reactive maintenance process, because the database will be operational during the system's periods of activity.

ODBC is an application programming interface that enables applications to access data in a database management system that uses the *Structured Query Language (SQL)* as its database interaction standard, with only relational databases using SQL. The system's web pages will have to access the database and perform actions.

The web pages will have to interact with the database and retrieve and enter information, and then structure the resulting viewed web pages with respect to the results. This is not achievable with web pages written using only the standard HyperText Markup Language (HTML). Data-driven web pages, which pass data back and forward between user and system, are required. There are two mainstream options, Active Server Pages (ASP) or Common Gateway Interface (CGI).

ASP pages can be written in any script language, such as: VBScript (most commonly used), Jscript (JavaScript or ECMAScript) or Perl, while CGI uses Perl, C, C++ or Java. The current trend in web development is towards ASP pages instead of the older CGI method, due to ASP being easier to develop. ASP was the chosen data driven method with VBScript as the major script language and JavaScript was used when VBScript was lacking the required functionality. The final piece in the jigsaw was ADO, an application program interface from Microsoft that lets programmers write applications which access to a database. ADO is the code in the ASP pages that creates the link between the web page and the database that the pages utilize.

The web pages created are Microsoft Internet Explorer browser compliant. Security is achieved by having a login entry point to the system. The user must have a valid username and password. Only industrial partners, or other valid users, were provided with the necessary login details and therefore allowed to access the system.

5.2.4 System Users and Roles

The innovation of MoPMIT lies in its connectivity, i.e., connecting all parties using computing network technology. The communication between the parties is done through the Internet replacing faxes, phones, emails etc. Use of this system is controlled through a username and password. All users will be allocated access rights. When the user logs into the system, the tasks they can perform are determined by the role the individual plays. For example, the client management team can see the performance of the managing agents, call centres, contractors and units, whereas the call centre operative can only see the performance of the contractors and units.

Hence, the users for the system, and even more importantly the actions and roles that they perform, had to be defined. Five main users were defined for the reactive maintenance system, Unit Manager, Contractor, Client Managing Agent, Client Call Centre and Client Management. A System Developer user was also created for development purposes.

The roles and actions performed by the different users can be seen in Figure 5.2, and these are discussed in the MoPMIT system section, see subsection 5.3.4. It illustrates the different users and what actions they will be allowed to perform when logged into the system. These functions reflect the responsibilities of various parties currently involved in the reactive maintenance process.

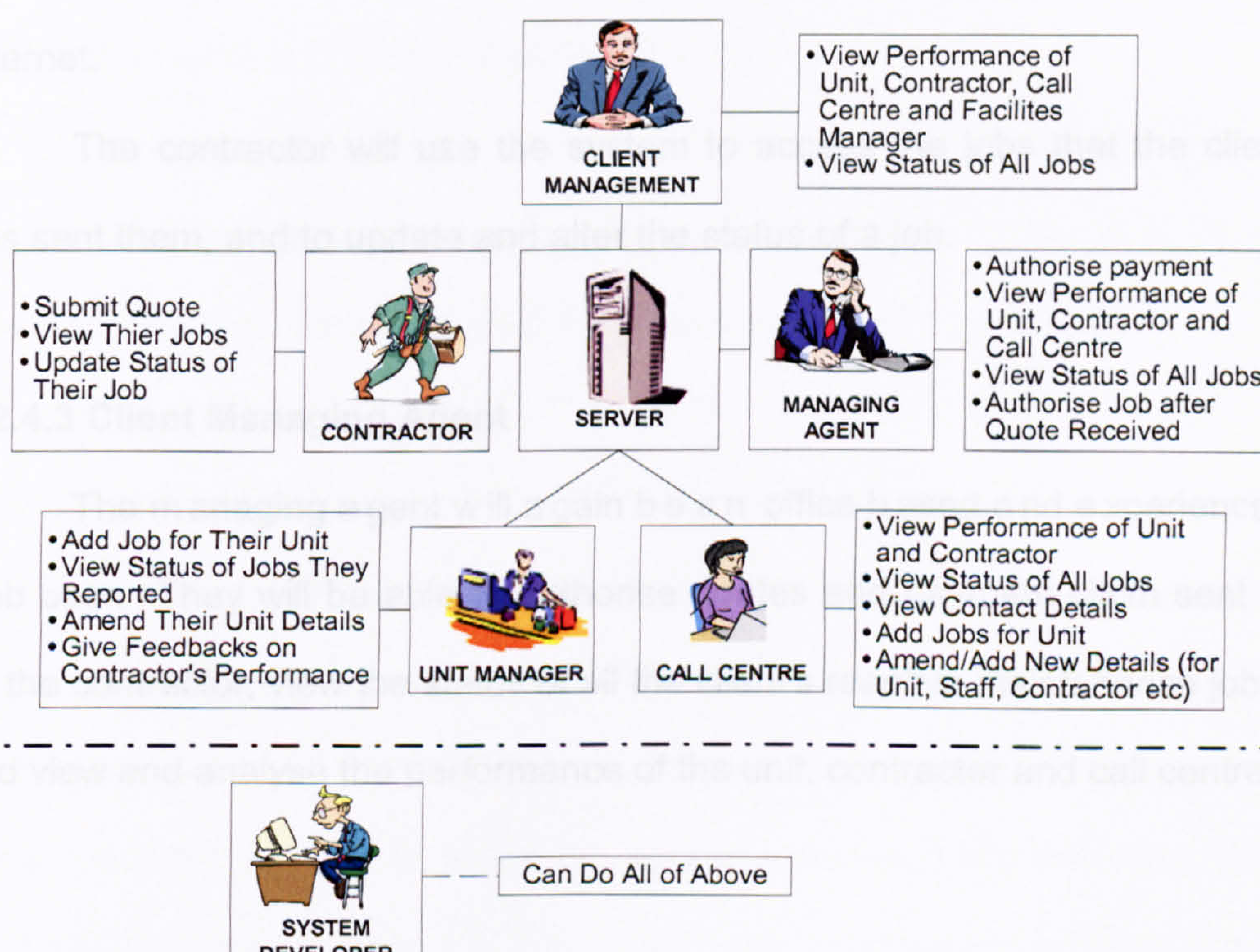


Figure 5.2: System Users and Their Roles

5.2.4.1 Unit Manager

The unit manager's IT experience may be limited. However, the majority of people in the UK are used to the Internet and are comfortable with it. Therefore, a system with an easy to operate user interface, with help and explanation components, should be within the unit manager's IT capabilities.

The major task for the unit manager will be to enter new jobs, check the status of their jobs in progress, comment on completed jobs and correct any unit detail errors.

5.2.4.2 Contractor

The user based at the contractor will be a member of the office staff, and therefore is expected to be experienced in using computers and the internet.

The contractor will use the system to access the jobs that the client has sent them, and to update and alter the status of a job.

5.2.4.3 Client Managing Agent

The managing agent will again be an office based and experienced web user. They will be able to authorise quotes and payment claim sent in by the contractor, view the status of all the client's reactive maintenance jobs, and view and analyse the performance of the unit, contractor and call centre.

5.2.4.4 Client Call Centre

The call centre operatives have to use computers to enter the job details as provided to them in the existing system, and therefore should find the new system as easy to operate.

They can replicate everything that the unit manager is allowed to perform as the call centre operative will perform the role when the unit manager is in difficulty. For example, a power cut takes down the reactive maintenance system, or there is a problem with their understanding of the system's interface for the repair type they require fixing.

5.2.4.5 Client Management

The client management will be at the top level of the management staff at the client, and will be IT skilled.

The client management will use the system to view the performance of the reactive maintenance process, with access to the performance of all the other users in the process, and all the jobs in progress or completed.

5.2.5 Data Transfer

The contractor will access the system, but then find all the information shown on the system separate to their system. They will need to transfer the information from the MoPMIT system to their own system. The MoPMIT system needs to be able to export the data in a standard fashion using XML. XML was selected because it is the currently favoured data transfer standard, and XML is suited to web based systems with the readily available tools for the translation of XML documents to web documents and vice versa.

5.3 MoPMIT SYSTEM

A description of the MoPMIT system produced now follows, with this section split into the same five sub-sections as found in section 5.2.

5.3.1 Knowledge Acquisition and Utilization

The first body of reactive maintenance knowledge acquired was on the classification of the repair types. This involved the partitioning of all the possible reactive maintenance problems under the high level repair types which dictate the contractor required to attend the unit and resolve the problem.

A general reactive maintenance classification was defined and split into three top level sections:

1. Building - problems linked to the actual structure of the unit.
2. Equipment - problems with pieces of equipment used in the unit.
3. Services - external services called in to maintain the unit.

This classification is the knowledge framework for the system. The elements for each section are listed as below:

Building Maintenance

a) Doors and Shutters

b) Glazing

c) Lifts and Escalators

d) Flooring

e) Walls

f) Roofing

g) Ceiling

h) Storage Facilities

i) Heating

j) Lighting

k) Plumbing

l) Water Treatment Facilities

m) Drainage

n) Asbestos

o) Structural Surveys

p) Automatic Teller Machines

q) Security

r) Signage

s) Internal Fittings

t) Safety

u) Storage Tanks

v) Others

Equipment Maintenance

a) Refrigeration

b) Catering

c) Ware wash

d) Dispensary

e) Furniture

f) Cleaning

g) Tannoy Systems

h) Sound Systems

i) Transport

j) Tills

k) Others

Services

a) Pest Control

b) Gardening

c) Cleaning

d) Waste Disposal

e) Skips

f) Dispensing Machines

g) Others

However, considering the time and personnel constraints on the study, a decision was taken to concentrate on a sub-section of the reactive maintenance classification. This sub-section consisted of the most commonly reported repair problems i.e.:

Building Maintenance

a) Doors and Shutters

b) Glazing

c) Lifts and Escalators

d) Flooring

f) Roofing

i) Heating

j) Lighting

m) Drainage

q) Security

r) Signage

t) Safety

v) Other

Equipment Maintenance

a) Refrigeration

k) Other

Services

a) Pest Control

g) Other

The aim is to develop a system covering about 80% of reactive maintenance problems reported, while investigating in detail only 40% of the different repair types, 16 out of a possible 40. Having the 'Other' option within each top level classification allows the problems not covered in detail to still be entered by the unit.

The subsequent knowledge acquisition involves the question development for the 13 most important high level repair classifications (not including 'Other'). The questions are split into two categorises, the generic questions that apply across all repair classifications, and the specific questions for a classification.

The generic questions were separated into nine different areas. These are listed, with a description of the information they aim to retrieve, below:

a. Health and safety - Has anyone been hurt or endangered in the reactive maintenance incident?
b. Warranty - Can the responsibility of the repair be passed onto or charged to a third party?
c. Covered by Insurance - Can the cost of the repair be charged to the responsible party?
d. Self-check - A check list to ensure the report is necessary
e. Identification - A description of the problem object/area
f. Location - The position of the problem object/area
g. Response Time Required - Assess the effect on trading, and therefore the urgency to repair the problem
h. Service History - Has the problem object been serviced recently and did this cause the problem?
i. Reason for problem - Find out if the unit knows why the problem has occurred.
j. Ongoing, Re-occurring problem - Is this type of repair occurring frequently?

The specific questions are numerous. An example question is shown below to illustrate the style:

What is the roller shutter problem you are experiencing?

a. *Roller shutter is stuck*

b. *Roller shutter activated automatically*

c. *Other problem*

This knowledge is used to provide the system's web pages for the entry of new reactive maintenance jobs. The user selects a repair type and then passes through a standard number of generic questions, followed by the specific questions and then finally another set of detailed generic questions. Some of the answers provided during this process will affect the later questions displayed to the user.

The structure of question and answer session between MoPMIT system and the user is as shown in Figure 5.3. The arrows at the bottom of the table indicate the flow of questions that a user will encounter when adding a new job in the system.

5.3.2 Database Design

The database structure is defined within the relational database Access. The system was also successfully tested when linked to a database defined within Oracle. The structure developed was able to accept all the information generated during the whole of the reactive maintenance process. This data could then be easily retrieved for the reporting on jobs. The code for a job is the unique identifier used to link the information on a job stored in different tables within the database.

Figure 5.3: Structure of Questions

5.3.2.1 Data Structure

The data structure of the database, including all its tables and the fields within each table, is very large. In order to provide a feel for the structure, the major tables are presented, and a description provided of the information they capture.

The main and central table to the database records the job details. This table stores: the codes for the job, the unit reporting the problem, the job repair type, the date and times that the important points in the reactive maintenance process are reached, the status of the job, the response time required, quote details, and the report on the completed job.

There are separate tables for the unit details, contractor details, operative details, managing agent details, and supplier details. These tables link the code for the particular type of agent, which is used in the job details table, to the in depth details, such as name, address, etc. There is another set of tables that link the other codes used in the job details table to the more detailed and textual descriptions.

Also, there is a set of tables for each specific repair type, allowing the storage of the information that is specific to a repair type.

Finally, there is a table that links the post code (i.e. the location of the unit) and the repair type to the contractor used by the client.

Information that is now recorded and was missing from the previous systems are:

1. Job Details

Feedback on completed reactive maintenance jobs

2. Contractor Details

Contractors within range of a unit

3. Managing Agent Details

Contact details

4. Asset Management Details

Record of equipment in store

Record of warranties

5.3.2.2 Database Utilization

The data stored by the MoPMIT system provides benefits in two major ways, firstly, the extra information displayed to the users and the more educated reasoning that results. Secondly, the improved reporting of performances within reactive maintenance, made possible by the extra information. The two benefits are elaborated as below.

1. Extra information displayed to the users

The new information that is displayed by the system:

a) The job cost limit - a job that will cost more than this limit will require a quote and authorization.

b) The resulting costs warning - the user is warned about the cost of the response time they select.

2. Improved reporting of performance

The MoPMIT system can provide reports, using the data now stored in the database, on several areas of reactive maintenance. The user can perform an analysis on the following:

a) Unit Performance

Number of jobs requested and completed

Average cost per job

Cost per year of maintenance

Cost per year of maintenance compared to size

Cost per year of maintenance compared to revenue created

b) Contractor Performance

Number of jobs assigned and completed

Response rate of contractor

Operative's quality of work

Average number of operative visits per job

Number of jobs completed without the required authorization

c) Managing Agents Performance

Number of jobs authorized/aborted

Jobs visited and inspected

Amount of cost amendments

d) Asset Management

Equipment/warranties in Unit

Parts/equipment performance - frequency of failure

Total assets

5.3.3 Web Enablement

This system was installed on a Windows NT server using IIS Web Server software. The web pages are coded to run using ASP. Two scripting languages were used within a web page, the majority of the scripting is in VBScript. However, Jscript was utilized when the required functionality was unsupported by VBScript. The links from the web pages to the database were created using ADO, with the commands passed in SQL. The terminology used is outlined in more detail in section 5.2.3.

There is an initial web page for the user to login. The second web page then retrieves the type of user from the login details and then displays the page in a style and content relevant to the user. Now, the user has a number of options, from between five and ten in actual fact, and each with its own web page. Then for the option selected there will be numerous pages, for example, within the 'add a new job' option there are about 80 pages.

The reusable parts of the web pages are contained in *.inc* files, with a 100 of these used within the system. For example, an *.inc* file is used for the location part of the entry details, containing the display and text details for the entry boxes.

5.3.4 System Users and Roles

The actions that are replicated from the reactive maintenance process and performed within the MoPMIT system are listed in Table 5.1. Also shown are the types of users responsible for each action, and the actions that could possibly follow on after the current action is completed. There are fifteen possible stages in the MoPMIT System for reactive maintenance:

Table 5.1: Process Performed within the MoPMIT System

	Action	Taken By	Next Possible Action(s)
1	Report a new reactive maintenance problem	Unit	2
2	Designate an operative to problem	Contractor	3 or 4 or 5 or 8
3	Report work completed	Contractor	12 or 13
4	Submit quote	Contractor	10 or 11
5	Report operative visiting supplier	Contractor	6 or 3
6	State parts ordered and awaiting arrival	Contractor	7
7	Report parts arrive	Unit/Contractor	2
8	Report wrong repair type provided	Contractor	9
9	Select different repair type	Unit	2
10	Authorises quote	Managing Agent	2
11	Terminate job after reviewing quote	Managing Agent	END
12	Complete repairs feedback form	Unit	14
13	Restart job as NOT satisfied with repairs	Unit	2
14	Accept/adjust cost of repairs	Managing Agent	15
15	Pay contractor	Managing Agent	END

5.3.4.1 Unit

The unit enters the new reactive maintenance job, with the aid of the knowledge powered Web pages. The unit manager is asked to perform simple checks that might avoid an unnecessary call out. Also, the unit can report when any ordered parts for the repair arrive at the unit. The unit can be asked to enter the job with a different repair type when the first selection has been deemed incorrect by a visiting operative. Finally, the unit has to enter their comments on 'completed' jobs, and with this they finish their responsibilities within the reactive maintenance process for a job.

The unit can view the existing jobs, ongoing and complete. Jobs entered within the last 72 hours are pushed to the unit's attention to prevent the double entering of the same job.

5.3.4.2 Contractor

All jobs entered by the units will appear on the contractor's display as new jobs first waiting actioning by the contractor. The contractor is then required to update the status of the job as changes occur during the reactive maintenance process. Initially, the arrival of the contractor's operative at the unit, then the job being completed and the relevant information entered, or a quote sent, or that parts have been ordered, or the arrival of the ordered parts, or a wrong repair type selected.

The contractor can view any job waiting for actioning by themselves, and the other statuses found between actioning and completion such as Operative Sent to Job, Operative Completed Repairs, Send Quote, Quote Authorised by Managing Agent or Waiting Parts.

5.3.4.3 Managing Agent

The managing agent must authorise or terminate quotes via the system, decide to re-send a job when not fully content with the contractor's performance, and finally, accept or adjust the contractor's invoice and then authorise its payment.

The other major use of the system for the Managing Agent will be the performance analysis of Unit and Contractor.

5.3.5 Data Transfer

Development of XML standard for the transfer of reactive maintenance data is not covered in this study. Some ongoing researches (as explained in section 5.1.2) are developing such standard for this purposes.

5.4 SYSTEM ARCHITECTURE

The implementation of the MoPMIT system adopted a client and server configuration and web-based interface. Figure 5.4 shows the architecture of the system. It consists of a server, which runs both as a web server (for hosting the web pages) and a database server (for handling the

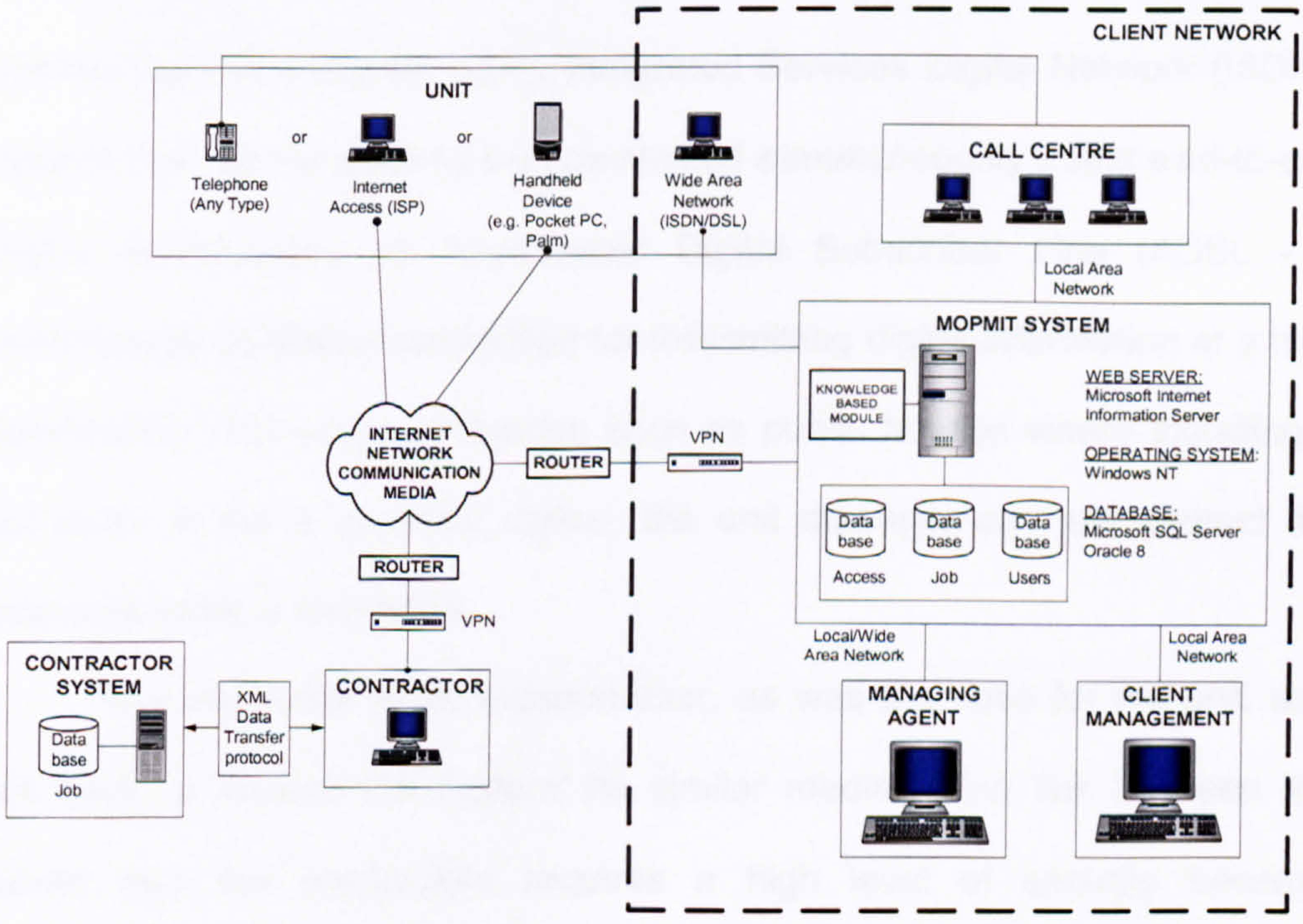


Figure 5.4: MoPMIT System Architecture

information), and many client computers located at various client's premises. The users interact with the server through a web-based interface.

The main component of the system is the knowledge based module. The system links to the existing Facilities Management (FM) system with a generic design that ideally allows it to port to other FM systems at a later stage. Since the system is web based, to access it the user has to have a device with a web browser and a connection to the Internet.

The diagram also shows the methods available for a unit to enter a job, either accessing the system themselves using a PC or handheld devices or by phoning the call centre, they can then access the system. The call centre, managing agent and client management will access the system from their PC, which will be within the client's network .

The connection between the client and server can be achieved through modem via Internet Network Communication Media such as an Internet Service Provider (ISP), Integrated Services Digital Network (ISDN - system that allows data to be transmitted simultaneously using end-to-end digital connectivity), or Asymmetric Digital Subscriber Line (ADSL - a continuously-available connection for transmitting digital information at a high bandwidth). For some properties such as public houses where installing a computer is not a practical option, the unit manager can still contact the helpdesk using a telephone.

The contractor is an external user, as was the case for the unit, and will have to access the system via similar media. The link between the server and the contractors requires a high level of security because quotations and payments will be transferred on-line. In such instances, a

Virtual Private Network (VPN) will be installed at each end of connection for security purposes. The VPN prevents hackers getting into the system using a firewall that only allows recognised IP addresses, and ensures that the data is transferred securely with encryption of the data (VPN, online).

Figure 5.5 – 5.8 show different operation scenarios implied to different users.

1. Web

Figure 5.5 describes how the unit uses the web site to inform the contractor of a reactive maintenance job.

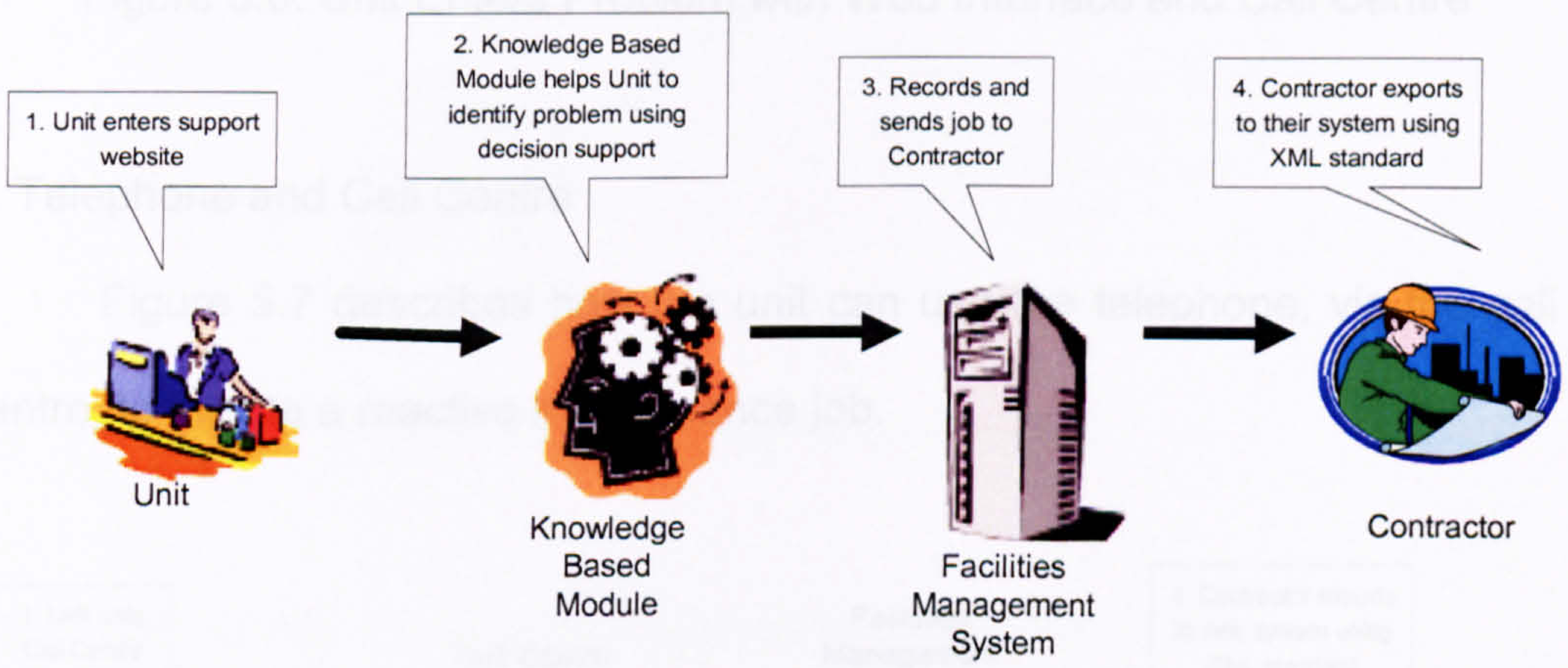


Figure 5.5: Unit Enters Problem with Web Interface

2. Web and Call Centre

Figure 5.6 shows the process when a unit starts entering a job and then due to irregularities the call centre is brought into the chain of actions.

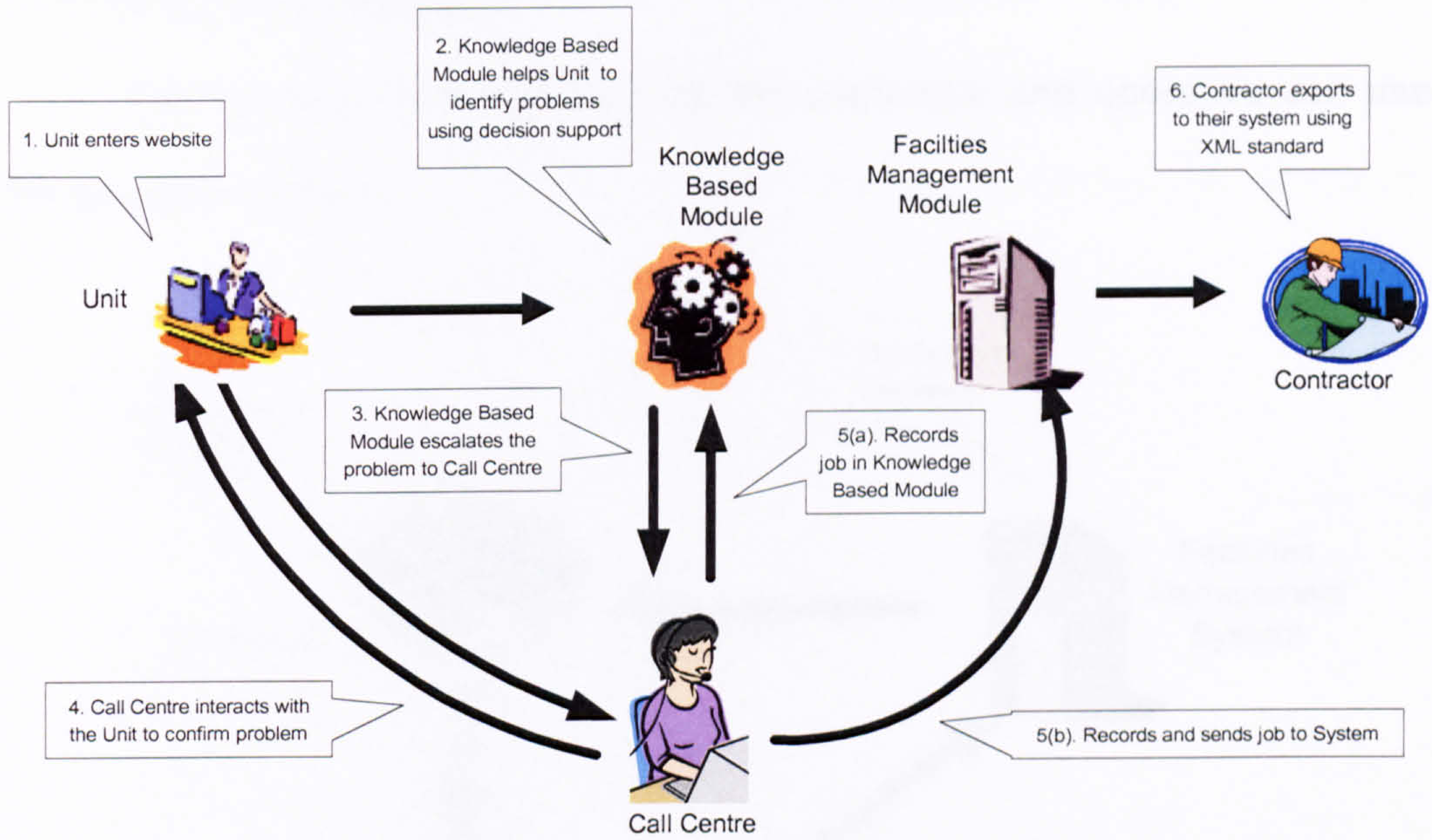


Figure 5.6: Unit Enters Problem with Web Interface and Call Centre

3. Telephone and Call Centre

Figure 5.7 describes how the unit can use the telephone, via the call centre, to initiate a reactive maintenance job.

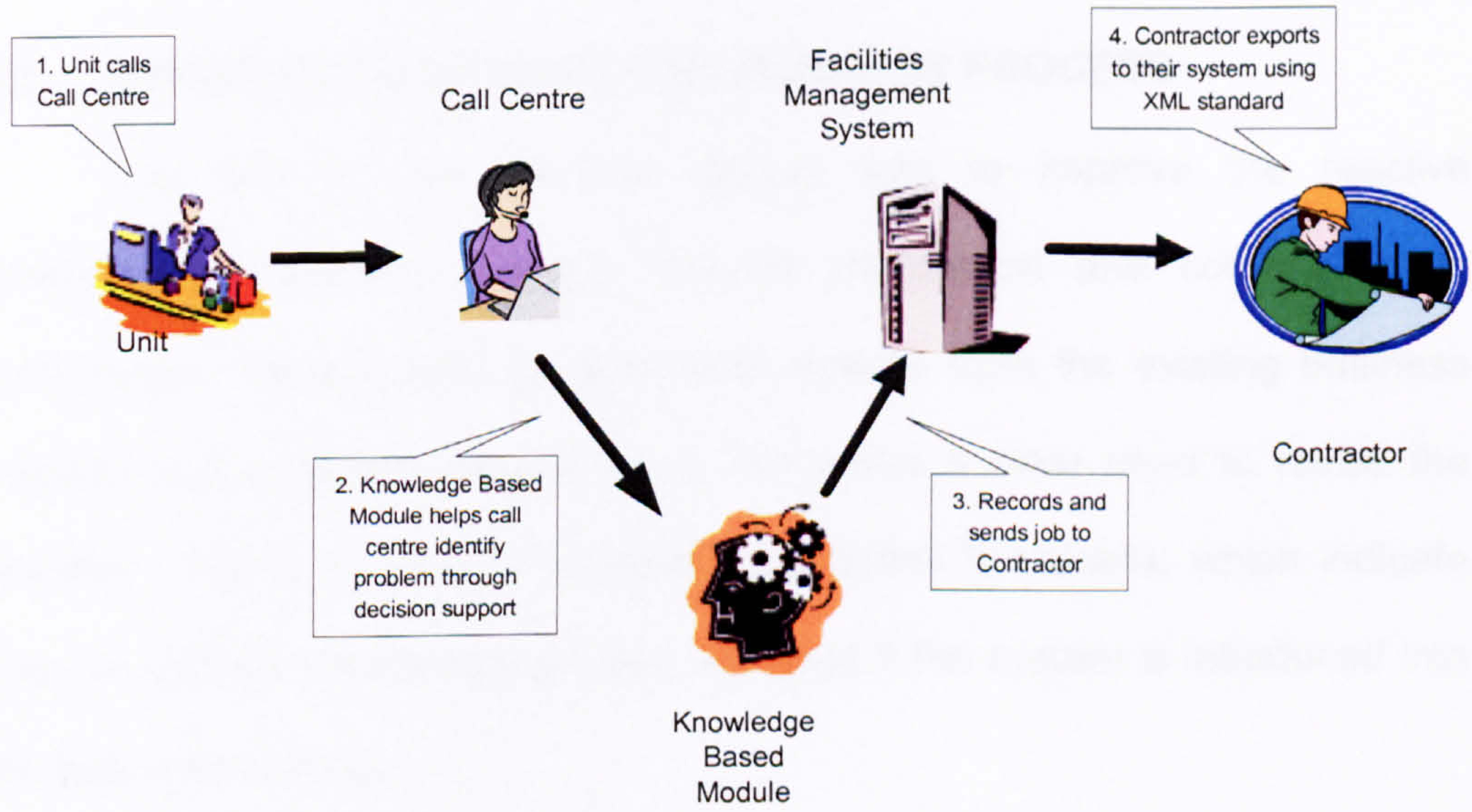


Figure 5.7: Unit Contacts Call Centre and They Enter Problem

4. Contractor and Operative

Finally, figure 5.8 outlines how the contractor and operative can use the proposed system.

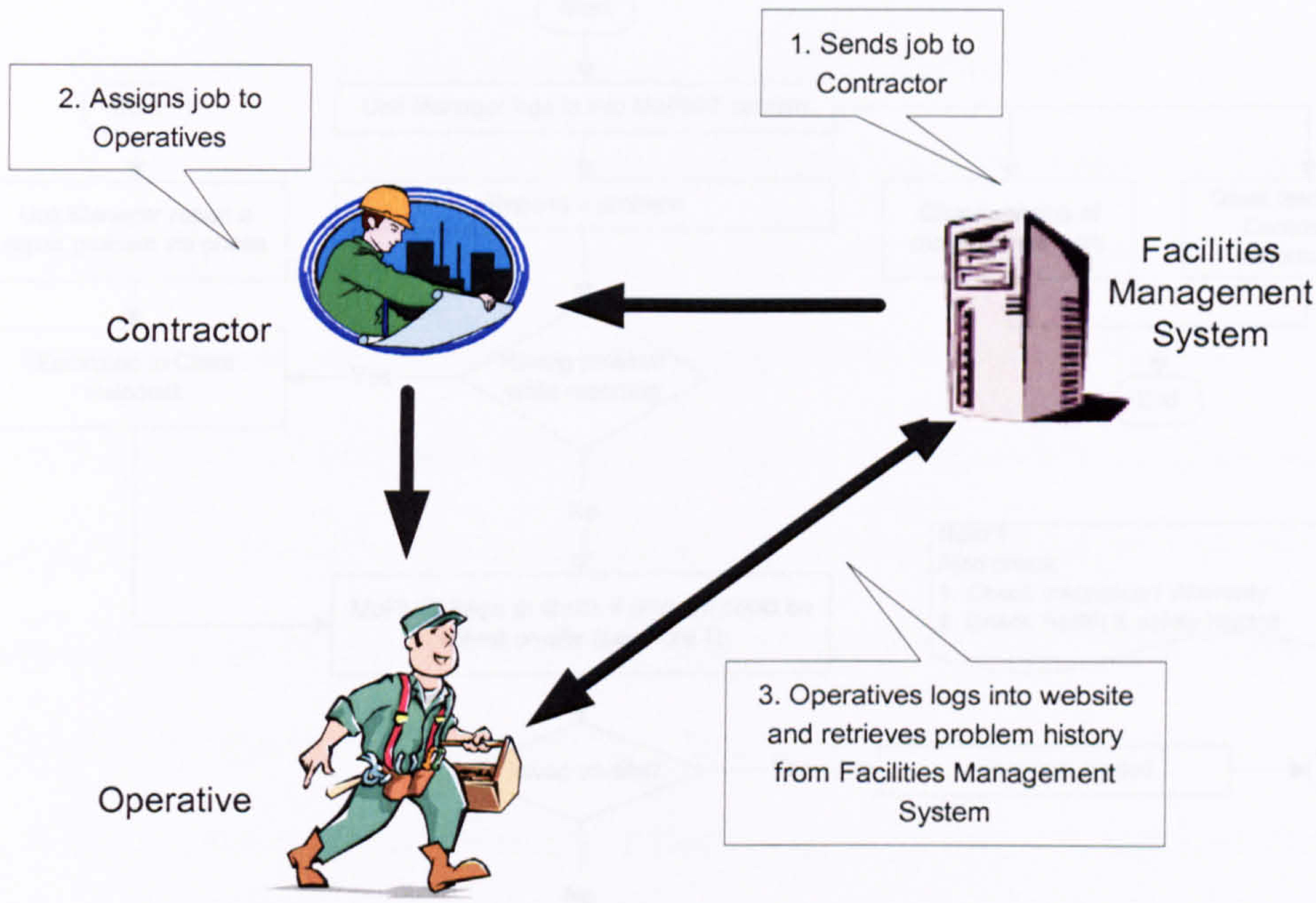


Figure 5.8: Contractor and Operative

5.5 IMPROVED RE-ENGINEERED BUSINESS PROCESS

The aim of this research project was to improve the reactive maintenance business process through information and communication technology. Having seen the problems emerge from the existing business process and proposed requirements, there was a clear need to revise the process. Figure 5.9 and 5.10 show the process flowcharts, which indicate how the parties should operate their activities if the system is introduced into the business process.

Similar to the AS-IS business process depicted in Chapter 4 (Figure 4.4 - 4.6), but with slight modification where some processes were eliminated, a job starts when a user, who is likely to be the Unit Manager,

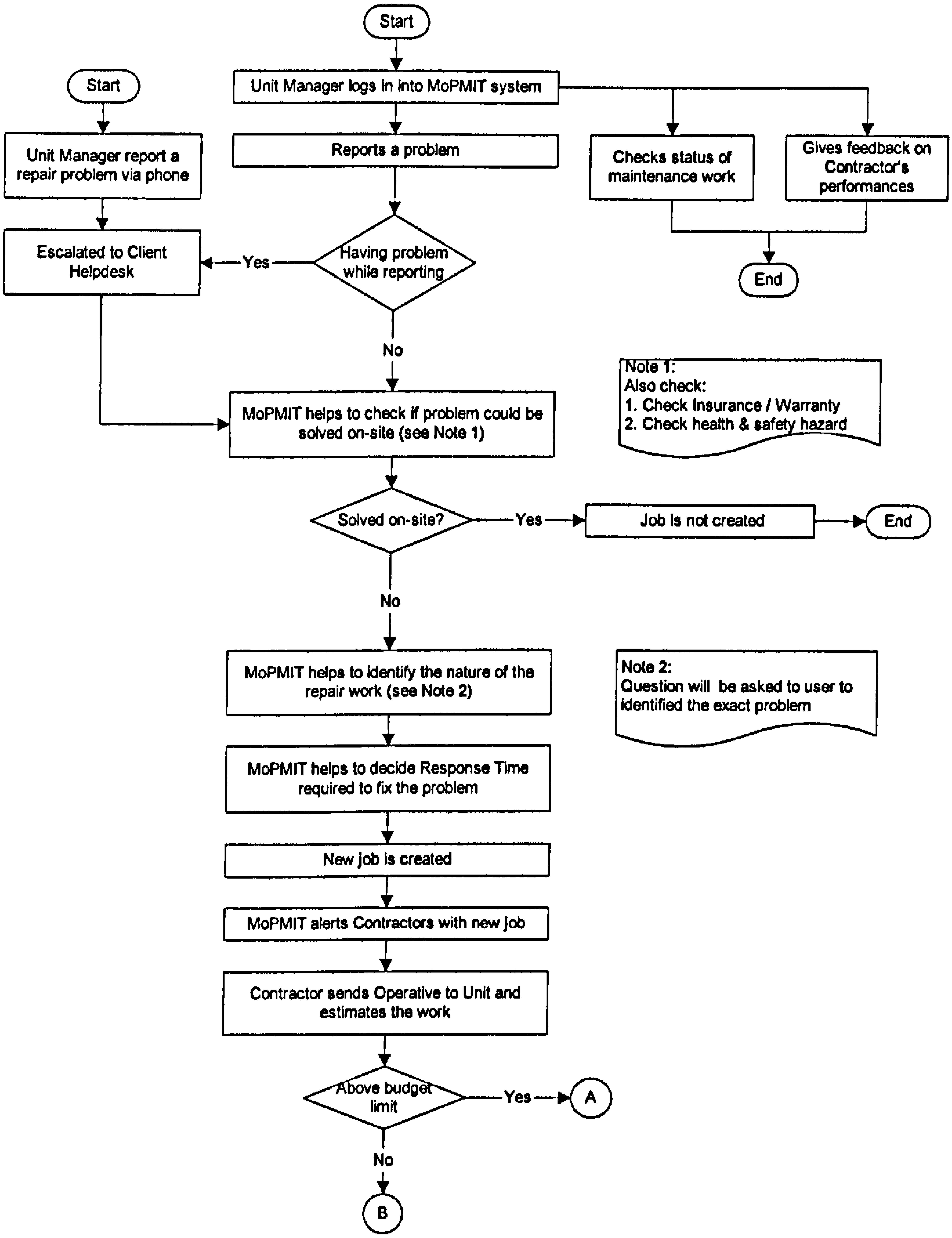


Figure 5.9: Re-engineered Business Process for Reactive Maintenance

contacts the Client Helpdesk to report a repair work (Figure 5.9). Instead of contacting the Helpdesk via the phone (which is still possible to do as not all premises will have an Internet connection), the user can log on into the MoPMIT system.

Once logged in, the system will show the Unit's details such as the address; contact number and person; available parking area, and status of work progress. The user is allowed to change any details on the screen. The same screen also provides a link where job will be reported. By clicking this link, the system will first help the user to check if the problem could be solved on-site. For example, when an automatic door is not closing, the system will suggest the user to check if anything has blocked the door laser beam that could prevent the door from closing. The user will check the situation and see if the self-check has actually solved the problem. A job will not be created if the problem is solved on-site. Otherwise, the system will proceed with a questions and answers session in order to identify the exact problem. This is important, as the system will rely on these answers to decide and select the appropriate Contractor to do the job who would consequently visit the Unit with the right tools and equipment. The questions and answers session basically replicates what a Helpdesk Operator would do in the current practice.

Apart from self-check, the user would also be asked if the problem is covered by insurance or warranty. For health and safety issues, the system will suggest what actions should be taken before the Operative arrives on site to see if the problem incurs any hazard. For instance, a warning sign should be put up to stop people from using the faulty elevator.

The user has to select the Response Time required for the Contractor to come and also identify the repair location. At this point, the system will assign a Contractor that would send an Operative to do the work.

It is possible that at any time while reporting the problem via online, technical problems might occur. The system should be able to escalate the report to a Helpdesk Operator whom will help the user via telephone. The Helpdesk Operator will be seeing the same interface as the Unit Manager is. In a way, this system would also offer an element for Helpdesk training purposes.

Until this point, the problem description is successfully entered into the system. MoPMIT will alert the Contractor about the new job when the Contractor logs in into the system. An Operative will then visit the Unit and estimate the repair work. If authorisation is needed from the Facilities Manager, the Operative will supply the Contractor with the quotation of the estimated work.

Instead of faxing the quotation to the Facilities Manager as in the normal practice, the Contractor could upload the quotation and measurement for the Facilities Manager to check (Figure 5.10). The system will alert the Facilities Manager about the awaiting job authorisation. Decision on whether the job should be authorised could be based on the information stored in MoPMIT server e.g. history of repair work at the Unit; Contractor's previous history data or cost of material. As usual, discussion or negotiation with the Contractor could always take place when necessary. A job will not proceed if authorisation is refused. The Facilities Manager will update the job status in the system once he has decided to grant the authorisation. The Operative will go back to the Unit with the necessary equipment to complete the work.

When the job is completed, the Contractor will update the job status in

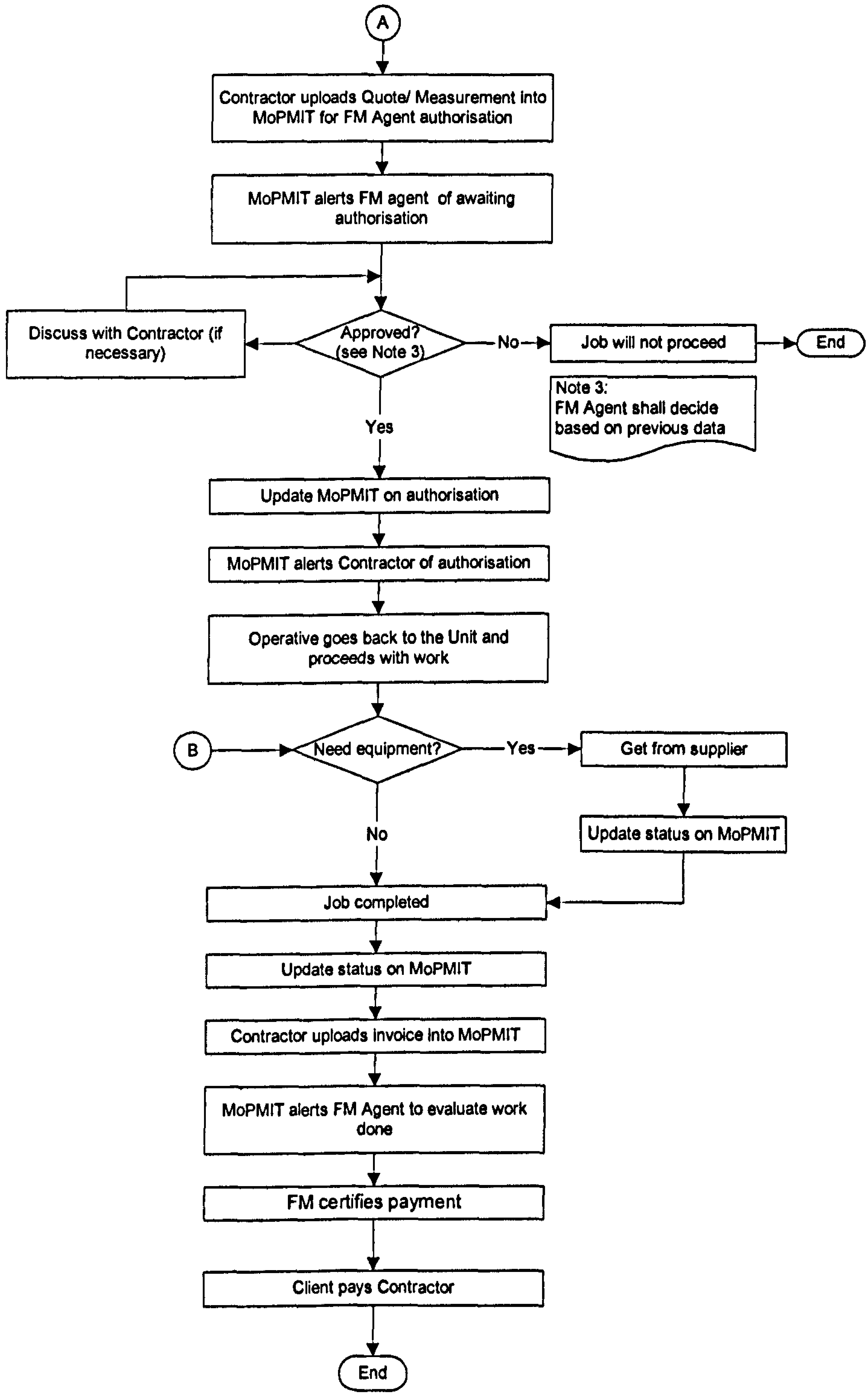


Figure 5.10: Re-engineered Business Process for Reactive Maintenance

MoPMIT. The Unit Manager could check the progress of work by logging in into the system and also give feedback on the Contractor's quality of work. This information could be used by the Facilities Manager to assess the Contractor's performance for future reference. To claim payment of work done, the Contractor may do so by uploading the invoice into MoPMIT. Once received, the Facilities Manager evaluates the invoice against work done and certifies the payment for the Client to pay to the Contractor.

Figure 5.11 shows a circle of process of how every party is interconnected by MoPMIT system and the flow of a reactive maintenance work, which starts when a problem occurred at a unit premises. The system allows them to share information and communicate on a common interface

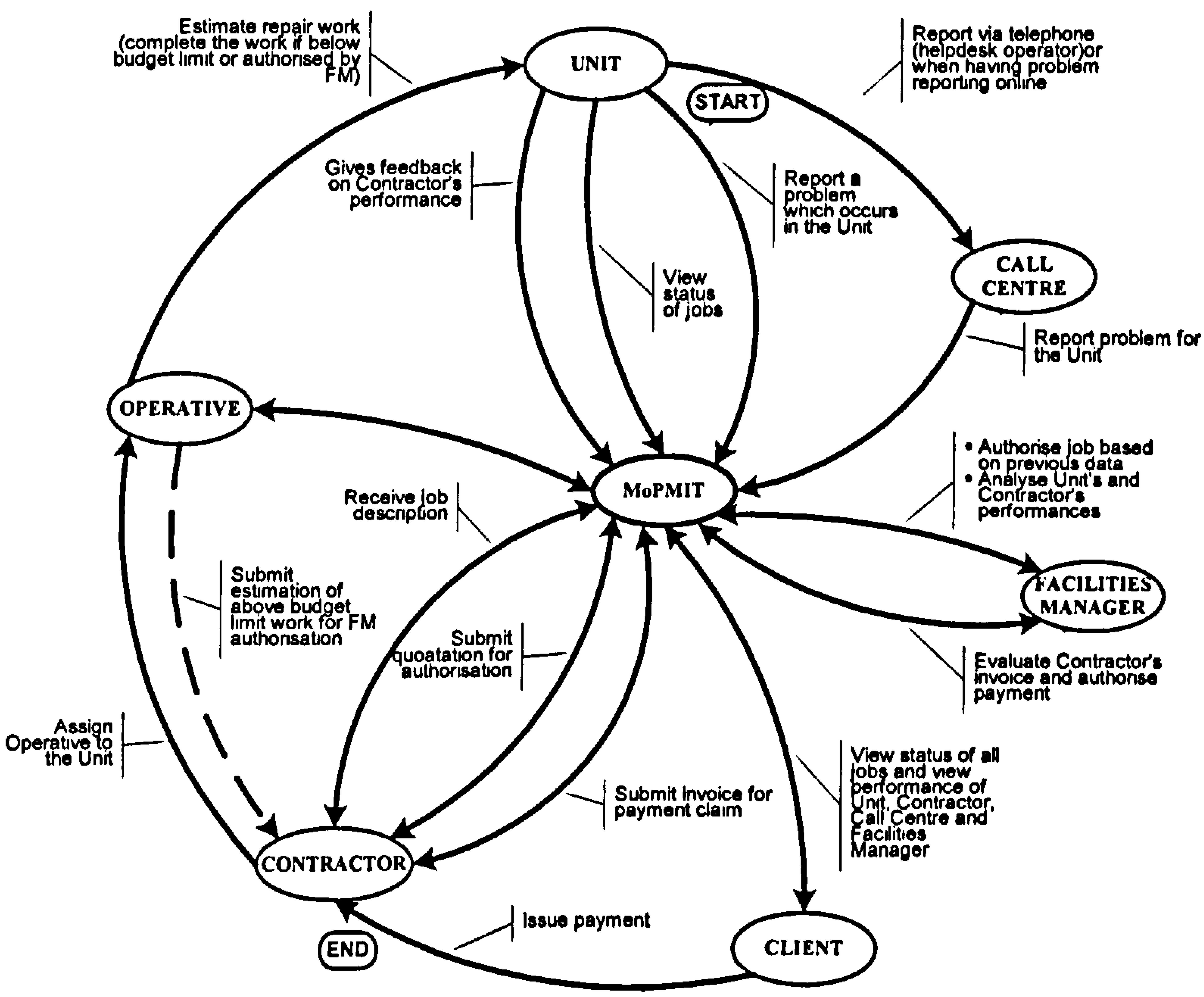


Figure 5.11: Process Flow for Reactive Maintenance Project with All Parties Interconnected by MoPMIT System

with pre-allocated password access as a control mechanism that will restrict each user to its role.

5.6 MoPMIT SYSTEM INTERFACE

This section describes a scenario for the operation of the system and the interfaces:

1. An electronic shutter at a retail shop has a fault and requires urgent repairs. A unit manager logs onto the MoPMIT server using a pre-allocated username and password to report a faulty roller shutter at his shop with a request for urgent repair (Figure 5.12).

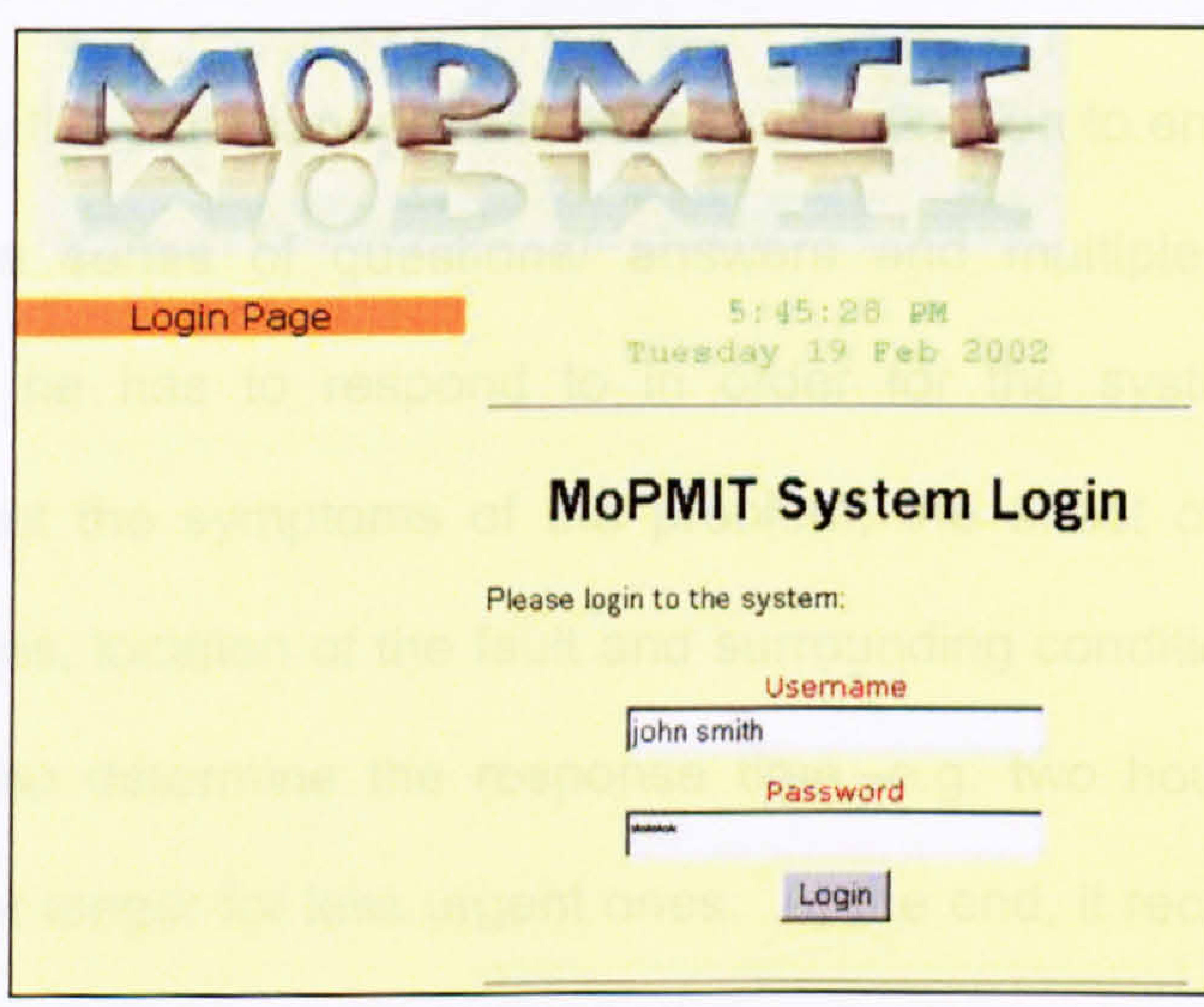


Figure 5.12: Unit Manager Interface: Login Page

2. Once it recognises the manager's identity the system brings up details about his store. The screen provides a range of functions for entering jobs,

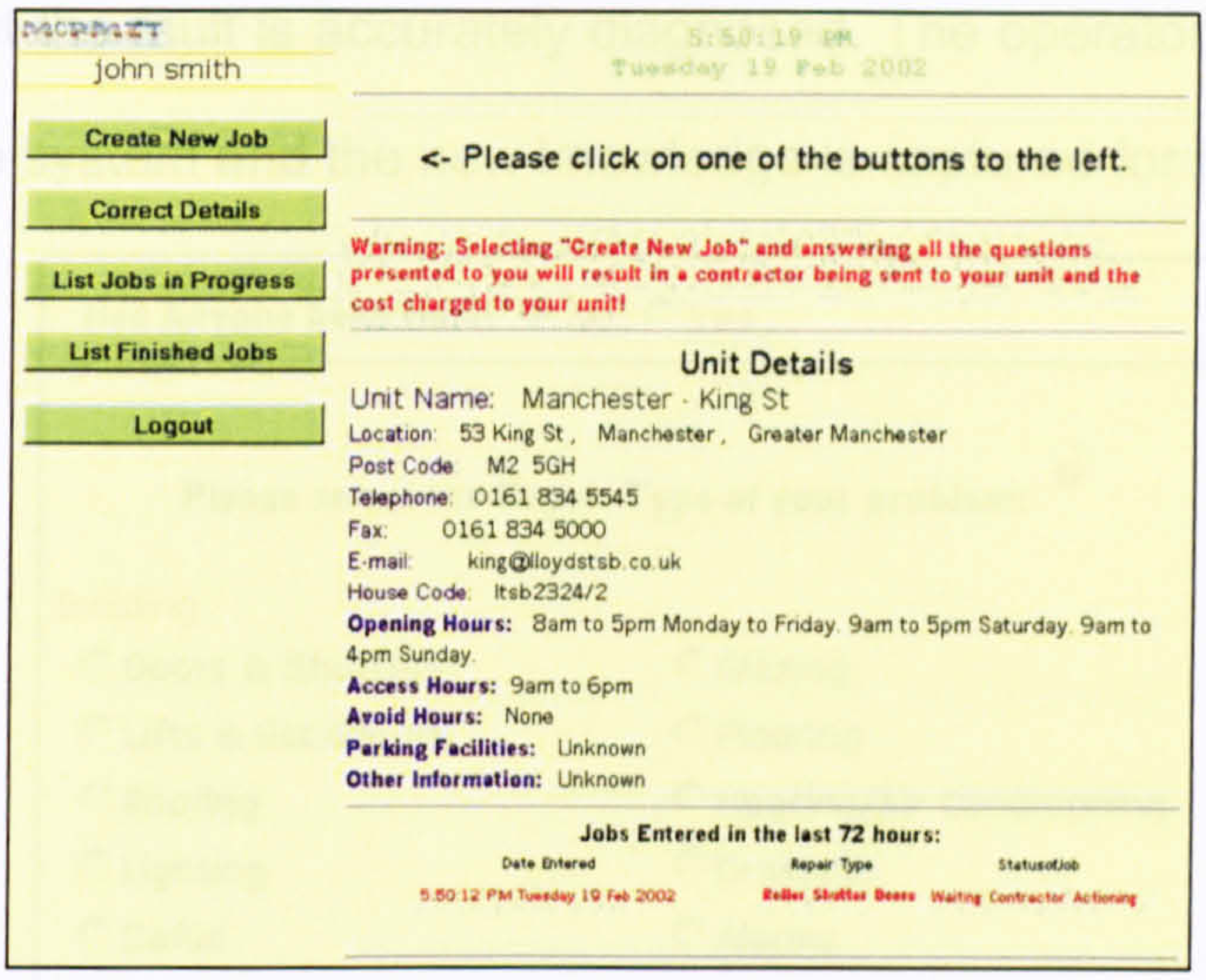


Figure 5.13: Unit Manager Interface: Unit Details

reviewing job status and providing feedback on a completed job (Figure 5.13).

3. At this point, the unit manager will choose the function to enter a new job. There will be a series of questions/ answers and multiple choice style interaction that he has to respond to in order for the system to gather information about the symptoms of the problem, the effect of the fault on business activities, location of the fault and surrounding conditions. The unit manager will also determine the response time, e.g. two hours for urgent jobs, 24 hours or longer for less urgent ones. At the end, it recommends the most appropriate contractor to do the job (Figure 5.14 – 5.18).

If the system has difficulty in either understanding or interacting with the unit manager. The problem will be escalated to the attention of a human helpdesk operator. The operator will telephone the unit manager and interact with the manager in the conventional manner. Through human intervention, it is hoped that the fault is accurately diagnosed. The operator enters the job details into the system and the new knowledge is captured for future cases.

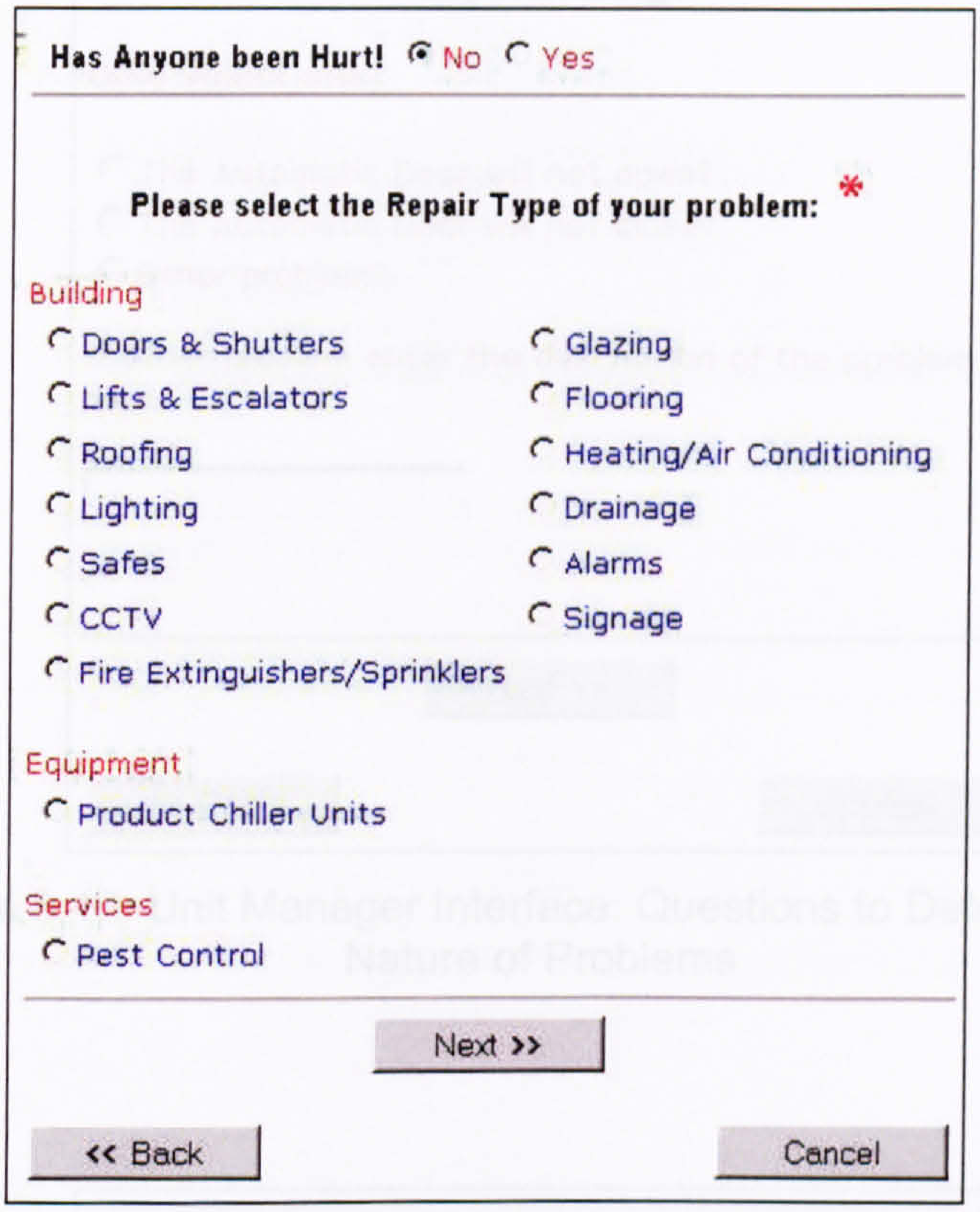


Figure 5.14: Unit Manager Interface: Classification of Repair Works

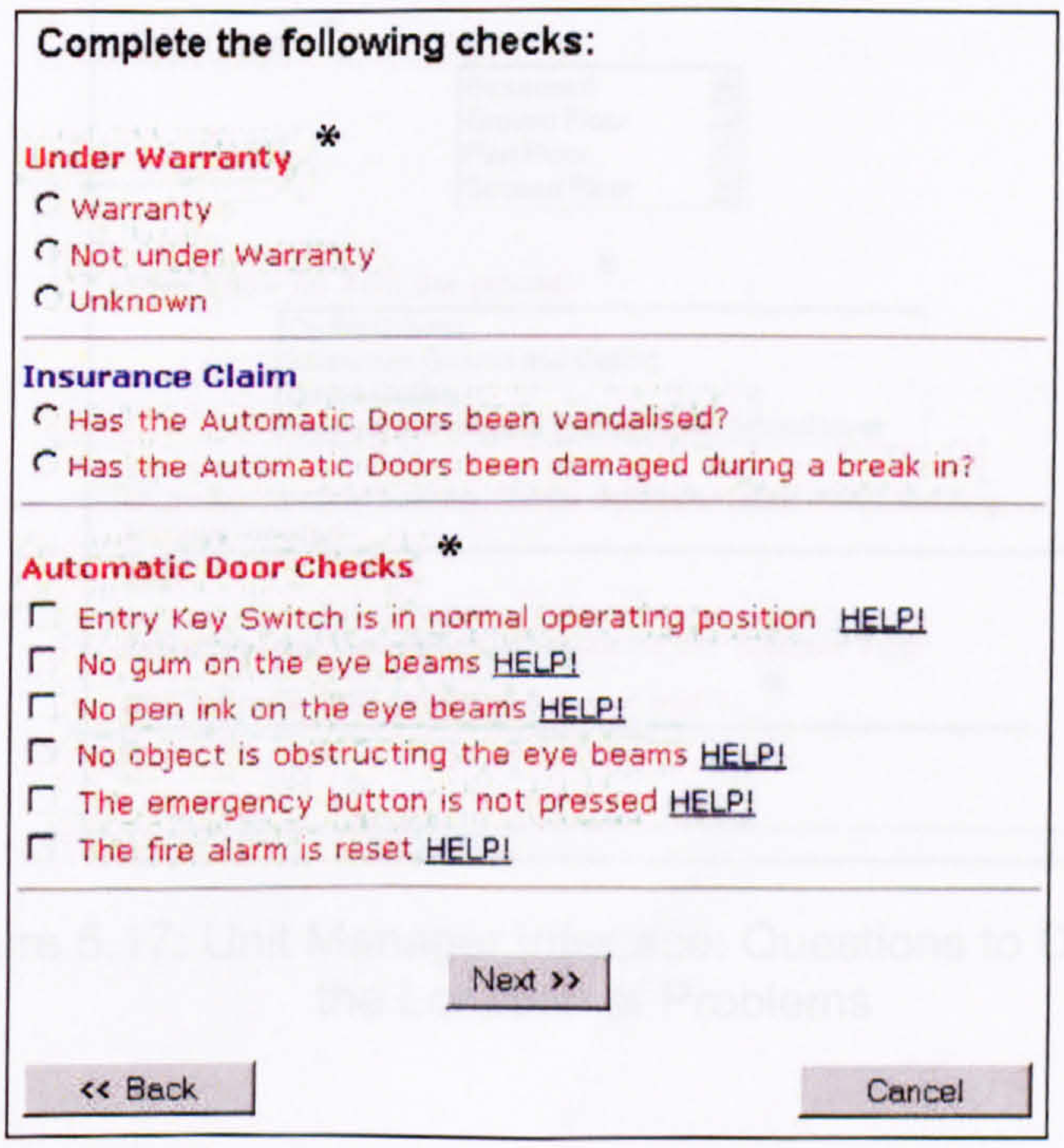


Figure 5.15: Unit Manager Interface: Self-check Page

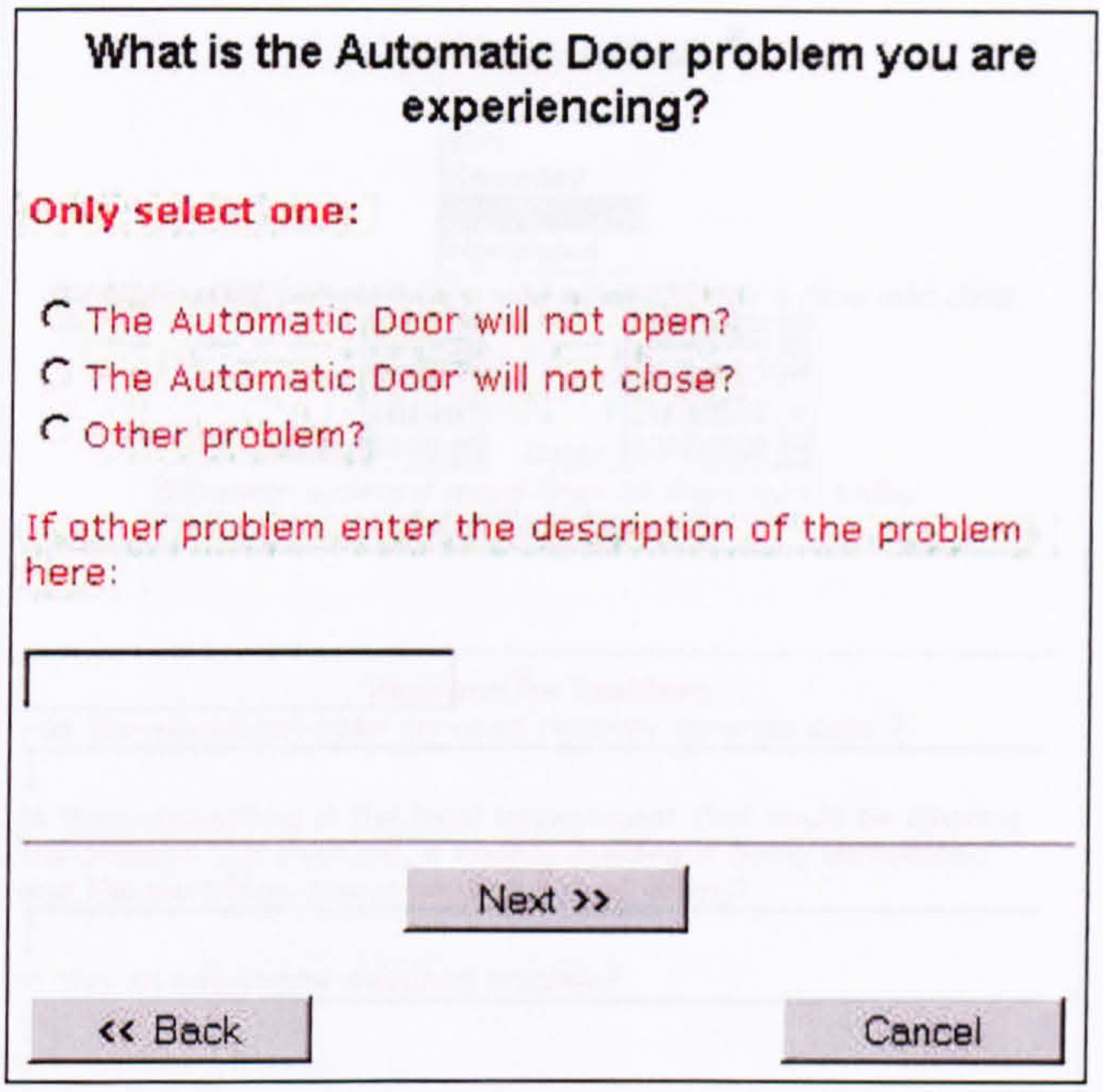


Figure 5.16: Unit Manager Interface: Questions to Determine the Nature of Problems

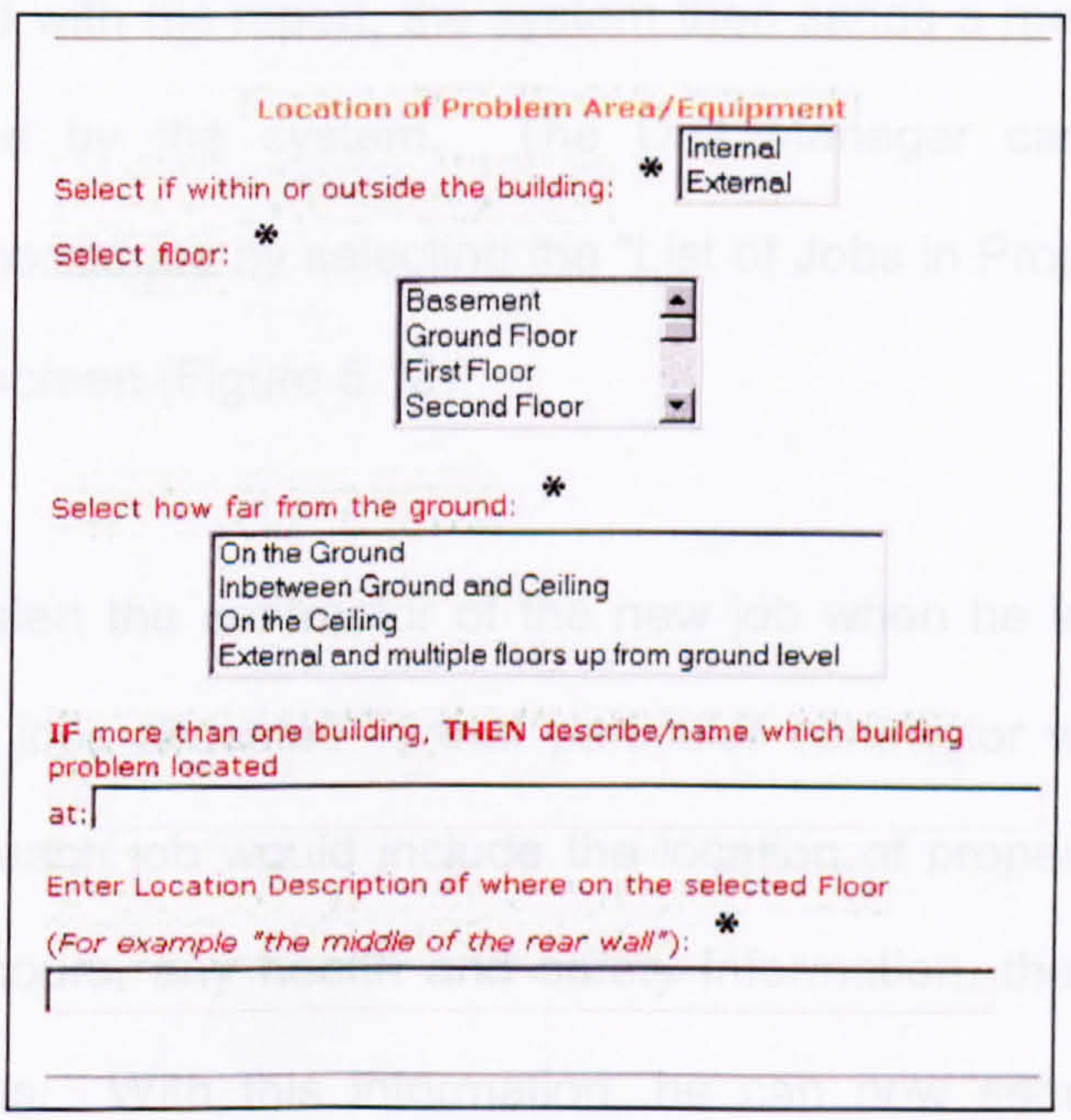


Figure 5.17: Unit Manager Interface: Questions to Determine the Location of Problems

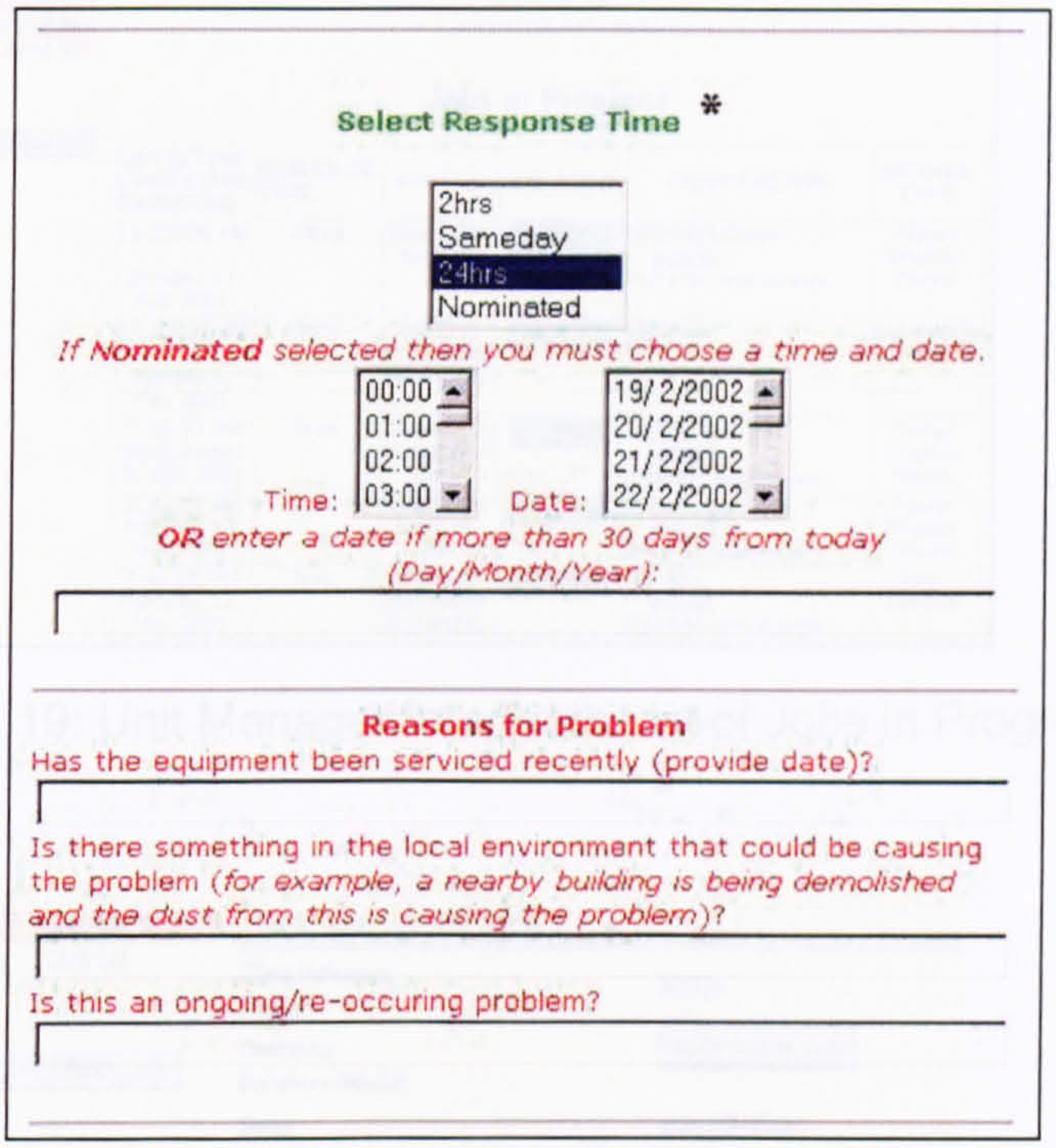


Figure 5.18: Unit Manager Interface: Response Time Required for the Problem

4. When satisfied with his report, the system then sends a message to the contractor selected by the system. The Unit Manager can check the progress of the reported job by selecting the "List of Jobs in Progress" button on the manager's screen (Figure 5.19).

5. MoPMIT will alert the contractor of the new job when he logs onto the server and all the jobs allocated to that particular contractor will be listed. Information about each job would include the location of property, available parking, opening hours, any health and safety information, the nature and details of the faults. With this information, he can now send a suitable operative to the job (Figure 5.20).

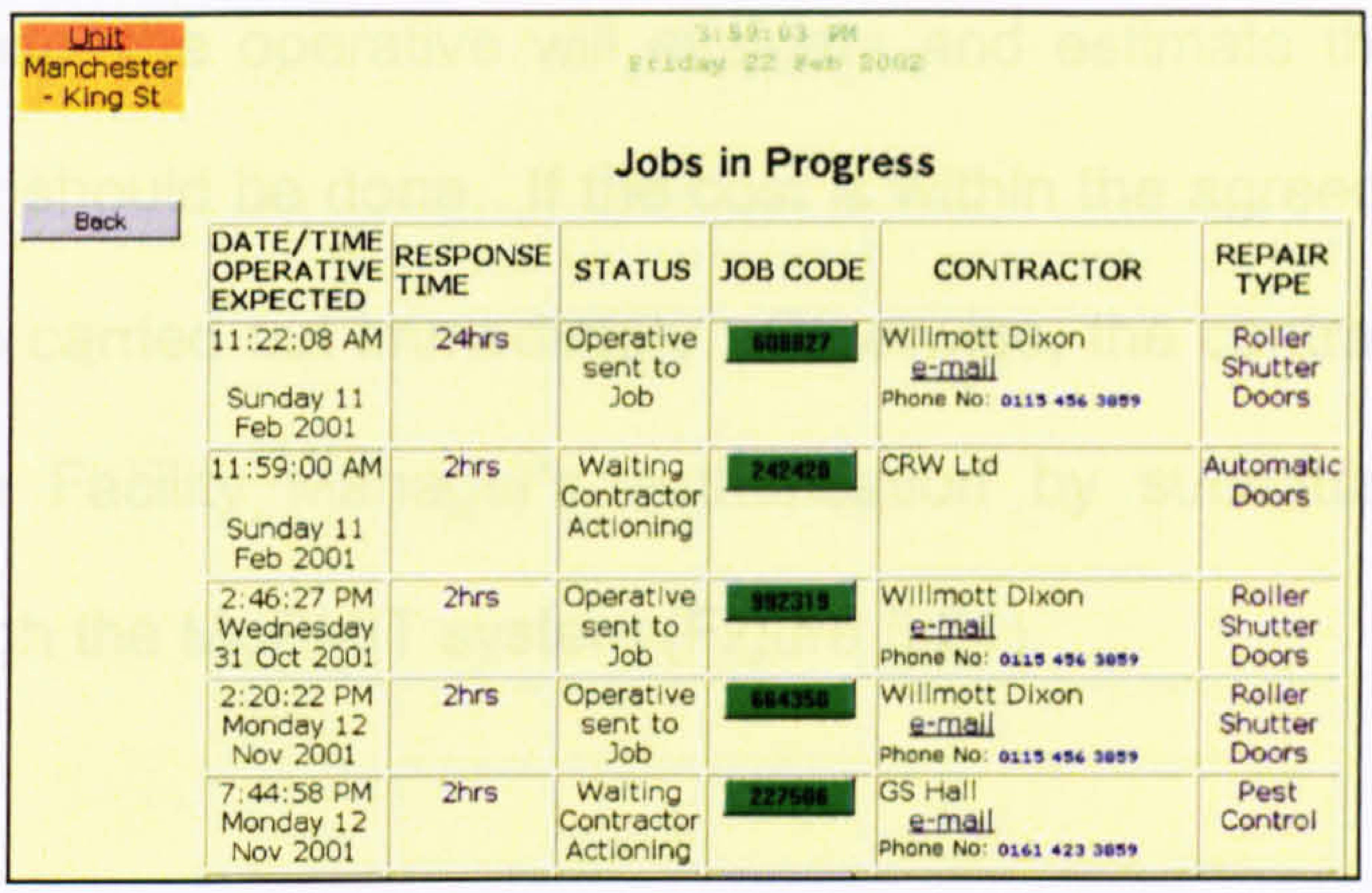


Figure 5.19: Unit Manager Interface: List of Jobs in Progress

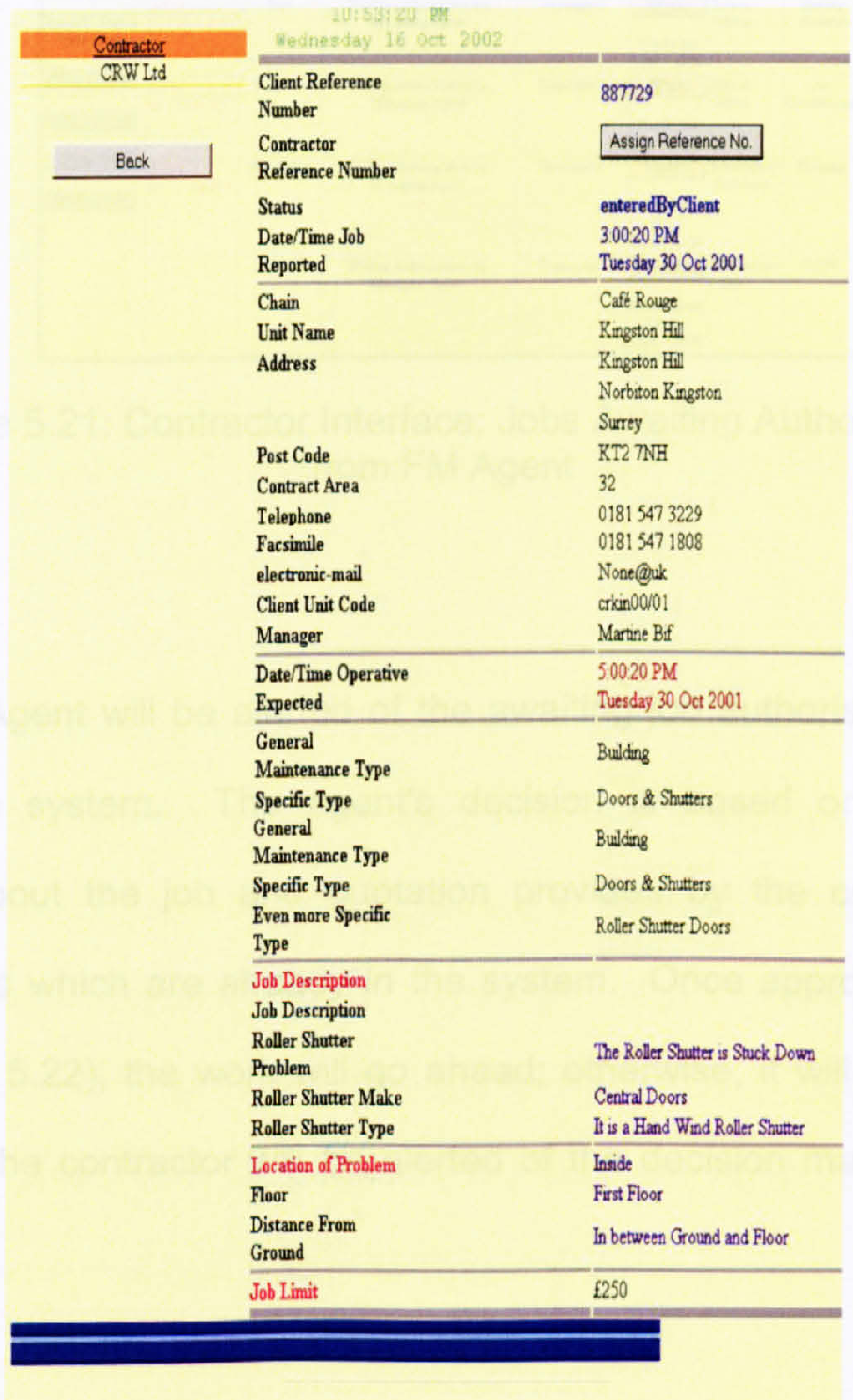


Figure 5.20: Contractor Interface: Details of Job Requested by Unit Manager

6. Once on site, the operative will evaluate and estimate the cost of the repair work that should be done. If the cost is within the agreed budget limit, the work will be carried out immediately. Otherwise, the contractor will have to wait for the Facility Manager's authorisation by submitting an online quotation through the MoPMIT system (Figure 5.21).

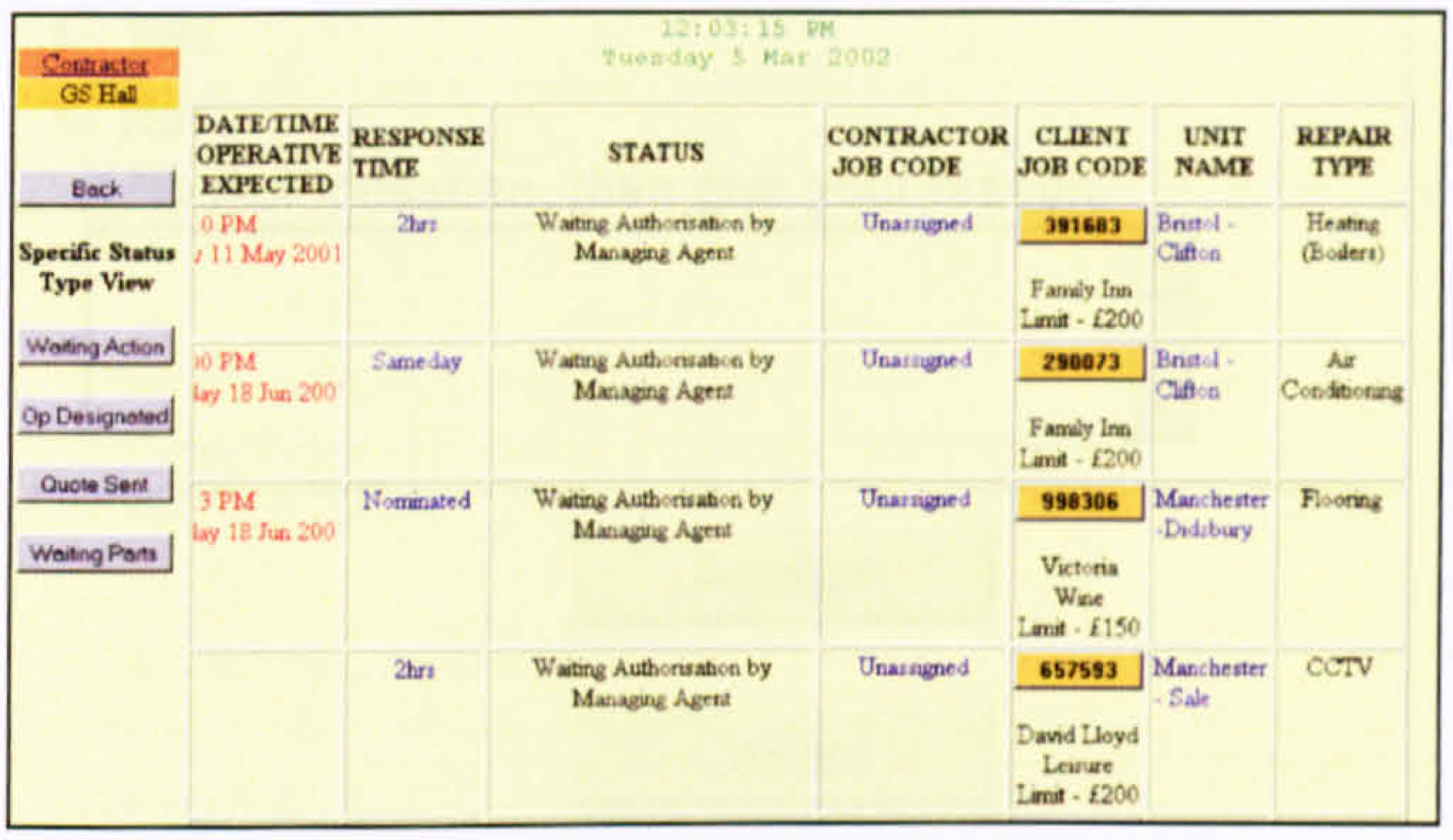


Figure 5.21: Contractor Interface: Jobs Awaiting Authorisation from FM Agent

7. The FM Agent will be alerted of the awaiting job authorisation once he logs onto the system. The agent's decision is based on the detailed information about the job and quotation provided by the contractor; and previous cases which are already in the system. Once approval is granted online (Figure 5.22), the work will go ahead; otherwise, it will be cancelled. At this point, the contractor will be alerted of the decision made by the FM Agent.

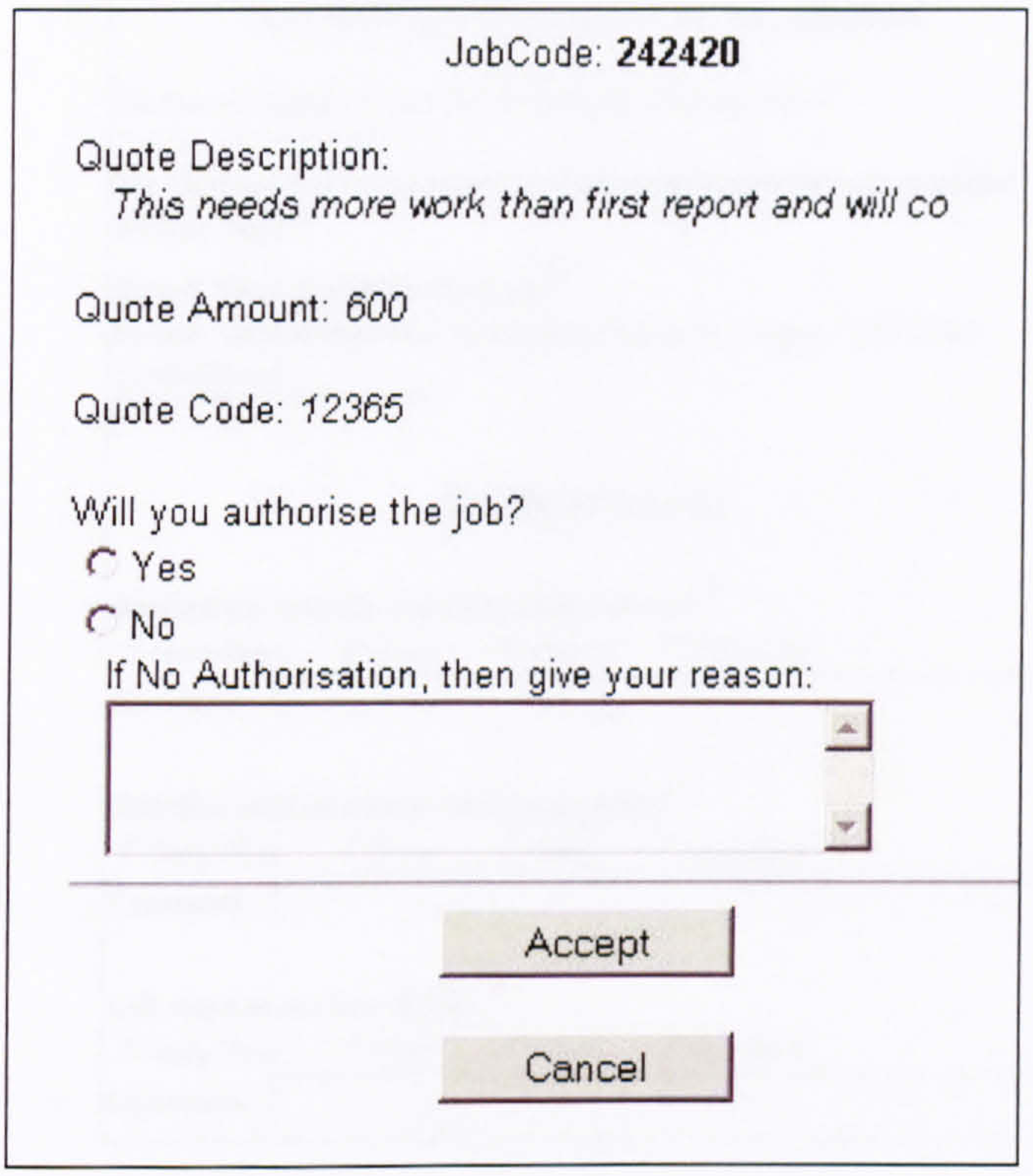
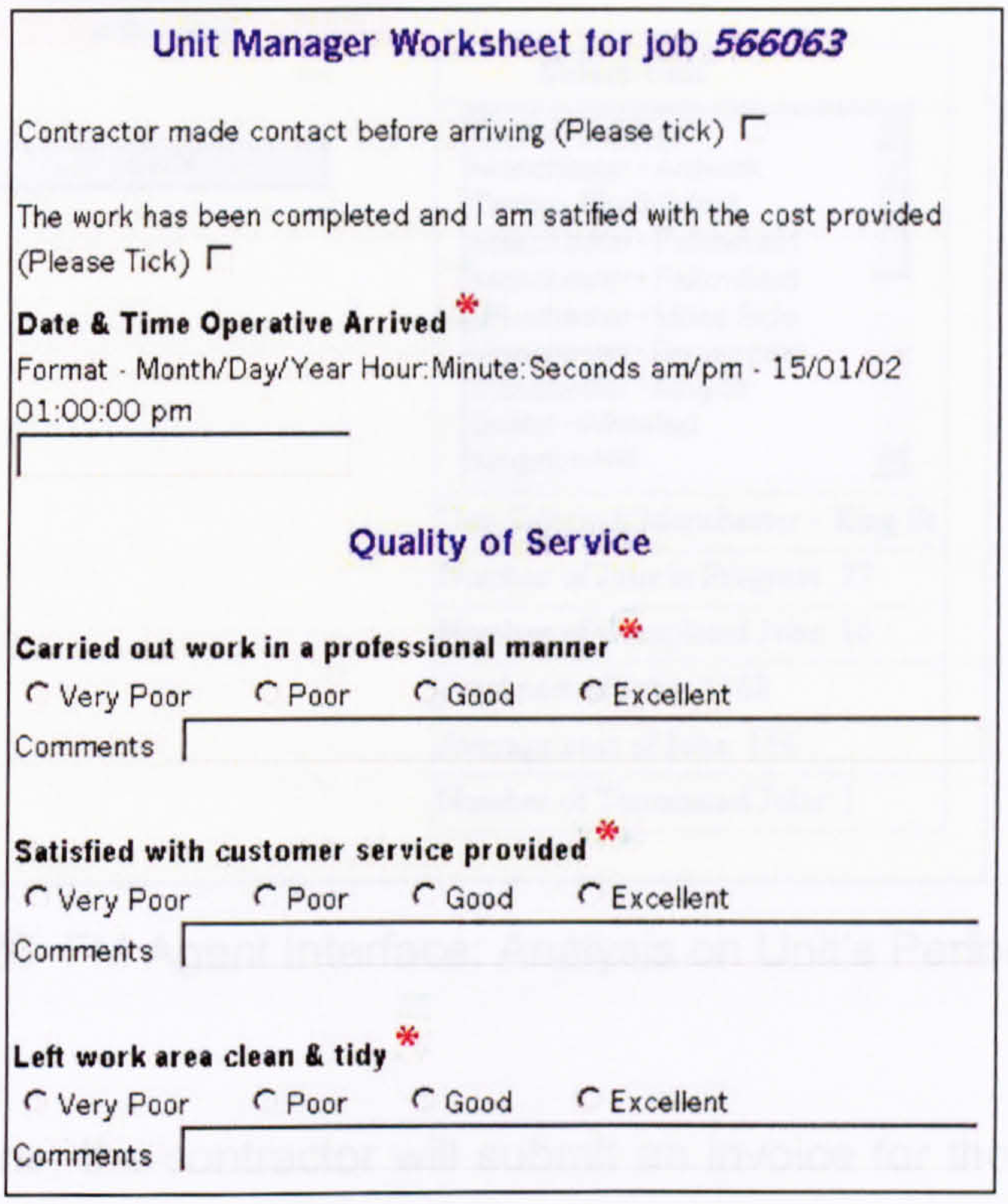


Figure 5.22: FM Agent Interface: Authorisation Page

8. When the job is completed, the Unit Manager will provide some feedback on the quality of the work and workmanship of the operatives (Figure 5.23). This can be done online. This information will be used by the FM Agent to assess the performance of the contractor and decide whether the contractor's services should be extended in the future (Figure 5.24). Unit performances could also be assessed by the FM Agent to monitor the maintenance costs that a Unit spends (Figure 5.25).


Unit Manager Worksheet for job *566063*

Contractor made contact before arriving (Please tick) ☐

The work has been completed and I am satified with the cost provided (Please Tick) ☐

Date & Time Operative Arrived *

Format - Month/Day/Year Hour:Minute:Seconds am/pm - 15/01/02 01:00:00 pm

Quality of Service

Carried out work in a professional manner *

○ Very Poor ○ Poor ○ Good ○ Excellent

Comments

Satisfied with customer service provided *

○ Very Poor ○ Poor ○ Good ○ Excellent

Comments

Left work area clean & tidy *

○ Very Poor ○ Poor ○ Good ○ Excellent

Comments

Figure 5.23: Unit Manager Interface: Feedback on Quality and Workmanship of the Operatives

11:43:44 PM
Wednesday 16 Oct 2002

Automatic Doors Contractor Performance

Performance Measure	All Contractors	CRW Ltd	Freds	GS Hall	Willmott Dixon
Number of Jobs Completed	7	4	1	2	0
Avg Cost of Repairs (£'s)	105	72	50	200	
Percentage of Jobs with Operative Arrival on Time	42.86	25	100	50	0
Avg Response Time (Hours)	41.57	60.75	0	24	0
Percentage of Jobs Completed on 1st Visit	100	100	100	100	0
Avg Number of Visits	1	1	1	1	

Figure 5.24: FM Agent Interface: Analysis on Contractor's Performances

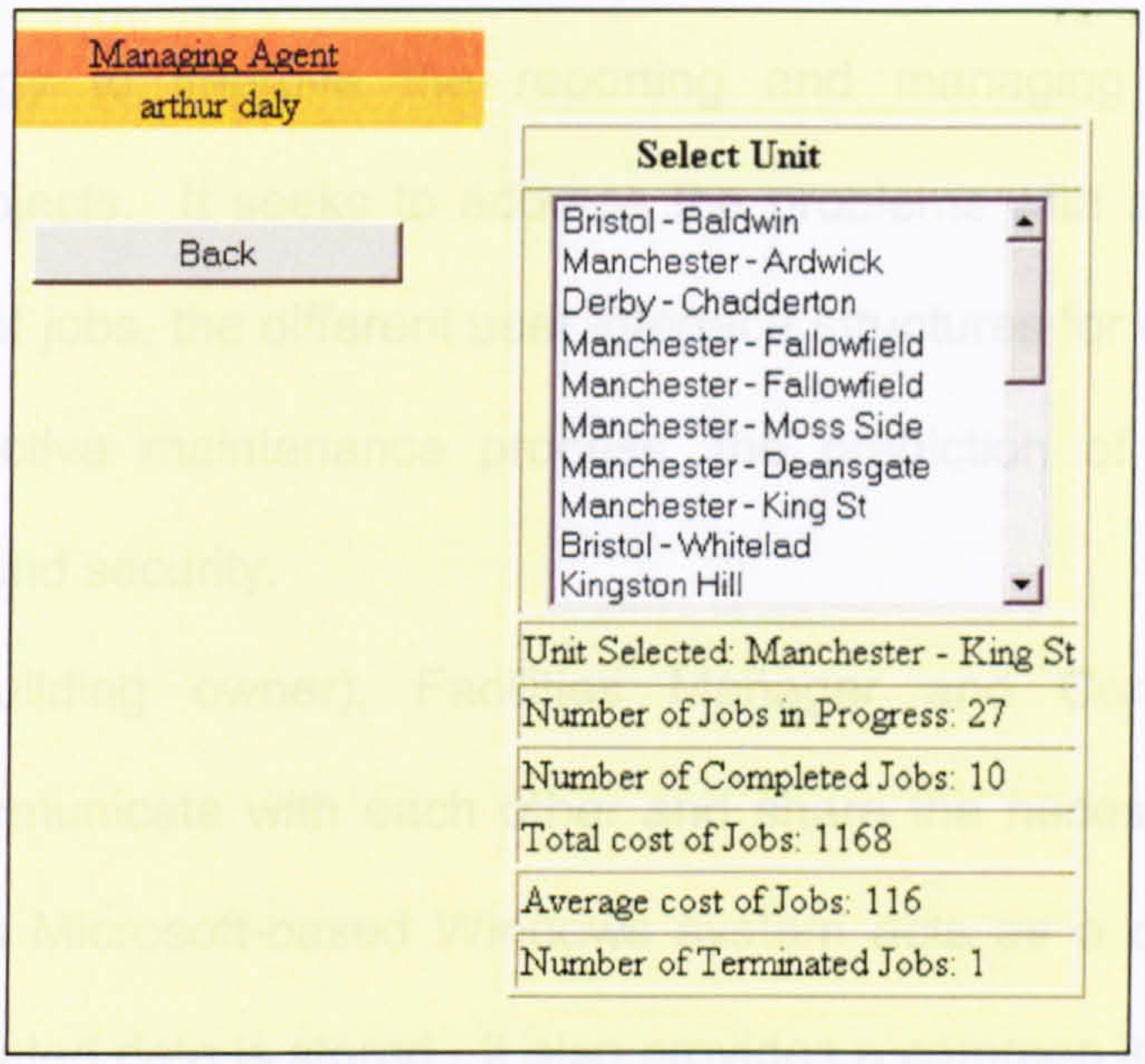


Figure 5.25: FM Agent Interface: Analysis on Unit's Performances

9. In the meantime, the contractor will submit an invoice for the completed job. If the agent is satisfied that the job has been completed satisfactorily, payment will be approved and made online.

5.7 CONCLUSION

The study has identified several existing deficiencies with the reactive maintenance projects. These include the lack of knowledge sharing and poor communication between the various parties, which often lead to a longer time period to fix the problem and higher costs. The development in Internet technologies has provided a platform for developing an on-line knowledge management system to improve the operation of these reactive maintenance projects. The MoPMIT prototype has shown the potential benefits of such a system.

The main aim of the MoPMIT system is to explore the use of a web-based technology to improve the reporting and managing of reactive maintenance projects. It seeks to address the problems with a unit or call centre entering of jobs, the different user interface structures for each type of user in the reactive maintenance process, the prediction of job details, communication and security.

Client (building owner), Facilities Manager and Contractor are expected to communicate with each other and share the necessary project information. This Microsoft-based Windows system acts as a client server where project related data is stored. It also provides a common interface that allows these parties to update the project information and exchange them. An online system was chosen because it could work as web-based system on the Internet platform, which is often accessible nowadays – anywhere and at anytime.

The system was demonstrated and tested to some relevant parties for their constructive comments and feedbacks. This is discussed in the next chapter.

CHAPTER 6

SYSTEM EVALUATION

6.0 INTRODUCTION

The previous chapter discussed the development of the prototype online knowledge management system necessary to address the problems identified in Chapter 3 and 4. The main goal of the system is to explore the use of technology to improve the reporting and managing of reactive maintenance projects. This research is not complete without the prototype system being evaluated by its target users. This chapter therefore looks at the evaluation of the prototype with the objectives to:

1. demonstrate that the prototype has achieved the aim of this research;
2. to recognise the weaknesses and strengths of the system and;
3. to obtain comments and recommendations as a guide for future developments.

The system evaluations were conducted with the participants drawn from the people in the reactive maintenance process, i.e. the building owner (client); the facilities manager team (their call centre in particular); contractors and their operatives. There are various evaluation techniques available (Pressman, 2000; Ould & Unwin, 1986), but this study adopted its own approach where the evaluation is categorised into two stages i.e. life-cycle evaluation and final evaluation. Life-cycle evaluation took place during the development of the system while final evaluation was carried out after the prototype had been completed.

6.1 SYSTEM EVALUATION

6.1.2 Lifecycle Evaluation

At many times during the development stage, the system was taken to the process owner of the project in order to validate the knowledge gathered for the system.

The aim of such evaluations was to gain some feedback on the system and to establish their agreement and reaction to the prototype, not only on the elicited knowledge that is represented in the system but also on how the system would provide efficient knowledge and function to the target users. Their opinions on the general usability of the system, at this particular stage, are very important to ensure the system's efficacy for the users. Most of the explicit suggestions generated from the discussion were implemented in the final prototype.

6.1.3 Final Evaluation

Prototyping is by itself a way of validating the users' requirements. The early version of the system is developed and implemented so that users can observe it in practice. This method is called *static validation* (Ould & Unwin, 1986). Another way of getting feedback from users is by installing a live system (with selected features) on one or more pilot sites. The users then try out the system and give their response. This method is a *dynamic* form of validation and is the method adopted in this study (Ould & Unwin, 1986).

MoPMIT prototype system is an early version that was developed to demonstrate the concept/ idea in improving the reactive maintenance project. It was also developed with features enough to be tried out by users as a pilot system. In this context, the system was implemented and demonstrated at two different events as a final evaluation i.e.; 1] demonstrated to a group with various levels of expertise; and 2] implemented in a one-day pilot study with one of the industrial partners in this research.

The strategy for the first event was to demonstrate the system to the participants in the group. They were shown the three user interfaces and their functionalities in the system, applicable to the Unit Manager (or Helpdesk), Contractor and Managing Agent. These three mains users were then asked if they would be able to understand, operate and view the system as beneficial; and also some general issues about the system. The questionnaires mostly asked them to state the extent to which they strongly agree, agree, disagree or strongly disagree on the issue. This helps to quantify their responses.

Issues were raised in between the demonstration and their responses were recorded by using a voting system (IML, online) followed by an extensive discussion. There were fourteen participants in the group consisting of various experts related to the nature of the project such as IT experts, facilities managers, surveyors, builders and project managers.

A similar strategy was carried out in the one-day pilot at the client's site except that the group of users that took part in the study were given the task of trying out the system according to the reactive maintenance business process and, questionnaire sheets (instead of the voting system) were distributed.

The team of six individuals from the Facilities Management Division consisting of four members from its Call Centre Division, with a various range of experience in handling calls, and two members from the Administration Division. In order to evaluate the usability of the system interface, the people selected had a varying range of computer skills for, realistically, the potential users for this system could have no IT experience.

During the one-day pilot, participants were all given the opportunity to actually test the prototype according to the cycle of a reactive maintenance process. Thorough discussion was held at the end of the pilot and questionnaires were distributed.

In addition to these two events, the system was also demonstrated to IT managers in contractors and facilities management firms involved in this research for their comments and feedbacks.

The following two sections present the responses by the users in both events.

6.1.3.1 Exercise1

Figure 6.1 illustrates the proportion of participants involved in the demonstration session. The participant were based on random selection of employees that are knowledgeable in construction IT. The majority of them (44%) are IT speacilist. Facilities Management and Construction

Management both constitute 14% respectively, Designers (7%) and others (21%).

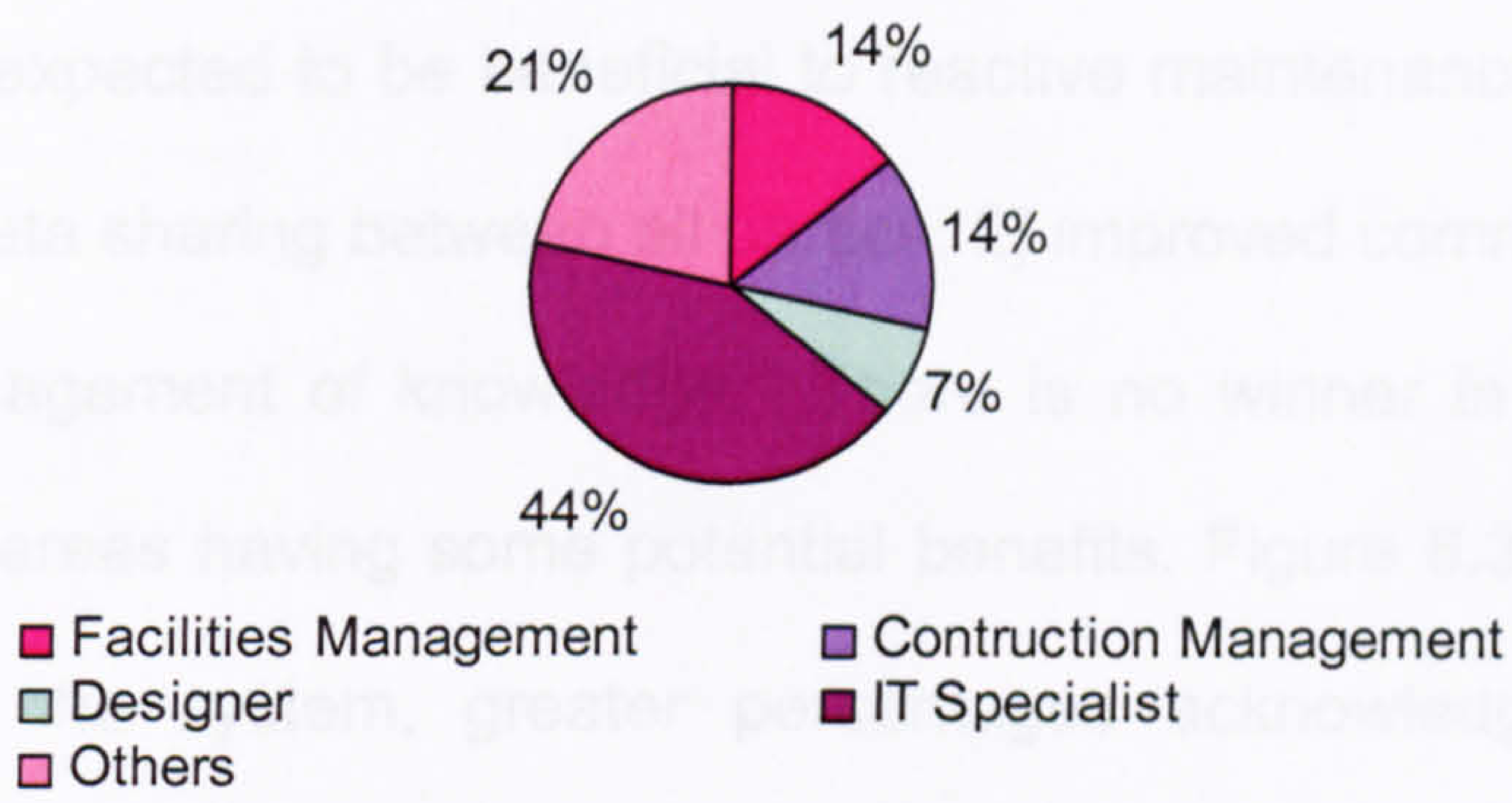


Figure 6.1: The Expertise Involved in the Final Evaluation

The respondents were further asked to rank the main problems in reactive maintenance projects. Figure 6.2 indicates that the quality of information is viewed as the major problem area in reactive maintenance.

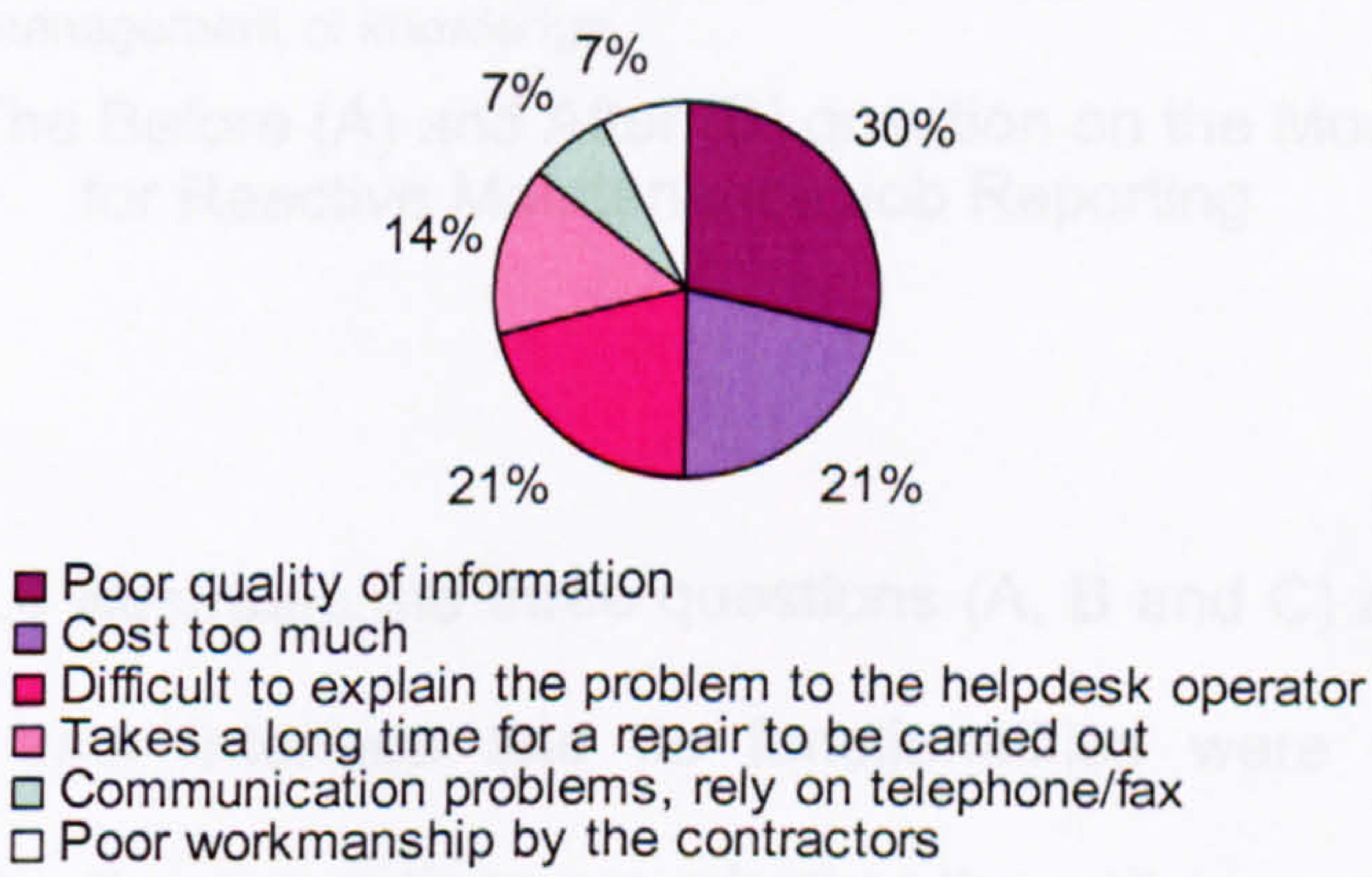


Figure 6.2: The Main Problems with Reactive Maintenance Projects

Figure 6.3 shows a before and after question where the participants were asked the same question before and after they were shown the system. The essence is to observe if the participants will change their view on the three factors expected to be beneficial to reactive maintenance job reporting vis-à-vis: 1] data sharing between all parties; 2] improved communication and 3] better management of knowledge. There is no winner in this question, with all three areas having some potential benefits. Figure 6.3 B shows that after viewing the system, greater percentages acknowledged that data sharing among all parties and better knowledge management are beneficial for reactive maintenance job reporting.

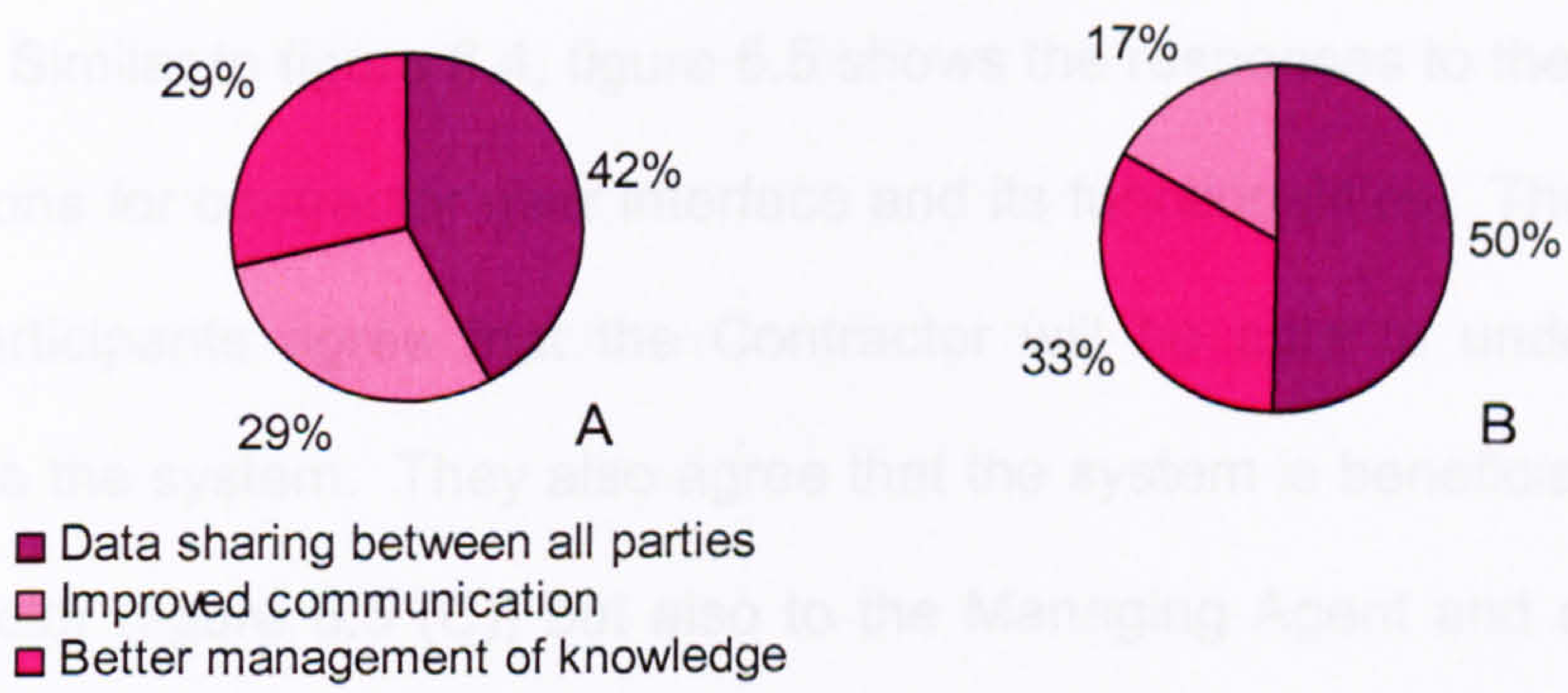


Figure 6.3: The Before (A) and After (B) question on the Most Beneficial for Reactive Maintenance Job Reporting

Figure 6.4 illustrates the three questions (A, B and C) asked after the Unit Manager user interface and its functionalities were shown to the participants. The three questions are whether the unit manager will be able to understand the system; will be able to operate the system; and whether the unit manager will view the system as beneficial. Majority of them agree that the Unit Manager will be able to understand and operate to system (A & B). However, they doubt if the system would be beneficial to them (C).

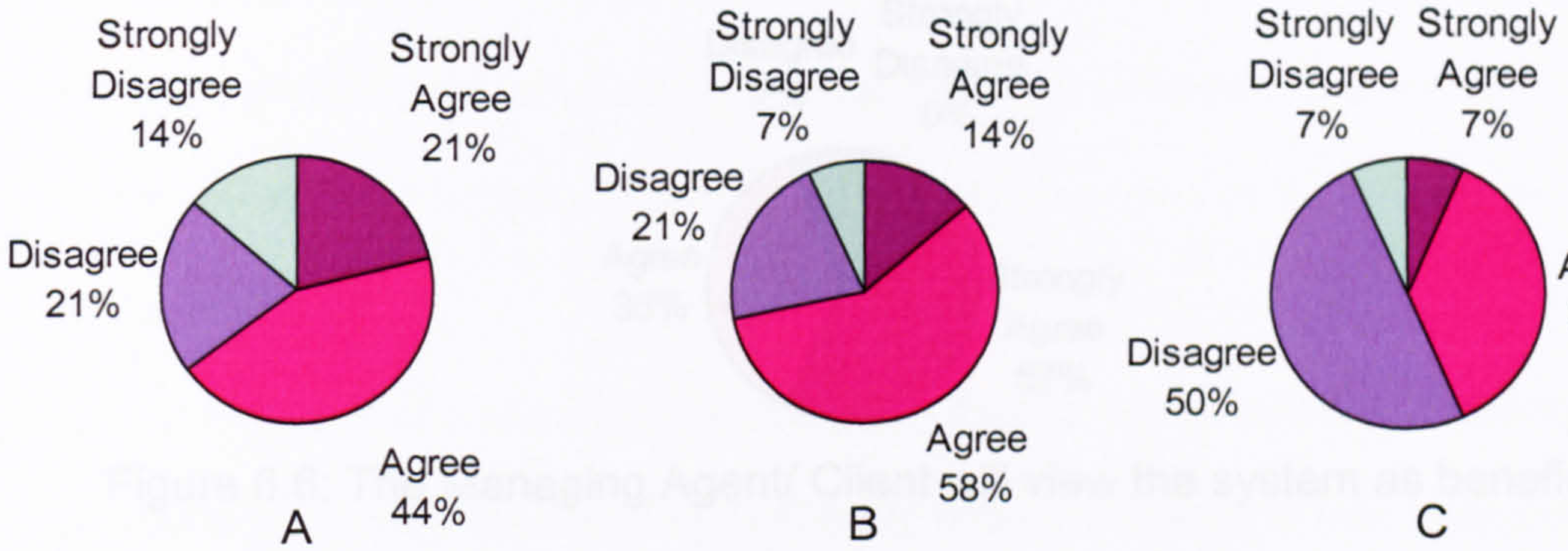


Figure 6.4: (A) The Unit Manager will be able to understand the system (B) The Unit Manager will be able to operate the system (C) The Unit Manager will view the system as beneficial

Similar to figure 6.4, figure 6.5 shows the responses to the same three questions for contractor user interface and its functionalities. The majority of the participants agree that the Contractor will be able to understand and operate the system. They also agree that the system is beneficial not only to contractor (figure 6.5 (C)) but also to the Managing Agent and client (figure

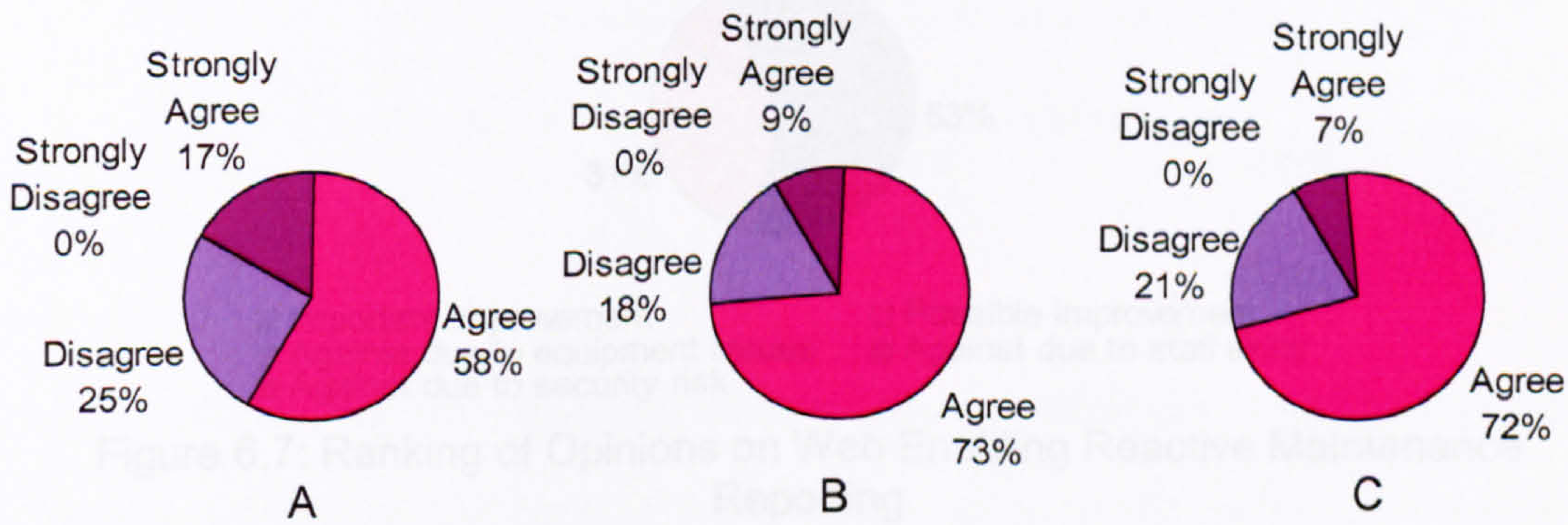


Figure 6.5: (A) The Contractor will be able to understand the system (B) The Contractor will be able to operate the system (C) The Contractor will view the system as beneficial

6.6). Figure 6.4 and 6.5 can be concluded that there is a noticeable degree of concern for the system to be implemented at the Unit level.

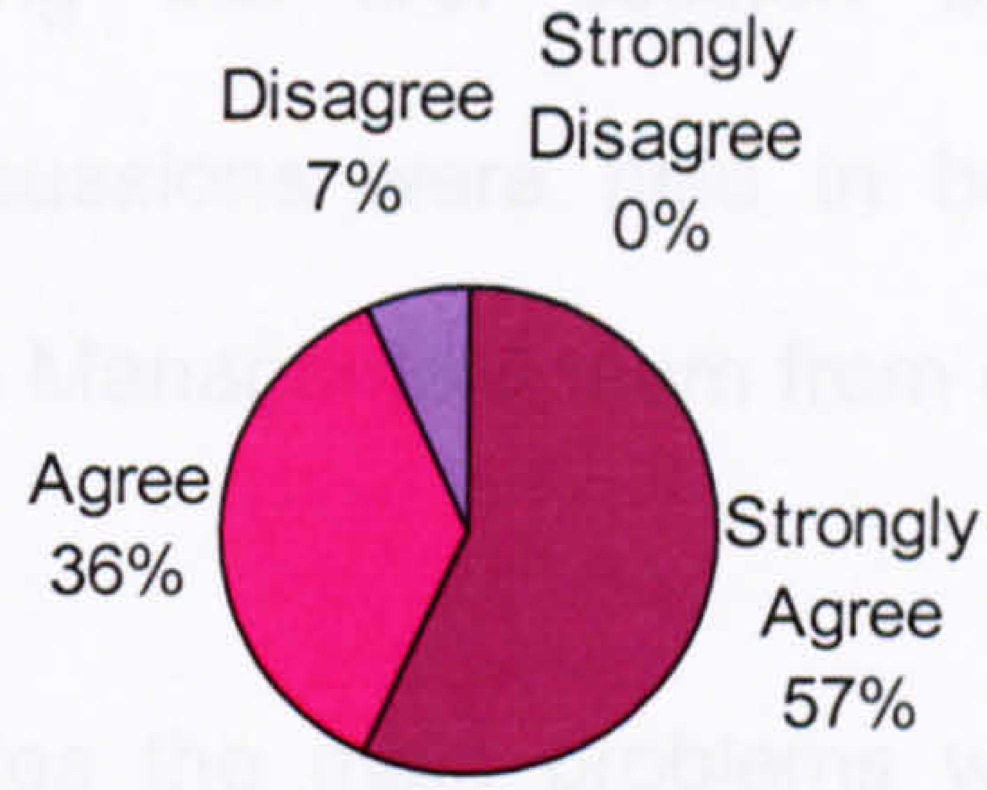


Figure 6.6: The Managing Agent/ Client will view the system as beneficial

Respondents were further asked to rank their opinions on web enabling reactive maintenance reporting (such as MoPMIT system). They seem to support the idea of web enabling reactive maintenance reporting (figure 6.7) as 53% and 31% of them agree this is important and a possible improvement and 8% of them are against due to equipment issues or staff skills.

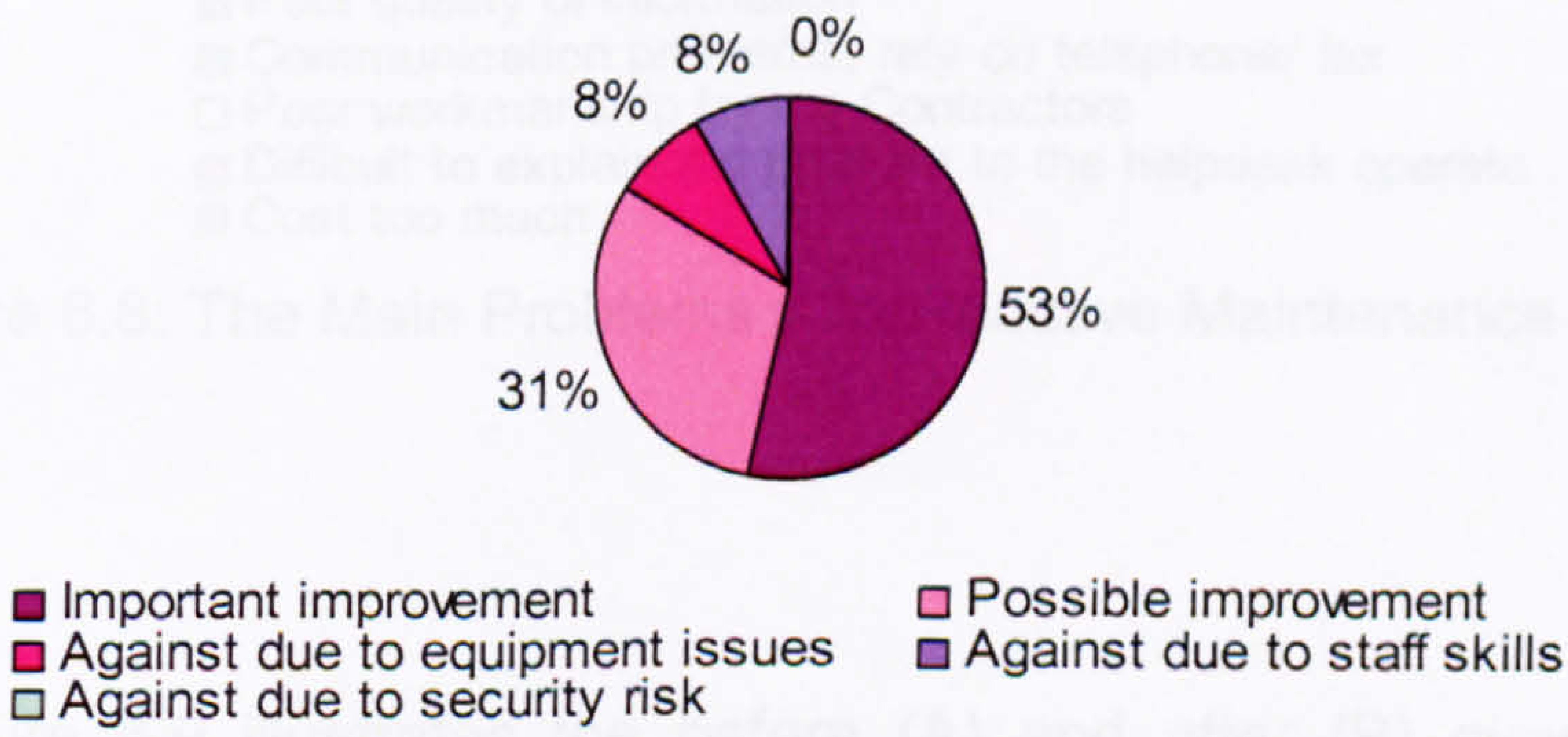


Figure 6.7: Ranking of Opinions on Web Enabling Reactive Maintenance Reporting

6.1.3.2 Exercise2

This exercise involves two separate sessions in which six people were simultaneously logged into the system. The participants tried out the system as unit manager during the first session and later as Contractor. Questionnaires and discussions were held in between the session. All participants are Facilities Management team from one of the clients involved in the research.

Figure 6.8 indicates the main problems with reactive maintenance projects. Although the ranking is slightly different from the first group (figure 6.2), both groups are aware that poor quality of information is the major problem.

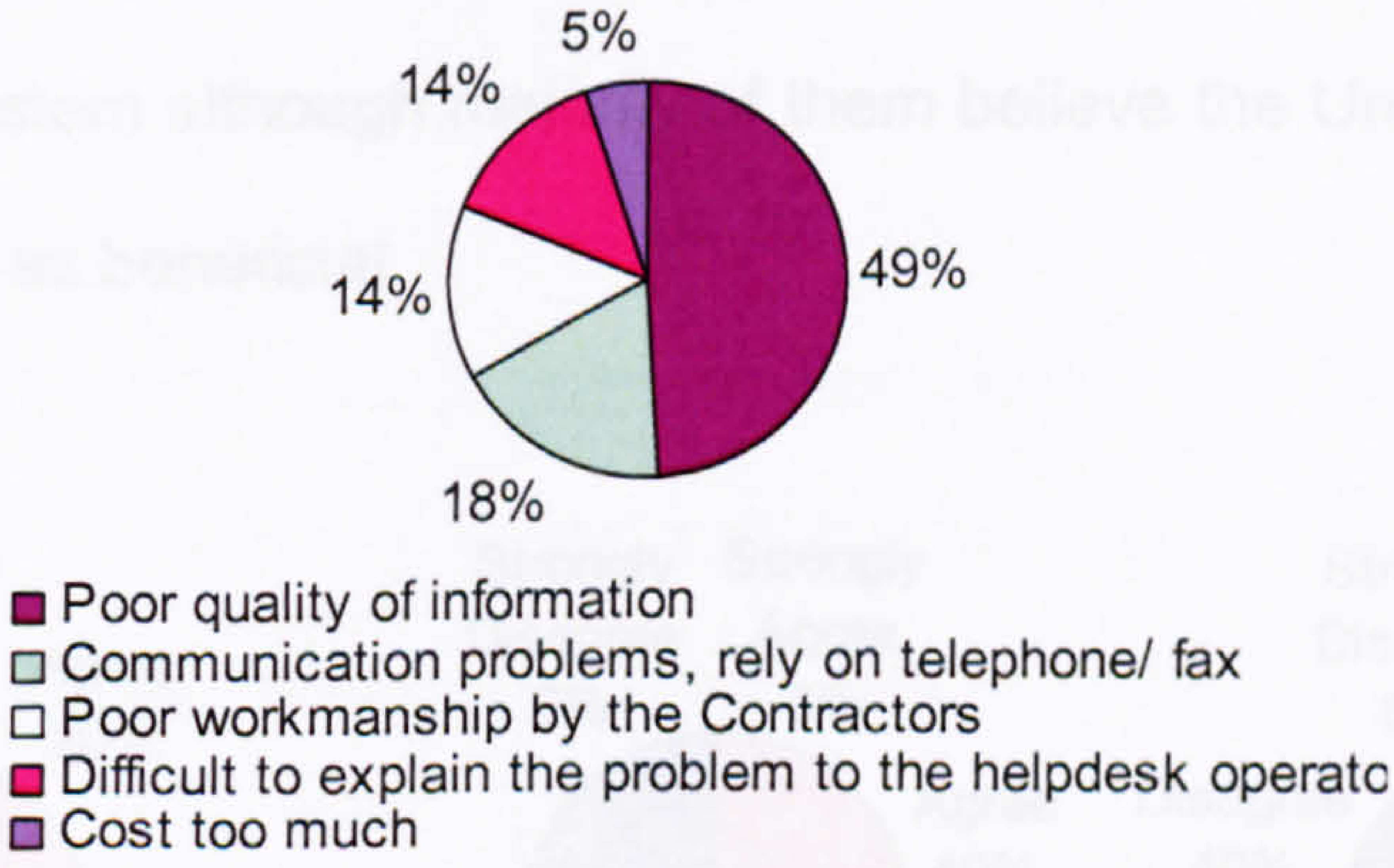


Figure 6.8: The Main Problems with Reactive Maintenance Projects

Figure 6.9 illustrates the before (A) and after (B) question for this group. Unlike the first group (figure 6.3), after using the system, the better management of knowledge has gone from bottom with 17% to top with 68%.

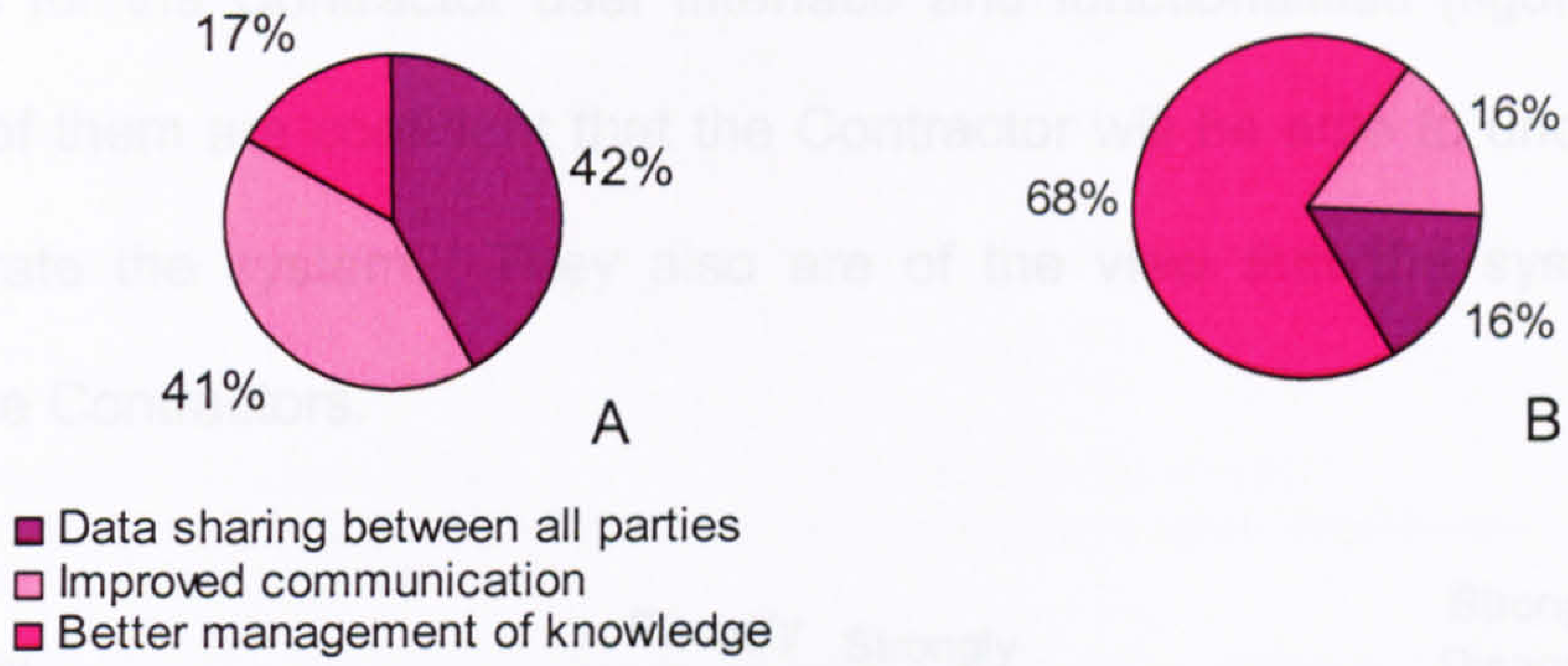


Figure 6.9: The Before (A) and After (B) Question on the Most Beneficial for Reactive Maintenance Job Reporting

Figure 6.10 reveals a contrast result from the first group (figure 6.4). While figure 6.4 shows some concerns that the system may not be beneficial to the Unit Manager, majority do agree the Unit Manager will be able to understand and operate the system, figure 6.10 shows a quite negative response about the Unit Manager's capabilities in understanding and operating the system although majority of them believe the Unit Manager will view the system as beneficial.

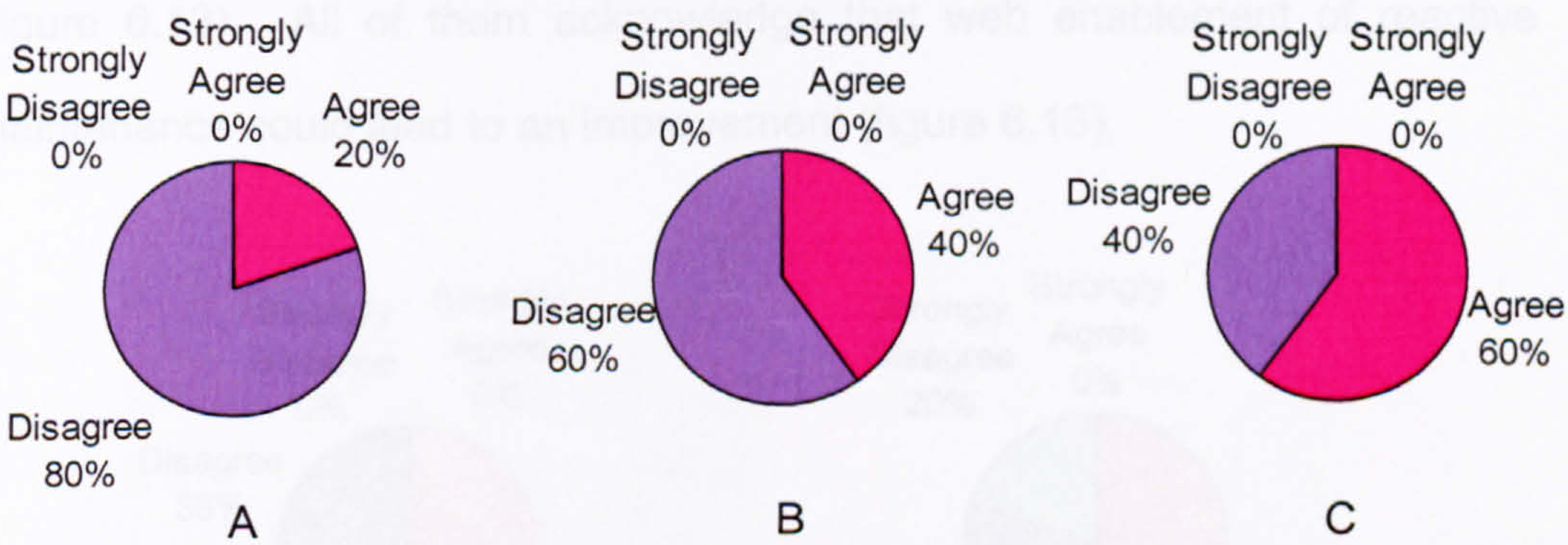


Figure 6.10: Unit Manager (A) The Unit Manager will be able to understand the system (B) The Unit Manager will be able to operate the system (C) The Unit Manager will view the system as beneficial

As for the Contractor user interface and functionalities (figure 6.11), majority of them are confident that the Contractor will be able to understand and operate the system. They also are of the view that the system will benefit the Contractors.

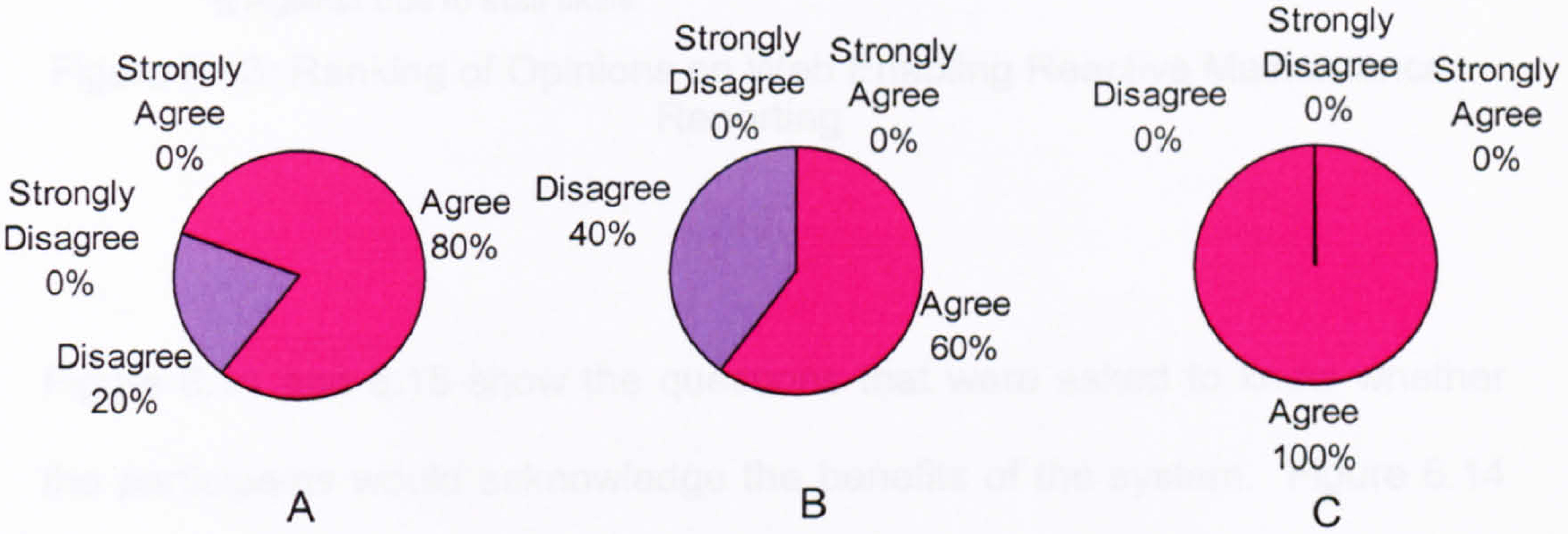


Figure 6.11: Contractor (A) The Contractor will be able to understand the system (B) The Contractor will be able to operate the system (C) The Contractor will view the system as beneficial

After trying out the system, 62% of the participants in this exercise thought the system was easy to use and generally found it easy to operate (figure 6.12). All of them acknowledge that web enablement of reactive maintenance could lead to an improvement (figure 6.13).

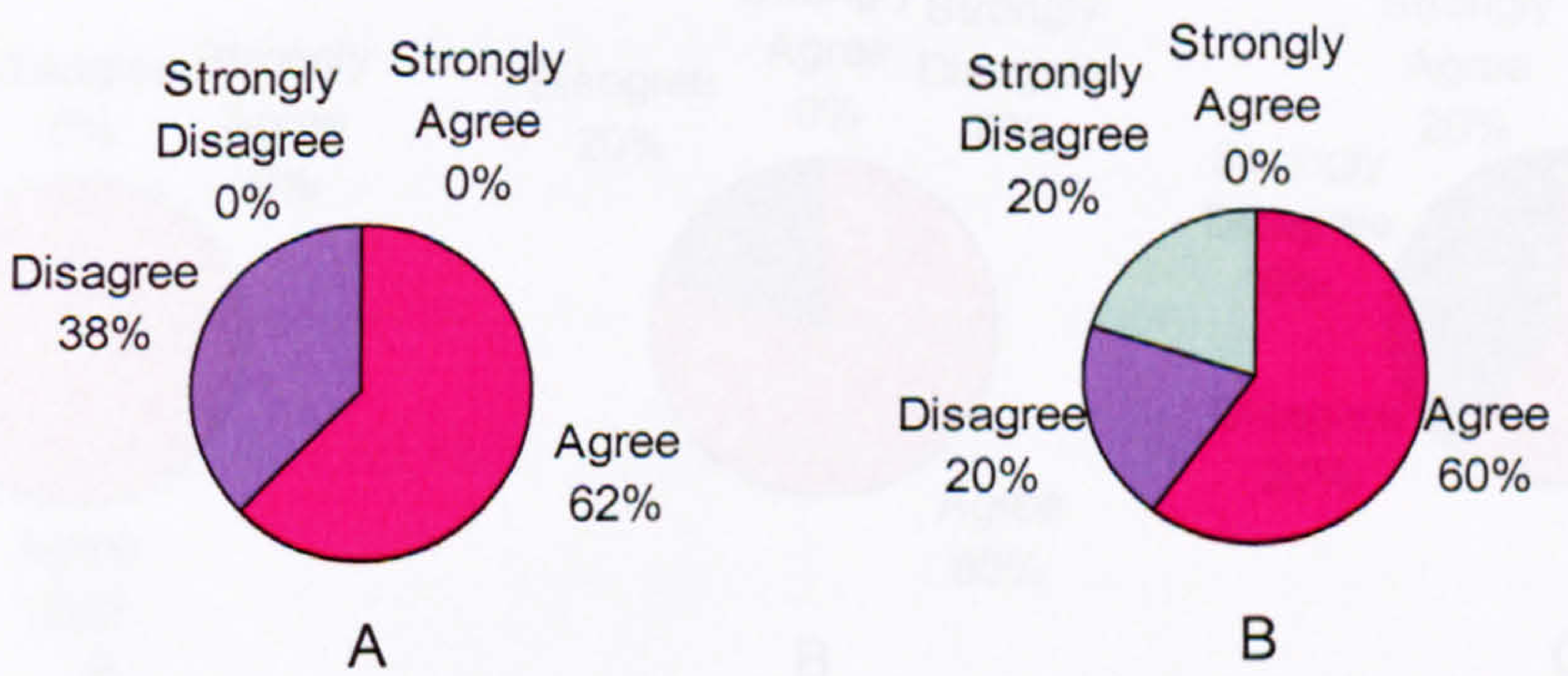


Figure 6.12: (A) The system was easy to understand (B) The system was easy to operate

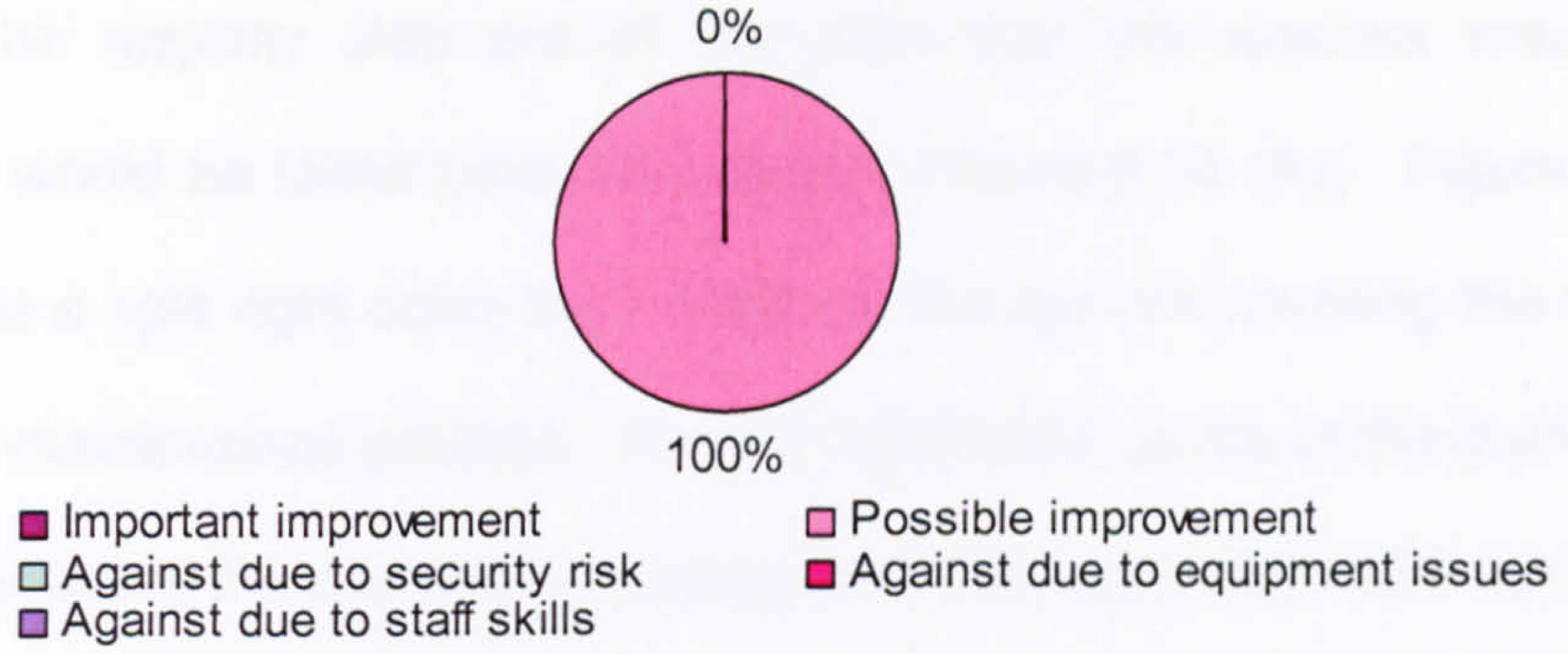


Figure 6.13: Ranking of Opinions on Web Enabling Reactive Maintenance Reporting

Figure 6.14 and 6.15 show the questions that were asked to know whether the participants would acknowledge the benefits of the system. Figure 6.14 illustrates the participants' opinion about the potential of system. All of them have the perception that the system will lead to better management of knowledge (A). A greater percentage of the participants acknowledge that the system was an improved method of communication (B) and a good majority were of the opinion that data sharing between all the parties in the reactive maintenance process would be better with the MoPMIT system (C).

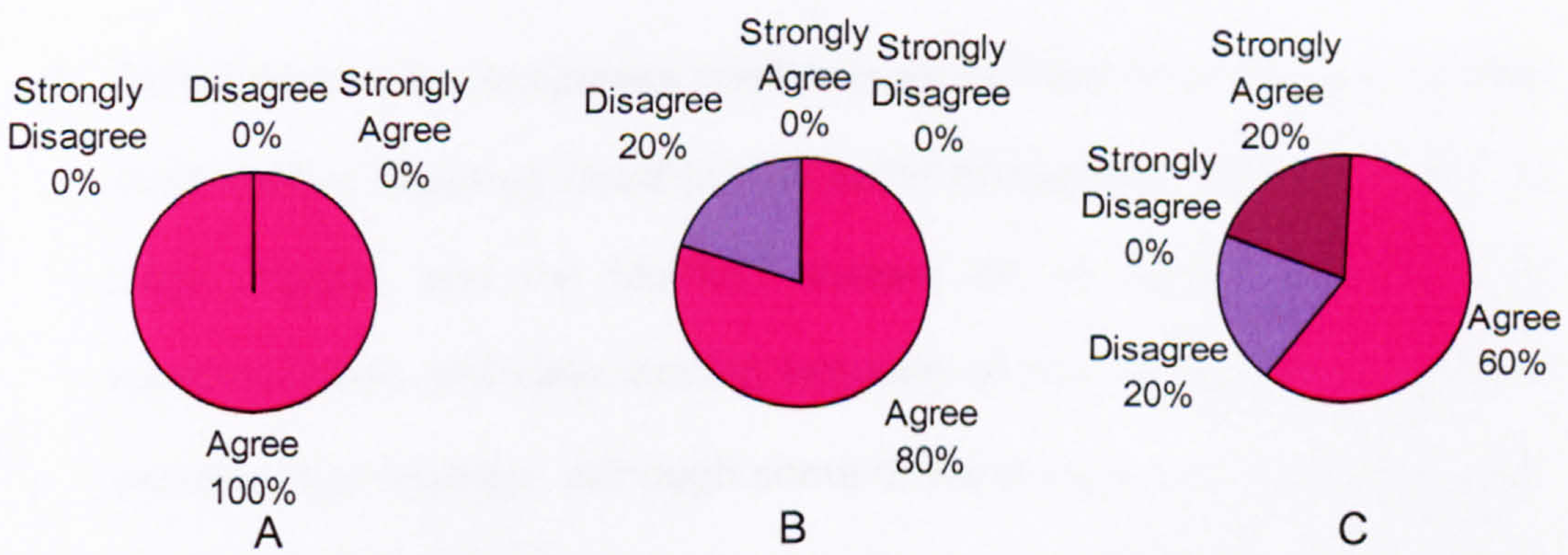
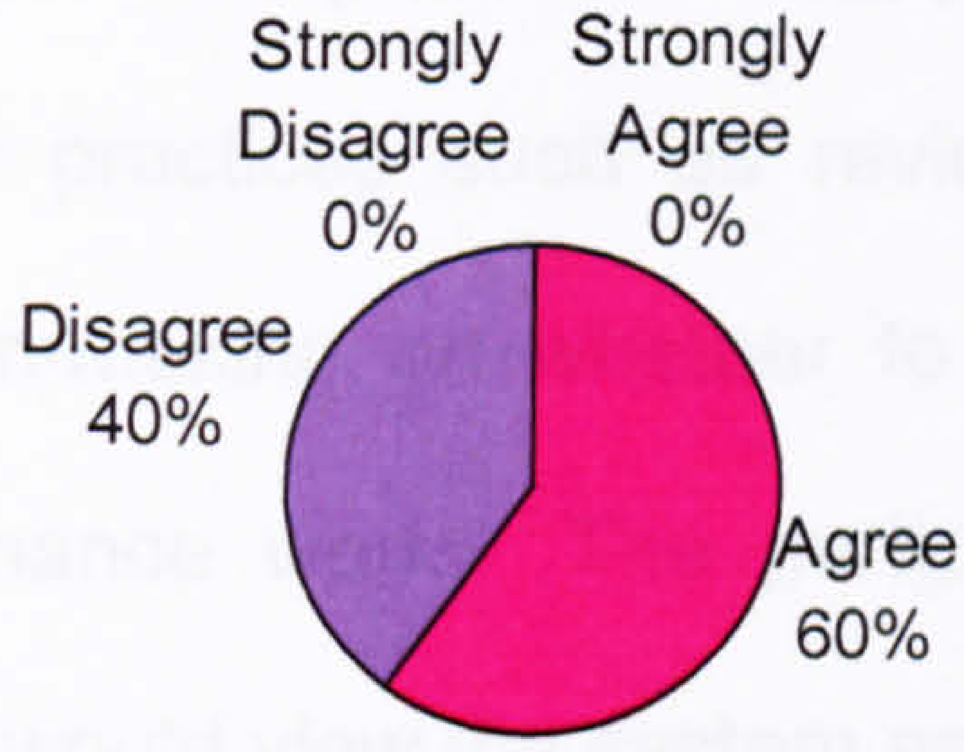
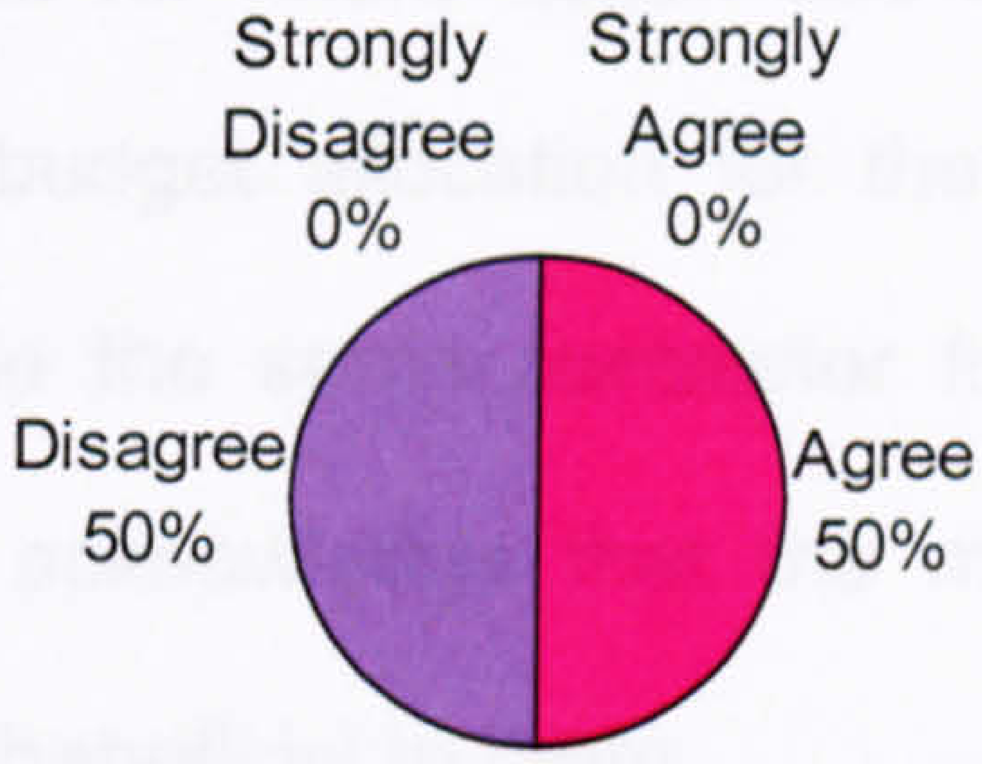


Figure 6.14: (A) The system will lead to better management of knowledge (B) The system will lead to improved communication (C) The system will result in better data sharing between all parties

The majority also are of the view that the reactive maintenance process would be faster using this system (figure 6.15 (A)). Figure 6.15 (B) illustrates a split right down the middle on the system covering the complete reactive maintenance process. As was mentioned, some of the invoicing and payment part of the process is missing from the current MoPMIT system.



A



B

Figure 6.15: (A) The system will speed up the reactive maintenance process (B) The system functionality covers the complete reactive maintenance process.

6.2 DISCUSSION

In general, the overall responses were very positive. The results produced from this evaluation were as follows:

1. Participants in the evaluation positively agreed that web-enabled reactive maintenance reporting could benefit better management of knowledge. A large majority see the MoPMIT system as an improved method of communication and data sharing between all the parties in the reactive maintenance process. Although some of the invoicing and payment parts of the reactive maintenance process are missing from the current

MoPMIT system, they believe that the system would be able to expedite the reactive maintenance process.

2. The participants have the perception that Managing Agents would be able to understand and operate the system. One of the features - that enables the Managing Agent to analyse the Units and Contractors performance - could be a very useful to support data for future action and decision-making practices such as review of budget allocation for the Unit or decision-making on whether to engage the same contractor for future maintenance work. The participants acknowledge that the managing agents would view the system as being beneficial to them.

3. Significant percentage of the participants agreed that contractors would be able to understand and operate the system. The system's ability to provide the correct description of repair work plus warnings on possible health hazards would greatly benefit the contractor as this will help them to decide on the correct tools and parts to take to the site. Nonetheless, the Contractors involved in the evaluation raised a concern about transferring the data from MoPMIT system into their system. Although this is not implemented in the prototype, the researcher is aware of this issue.

4. In general, majority of the participants agreed the system would be beneficial to the unit manager especially on checking the status of work and giving online feedback on completed work. In contrast, they had

concern that the Unit Manager may not be able to understand and operate the system if not properly trained. This is not unexpected as some persons at the Unit are often not conversant with computer applications involving some complex or rigourous use of Internet web.

5. It was suggested that for the benefits of all parties in the reactive maintenance process, an appropriate incentive based on a share of the reduced transaction costs would be necessary to motivate the Unit Manager to be involved in the re-engineered business model.

6. They also suggest that the system Contractor's Operative should be able to access the system while they are on the road. This could cut the unnecessary communication chain between Contractors and their Operative. Figure 5.8 in Chapter 5 illustrates the suggested scenario. Although it is possible to incorporate this into the system, especially with the handheld device widely available on the market today, Clients interviewed in the evaluation are concerned about the monitoring and security issues as they would prefer that the Operative be unable to have access to the system.

6.3 CONCLUSION

MoPMIT prototype system may not cover all of the repair work but it suffices to say that it was well received by the participants as an adaptable online self-reporting system. The system was evaluated during the development stage and after it was completed. A live MoPMIT system was demonstrated to a group of professionals and implemented in a one-day pilot at one of the client's site. The results of the evaluation proved that the system has achieved the aim of the research. Although the responses and comments on the system are generally positive, some concerns on cultural issues were raised especially on the implementation of the system at the Unit Managers and Contractor's operative level. This issue will be further discuss in the next chapter. The participants in the evaluation also deliberated on the benefits and limitations of the prototype system which are discussed further in the next chapter.

CHAPTER 7

DISCUSSION

7.0 INTRODUCTION

In the previous chapter, some potential users further evaluated the outcome of the primary data analysis including the MoPMIT prototype. This chapter discusses what has been done throughout the research process. It also presents the benefits and the limitations of the system; and the recommendations for its future development.

7.1 DISCUSSION OF RESEARCH FINDINGS

Awareness of the importance of knowledge management for competitiveness, has led many businesses to review their business process. Knowledge management, a term that has been receiving popularity in the past few decades, is about acquiring, organising, storing, distributing and reusing knowledge among the individuals in an organisation.

Is information technology part of the knowledge management or vice versa? In recent thinking, knowledge management does not only restrict to rules in an expert system that replaces human ability in making decisions. The interaction and balance of four other important elements i.e. people, process, strategy, and the culture of the organisation, are essential for effective management of knowledge and competitive advantage. In as much as all the elements are equally important, it is essential that the organisation understands that human factors i.e. people and culture, are vulnerable to changes. Changes in process, strategy or technology could also alter their approach to doing business. Therefore, while giving equal consideration to these elements, management of knowledge should be able to encourage the organisation to create environments for employees to learn and share knowledge. IT here plays a role as an enabler contributing to this business need. Hence, significant analysis in the organisation business process is vital before an IT system could be implemented in the organisation.

To answer the question posed earlier, IT itself has a function for managing knowledge i.e. to create, capture, organise and disseminate knowledge and expertise to improve the process. There are many IT systems and tools (software and hardware) that support tacit and explicit knowledge in knowledge management. However, nowadays, it is web-based technology that is gaining the interest of most business operations because it facilitates inter-organisational communication and information flow besides allowing information to be accessed by anyone, at any time and from anywhere.

Significance of Reactive Maintenance Work

Despite many research works on knowledge management in the construction industry, there are not many published materials on knowledge management for the building maintenance sector. In the UK, expenditure in this sector is always well over 50% of the annual construction activities and they are carried out by firms with less then 20 employees that constitute 84% of the industry.

The literature review in Chapter 3 reveals that the high volume of maintenance works has caused difficulties in the management, especially when unplanned maintenance or also known as reactive maintenance work covers two thirds of the overall maintenance. The unexpected nature of reactive maintenance causes disruption to the daily business and requires immediate repair, besides it often put the building occupants and the repairman at risk. In addition, it consumes a lot of paperwork along the process. Although on average the cost of individual maintenance work is generally small, due to its high volume, the annual total cost makes it too much for the business to bear. Hence, it demands effective management to avoid unnecessary cost, time and energy which unfortunately occurs much too often.

A maintenance project involves the Client, who is the building owner; Facilities Management team, in-house or outsourced by Client; Contractor and Supplier. Obviously, maintenance projects are laden with information and knowledge. However, owing to the fact that it involves various parties for each maintenance job, this knowledge and information is not well communicated and shared among the parties.

Research Methodology

This research adopts the qualitative method with a case study approach to achieve the objectives of the study that require an in-depth investigation into building maintenance projects. Unlike the quantitative method, qualitative phenomenological paradigm is a discovery and process oriented approach; and close to insider perspective. It appropriately fits the exploratory nature of the research.

Process Modelling

Process analysis in Chapter 4 is not only used to understand the business process of reactive maintenance project and assert the underlying problems, but also to reflect some of the issues highlighted in the literature. A generic process flowchart for reactive maintenance work is mapped out based on the analysis of primary and secondary data. Flowchart techniques were used to picturise this business process. Even though other techniques such as IDEFx and RAD/RIN that model functional, behavioural and organisational views of a process could possibly model the reactive maintenance process in more detail, the traditional block diagram flowchart technique was chosen due to its simplicity and the ease with which it understood by layman such as the process owners.

Analysis on Business Process of Reactive Maintenance

This flowchart reveals some very important aspects of the maintenance work i.e. parties involved in the project and their role; IT system used in the process; and the underlying problems.

Research findings from the process analysis indicate the deficiencies in the existing business process. The first, relates to the knowledge management aspects of the problems. In terms of data storage, the Client/ FM's system databases are not technically complete, where some useful information is not stored and they are not updated with new information. The large volume of papers involved in the documentation process make it cumbersome to reuse the information. Furthermore, the large numbers of maintenance jobs stored in the database without archiving always cause the system to slow down.

Most of all, the major problem is the inadequate knowledge management support for the Client/ FM helpdesk operator in the Call Centre who uses the system to enter fault reports. Occasionally, errors in reporting can cause unnecessary visits by the Contractor for which the Client's unit will have to bear the cost.

Helpdesk Operators are non-technical staff with limited knowledge in building maintenance. The existing FM system requires them to describe the fault based on the caller's report. Without experience or guidelines, some job descriptions are eventually directed to the wrong Contractors.

In addition, this job description does not usually contain a hazard warning. Hence, the plain description does not help Contractor's expectation when they visit the Unit. In addition, it is not unusual for the Contractor's Operative to come with incomplete repair tools or not enough spare parts in their van which consequently requires them to revisit the site. This certainly affects the progress of work.

An experienced helpdesk operator might resign and leave the organisation along with the knowledge accumulated in them and training new staff to a similar standard of experience requires lengthy time and extra cost.

Due to lack of industry data protocol, job instruction has to be manually entered into the Contractor's system. This is unnecessary double handling work between Client/ FM system and Contractor's system. Not only that, double handling also occurred between the Client's system and its outsourced FM's system.

The second aspect of the problem relates to the procedures in the reactive maintenance. Conventional communication methods such as facsimile machine, post, telephones and paper form of documents have resulted in double handling as well as information not being kept up-to-date. This has also caused inefficient payment procedures once a job has been completed, besides the high cost and time spent traveling to validate a completed job.

In some cases that involve a sub-contractor, some important information was not made known to them. For instance, without the Facilities Manager's approval, they proceed with jobs that have been estimated above the budget limit because they are not aware of the limit. A similar situation is when job criteria specified by the Client are quite vague and so the Contractors/ Operative usually choose to ignore them and proceed with the job. Both cases can consequently cause unnecessary cost to the Unit. Another problem regarding the procedures is a purchasing agreement between Client and suppliers which is not followed by the operative when getting spare parts from suppliers especially on the agreed price.

Job authorisation by the Facilities Manager usually involves a long communication chain and re-visits by the Operative. Re-visits also occur when the job requires a tool or spare part that is not in their van. Thereby, this situation requires longer time to complete the job. A long communication chain often resulted in parties skipping the chain in order to convey the information faster to the recipient.

Finally, the third aspect of the problem is about the overall IT system that is being used now. The Client's system is on a DOS operating system that comes with unfriendly interfaces and is not compatible with other parties' more modern systems and machines. Since it is a stand alone system, data transfer to external systems is impossible. Moreover, rigid data and information are not easily manipulated for analysis.

In conclusion, poor communication among different parties in the process; lack of knowledge sharing; and poor quality of information summed up the findings from the business process analysis.

MoPMIT System

Hence, these findings have led to the development of an online knowledge management system called MoPMIT (More Productive Minor Construction Projects through Information Technology) in which the main idea is to bring all parties onto the online system so that they can share the necessary project information for better management of knowledge. The system allows them to communicate and share the information available to them via a common interface with pre-allocated password access as a control mechanism that restricts each user to its role. A re-engineered business process flowchart is developed that illustrates the operation of the reactive maintenance projects with the MoPMIT system.

The system is a prototype that was developed with selected features to demonstrate the idea of an online knowledge management system. Due to time constraint and lack of resources, the system covers only the most common building maintenance work and demonstrates most of the operational stages except payment and invoicing.

System Evaluation

In the evaluation process, potential users were brought in even during the development stage to ensure the completed prototype fits the user requirements. Once the system was ready, it was evaluated in two ways i.e. demonstration and pilot implementation. Both approaches led to discussions and distribution of questionnaires. The result was very encouraging. The majority of the users that took part in the evaluation are of the view that MoPMIT will lead to better management of knowledge, improve communication and better data sharing between all parties. The following sections will discussed the benefits, limitations and recommendations of the systems.

7.2 BENEFITS OF THE MoPMIT SYSTEM

At the moment, the system may seem to only accomplish the reactive maintenance process but with the reactive maintenance information and knowledge accumulated over time in the system, the Facilities Management team could plan for future planned maintenance purposes. The next three sections look at the benefits of this system to Client, Facilities Management, Contractor and Unit Manager as they are the main roles in reactive maintenance projects.

7.2.1 Client/ Facilities Management

1. Review Contractor's performance. Feedback on the Contractor's quality of work is essential for future contractual arrangement with them.

Similarly, history of jobs carried out by each Contractor can also contribute to the FM's decision making when reviewing the Contractor's performance. With the system, factors such as average cost and time spending on projects could be analysed.

2. Review Unit's performance. Every Client's Unit is given an allocation for maintenance purposes. It is important for them to keep the maintenance work within the budget. Being that the cost information of every project is stored in the system, an analysis could be done to review their performance in managing the maintenance work.

3. Decision making. Helps Facilities Manager in authorising pending jobs or payment.

4. Less paper work. Having most of the information transits in electronic forms, it contributes to the reduction of paper work.

5. Electronic data also allows users to optimise the re-use of information, especially in the case of using them as reference for new projects.

6. Asset management. At the moment, records on their assets are almost non-existent or if they are available, they are not fully utilised or monitored. MoPMIT could play a role as a stepping stone to better management of assets.

7. Reduce the number of Helpdesk Operators. Allowing the reporting task to be entered by the Unit will eventually reduce the need to depend on the role of a Helpdesk Operator.

8. Information built up in the system over time could enhance MoPMIT's features for handling planned maintenance works.

9. In the long term, when whole life cycle integration becomes a reality, the MoPMIT system will be able to integrate with other design and construction systems. Information, such as assets lists, from the design and construction phases can be imported directly into the MoPMIT database. Knowledge captured by the system can also be used for the design of future buildings.

7.2.2 Contractor

1. Reduction in double handling work. Electronic form of information allows them to transfer the information into their own system. This helps to reduce the amount of double handling work in entering the data.

2. Helps Operative to prepare for the upcoming maintenance job. With the detailed information given in the job instruction, the Operative could prepare themselves with appropriate tools and spare parts before moving to the Unit. Hence, avoiding delay in the work progress when parts or tools are not available in their van.

3. Health and safety. The job instruction produced by the system includes the possible health and safety warning hazard. This is essential for the Operative to equip their van with appropriate tools and prepare them for the expecting hazard.

4. Avoid unnecessary visits. Occasionally during the first visit, the Operative discovers that the fault is not within their scope of work or it can be solved without them attending the fault. Although the Contractor can claim payment on such visits, these unnecessary visits squander their time for more important ones.

7.2.3 Unit Manager

1. Avoid unnecessary cost. The wrong Contractor attending the fault; Operative visits a problem that could be solved on site by Unit; or delays because of spare parts being not available are examples where unnecessary cost could occur. With the system, it helps them to monitor their maintenance budget allocation.

2. Check status of work progress. Unit can check the status of work online without having to call the Helpdesk.

3. Giving feedback on Contractor's quality of work. These feedbacks reflect the Contractors' overall performance which can be used by the Facilities

Manager when renewing their contract.

4. Health and safety. It is important for the Unit to be able to warn the building occupants regarding the hazard that may be caused by the faulty while waiting for the contractor to visit the repair work. The system provides the steps that should be taken by Unit Manager when hazard is expected on the site.

7.3 LIMITATIONS OF THE MoPMIT SYSTEM

1. Culture

Interestingly, the Unit Manager can be considered as the main factor in the re-engineering business process of reactive maintenance if this system is being implemented. However, it can be an issue to get the person at the Unit to use the system. This is possibly due to unfamiliarity with computers/ Internet or they prefer to report the problem by phone as it is much easier, but this does not help the Client/FM in reducing the cost by decreasing the number of Helpdesk Operators in their Call Centres.

2. Security

This issue can also be part of the previous point. For instance, the Operative should be able to access the online system for features such as checking the equipment's fault history or the Unit's, and update the status of the work progress (instead of doing it through Contractor). However the Client would not allow them to do so. During the evaluation, participants did not raise this issue as much but meetings with parties involved in the case study, the Clients have made clear of their concern on the extent of access other parties will benefit from and the level of security the system provides.

The reason behind this is that Clients are very concerned about what the outsiders can do with their system that contains valuable information. Although many highly recommended security devices (hardware and software) are available in the market, people are still in doubt, especially with the increasing numbers of hackers in the World Wide Web (WWW). This decision somehow holds back the system from being fully utilised.

3. Database

Steps have to be taken in order to ensure the reliability of the database. The amount of maintenance work increasing over time could slow down the system. Archiving might be necessary but at the same time the knowledge essential for decision making should remain available.

7.4 RECOMMENDATIONS ON THE SYSTEM

1. More real data from previous projects is required to complete the system with robust information. The system would benefit from this especially in identifying the type of repair work, maintenance cost estimation and contractor's performance. This research has tried to gather most if not all of the information available on maintenance works. However, the current MoPMIT system has been limited to cover the most common maintenance problems that occur. It is recommended that the system

includes a variety of maintenance problems (as listed in section 5.3.1 Chapter 5).

2. Asset management data is additional information that could be added into the system. For now, the system is not able to help in determining the location of the problem that needs to be dealt with. A standard structure to identify the location of a reported problem could be developed to help overcome this drawback in the system.

3. Likewise, a history of particular elements or equipment - such as automatic doors or heating boilers - could also help the contractor understand its previous maintenance history and be aware of actions that should be taken. At the moment, records on assets are almost non-existent or if any, are not available in electronic form.

4. Many of the large contractors in the reactive maintenance projects have their own facilities management system be it bespoke or off-the-shelf software. At the moment, the report sent to the contractor has yet to be directly transferred into the contractor's system. Therefore, a link between these two systems that will allow data transfer is something that could be looked into.

5. The questions and answers part in the system could be enhanced with a more intelligent knowledge based system. The decision tree should be

expanded and made robust so that it would lead to better decision-making based on previous project data and assets records.

7.5 CONCLUSION

The discussion has summed up the study on minor construction projects in the UK. The study, as in previous works reviewed has shown that there are fundamental problems with the existing reactive maintenance business process. Based on these problems, an online knowledge management system was developed to improve the building maintenance projects. This chapter has laid down the benefits of the system for the client, facilities manager, contractor and unit manager. These benefits highlight the reduction of operational cost through better communication, the valuable information for health and safety issue and the reduction of operational time through accessing information from the system. The limitations highlighted in this chapter are the reality that an organisation has to face when implementing the web-based system in their business process. The next chapter makes some concluding statements on the research.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.0 INTRODUCTION

This chapter summarises the thesis and concludes the findings of the study. Some recommendations for the industry and potential future research in similar area are listed at the end of the chapter.

8.1 SUMMARY

1. In the UK, building maintenance makes up more than 50% of total construction output while reactive maintenance covers two thirds of the overall building maintenance projects. Therefore, it was found not surprisingly that reactive maintenance work receives the most complaints and inherent with it more negative impacts on business activities in terms of time, cost, and the health and safety of the users. The large number of individual items of work do not only cause financial burden but also can lead to management difficulties. The process of dealing with each job is relatively slow due to the uncertainty of the nature of the work.

   Since this type of maintenance work is mostly carried out by firms with less than 20 employees, which constitutes 84% of the industry, reactive maintenance is hence the major focus of this study.

2. Knowledge assets have been recognised as valuable to organisations. This intellectual capital of a company, can add great value to the company's daily operation. The conversion process of tacit and explicit knowledge between the individuals is essential to the organisation. Between the two types of knowledge, tacit knowledge is easier to loose when individuals leave the organisation. Hence, knowledge management is adopted to ensure that tacit knowledge is captured for the benefits of other individuals in the organisation. Many literatures on knowledge management have listed out the benefits of having successful knowledge management programme in their business.

   This research explores how knowledge management could help to improve the management of building maintenance, particularly the reactive maintenance works by looking at the potential of IT as an enabler.

3. IT application for reactive maintenance work is the major focus of the study. It seeks to look at the use of a web based technology to improve the management of reactive maintenance projects. The aim is to provide support during fault reporting, contractor allocation, job approval and performance evaluation.

4. The process of reactive maintenance projects involves four main parties: a number of building owners, facilities management teams, contractors and suppliers. Process analysis provides valuable insights into the existing business process of reactive maintenance and also the

information and communication technology that is being used by the parties involved in the process. It unearthed problems that impede the process in terms of time, cost, quality of work and the health and safety of the users.

5. These problems can be encapsulated as [1] poor communication among different parties in the process; [2] lack of knowledge sharing; and [3] poor quality of information; which often leads to a longer time period to fix a problem and at a higher cost. An online knowledge management system named MoPMIT (More Productive Minor Construction Project through Information Technology) was developed as a prototype with the aim of improving the operation of these reactive maintenance projects.

6. Several demonstrations and a pilot exercise were performed to evaluate the system. The participants are potential users of the system such as building owners, helpdesk staff, facilities managers, contractors, project managers and IT managers.

8.2 CONCLUSIONS

1. Process analysis on the business process of the reactive maintenance project reveals some important issues that restrain the maintenance operation in term of cost, time, quality of work and the health and safety of the users. Conventional methods of transferring information and resolving problems among existing parties have resulted in poor

communication. While some explicit knowledge is left without being fully utilised, tacit knowledge is left uncaptured within the individuals in the organisation. The existing business process does not encourage the sharing of knowledge among the parties or reusing it for future projects. Instead it produces considerably static information that not only lacks flexibility in providing useful information for a particular maintenance work, but also does not generate vital analysis for future reference.

Information and communication technology tools that support knowledge management can be divided into two i.e. tools for managing tacit knowledge and tools for managing explicit knowledge. However, both are dominated by the advanced technology of networking i.e. Internet, intranet or extranet. Networking enhances the functionalities of these tools which technically are meant for organising, applying, communicating or sharing the knowledge.

The problems unearthed in the process analysis have opened an opportunity for improvement. The main concern is improving the management of knowledge, communication, information flow and data sharing by eliminating some unnecessary routines in the process. Hence, reactive maintenance projects could benefit from a system that allows the acquisition, storage, distribution and reuse of knowledge. The system permits all parties to access the system to update, share and retrieve information stored in the server with a certain level of access control.

The discussion on process analysis and knowledge management tools and systems gives the impetus to say that objective one and two of the research have been achieved.

2. In order to achieve the third objective of the research, a prototype system has been developed. The development of knowledge management and internet technologies has provided a platform for developing an on-line knowledge management system to improve the operation of these reactive maintenance projects. The MoPMIT system has demonstrated how this technology could enhance effectiveness and efficiency in the delivery of minor construction projects. It addresses the problems with a unit or call centre in entering jobs; the different user interface structures for each type of user in the reactive maintenance process; the prediction of job details; communication between various parties; and security. The introduction of a central system that is able to be accessed by the contractors, the client's units and the client's facilities management agent, removes a lot of the communication problems.

The main idea of the MoPMIT system is to bring all the different parties to share information and communicate on a common interface with pre-allocated password access as a control mechanism that will limit each user to its role in the reactive maintenance process. The knowledge management side of it allows the system to create new knowledge; store the knowledge for any authorised person who may need it; use the knowledge when necessary; and disseminate the knowledge. In addition, it is also able to guide the users through the decision making process. Internet technology is the ideal platform for such a system to be accessed by anyone, anywhere and at anytime. In the context of this system, access is controlled by a valid password.

3. The system was evaluated by various experts in building maintenance industry which has helped to achieve objective four of the study. In general, feedback from the industry about the system is positive. Some of them expressed their concern about the effects of adapting to the new system, but they believed the system would lead to better management of knowledge, improved communication and better data sharing between all parties. Above all, they are of the perspective that MoPMIT will be able to speed up the reactive maintenance process and produce significant savings in transaction cost.

   Although they recommend that training would be required for non-technical users, they acknowledge that the prototype has potential benefits to minor construction or reactive maintenance in particular.

4. Knowledge management is a management process that embraces some key elements i.e. people, process, strategy, technology and cultural. The balance interactions between these elements will allow the knowledge to be managed effectively. It is essential not to diminish issues related to people who are at the heart of the process. Culturally, without persuasive incentives people are reluctant to change the way they are used to behaving though sometimes changes (in strategy, process or technology) are necessary for the sustainability of the business. Therefore, giving the people appropriate incentives as well as letting them be aware of the highlighted benefits of having the system in their business process could encourage them to start using such system.

8.3 RECOMMENDATIONS FOR INDUSTRY

1. It is recommended that the MoPMIT system be adopted and promoted within the construction industry and for reactive maintenance projects in particular. This recommendation is informed by the identified advantages inherent with the adoption of the MoPMIT system such as improved communication, help in monitoring the maintenance cost, performance analysis and improvement in future planned maintenance works.

2. The reactive maintenance project starts at the Unit and the process commences when a person at the Unit, particularly the Unit Manager, reports the problem requesting a Contractor to visit and repair the problem. As highlighted in the previous chapter, the Unit Manager might be reluctant to use the system owing to technical incompetence and /or cultural uncertainty of switching from traditional method of job operations to the new MoPMIT application. To allay this concern it may be necessary to give the unit managers some preliminary orientation leading to the use of MoPMIT system. Given that the call to the Helpdesk could be bypassed with the system, the Client can motivate the Unit Manager and other users to use the system by highlighting it as an operation cost savings device in routine transactions and the reporting of reactive maintenance problems. In the same vein, the Client can create incentives drawing on savings in transaction costs in order to motivate users to use the system.

3. Nowadays, the handheld device is commonly used in other industries. This device can be connected to a network and allows users to access information from almost anywhere and at anytime, provided that the system is furnished with good security technology embedded in the system. As the MoPMIT is flexible enough to allow communication with these devices, the Contractor's Operative could be allowed to view the information accessible to them by using the handheld device.

8.4 RECOMMENDATIONS FOR FUTURE RESEARCH

This research has demonstrated a huge potential for improving the reactive maintenance project. The MoPMIT prototype system was designed to demonstrate the idea derived from issues in the research. By its nature, the prototype represents only part of the knowledge and expertise of various parties in the reactive maintenance process. Similar to human knowledge the system can be improved and expanded. The possibilities for further work are therefore substantial.

Apart from recommendation on the system illustrated in Chapter 7, 7.4, further study should look into:

1. Developing a case based component within the system that evolves with time, by using previously completed jobs to help with the handling of new jobs.

2. Expanding the system features to cover the process which is missing such as invoicing and payment and a broader scope of repair work.

3. Developing industry data protocol for transferring data from various systems among the parties.

A major limitation in this study is that the study involved two facilities management organisation (one outsourced and one in-house) and three clients which might not be enough to make a generalisation of building maintenance industry in the UK. Multiple case study involving more facilities management and clients could provide more impetus for generalisation.

It is hoped future studies could lead to a better MoPMIT system with expanded features that would benefit the building maintenance industry, in particular, and construction industry as a whole.

REFERENCES

Acquired. (online). Knowledge Acquisition for Expert System. www.aiinc.ca . 30Jan 2004

Ahmed P.K., Lim K.K. and Ann Loh Y.E. (2002). *Learning through Knowledge Management.* Oxford: Heinemann

Albert T.P. & Chan W.L. (2002), LAN-based Building Maintenance and Surveillance Robot. *Automation in Construction.* Volume 11. Issue 6. pp 619-627

Alexander, K (ed.) (1996), *Facilities Management – Theory and Practice,* London: E & FN SPON

Ali K.N. Sun M. Petley G. and Barrett P. (2002). Improving the Business Process of Reactive Maintenance Projects. Facilities. Vol. 20. No. 7/8. pp. 251-261.

Allee, V. (1997). 12 Principles of Knowledge Management. *Training & Development.* Vol. 51, pp. 71-74.

Allen D. (1993). What is Building Maintenance?. *Facilities.* Volume 11. Number. 3. pp. 7-12

Amaratunga D., Baldry D., Sarshar M., Newton R. (2002/2000). Quantitative and Qualitative Research in the Built Environment: Application of "Mixed" Research Approach. *Work Study.* Vol 51 No. 1. pp 17-31.

Aouad G., Child T., Farhi M., Brandon P. (1997). *Open Systems for Construction (OSCON): Industrial Report.* Salford: University of Salford.

Aouad G., Kagioglou M., Cooper R., Hinks J. & Sexton M. (1999). Technology Management of IT in Construction: A Driver or an Enabler?. *Logistics Information Management.* Volume 12. Number 1/2. pp. 130-137

Aouad G., Sun M., Bakis N., Swan W. (2001). Gallicon - Supporting Partners: Industrial Report. Salford: University of Salford

Argyris C. & Schon D. (1996). *Organizational Learning II - Theory, Method, and Practice.* New Yor: Addison-Wesley Publishing Company

Ash J. (1998), Managing Knowledge Gives Power. *Communication World.* Vol.15 No. 3. pp. 23-26

Assistum. (online). Knowledge Editor. http://www.assistum.com/ 30Jan 2004

Attar Software (Attar). (online). Attar Software: Xpert Rule Knowledge Builder for eBusiness, eGovernment and eLearning. www.attar.com 30Jan 2004

Autonomy. (online). Autonomy System. http://www.autonomy.com/ 30Jan 2004

Baker, M. and Barker, M. (1997). Leveraging Human Capital. *The Journal of Knowledge Management.* Vol.1. No.1. pp 63-74

Baldry, D. (2002). Overview of the BIFM agenda. Paper presented at the *International Research Symposium in Facilities Management.* University of Salford, Salford.

Barrett P. & Baldry D. (2003). *Facilities Management: Towards Best Practice.* Second Edition. Oxford: Blackwell Science

Bell J. (1993). *Doing Your Research Project.* 2nd ed. Buckingham: Open University Press

Belmiro T.R. and Pina A.A.D. A process modelling approach at Xerox of Brazil. Work Study Volume 50 " Number 7 " 2001 " pp. 269-275

Betts M. (1999). The Significance of IT. In Betts. M. *Strategic Management of IT in Construction.* Oxford: Blackwell Science Ltd

Bhatt G.D. (2001). Knowledge Management in Organizations: Examining the Interaction between Technologies, Techniques and People. *Journal of Knowledge Management.* Volume 5. Number 1. pp. 68-75

Bhatt G.D. (2002). Management Strategies for Individual Knowledge and Organizational Knowledge. *Journal of Knowledge Management.* Volume 6. Number 1. pp. 31-39

Blaxter L., Hughes C. and Tight M. (2001). *How to Research.* 2nd ed. Buckingham: Open University Press.

Bluetooth. (online). The Official Bluetooth Wireless Info Site. www.bluetooth.com 30Jan 2004

Bruton N. (2002). How to Manage the IT Helpdesk - A Guide for User Support and Call Centre Managers. Oxford: Butterworth-Heinemann

Chanter B. & Swallow P. (1996). *Building Maintenance Management.* Oxford: Blackwell

Chudley, R. (1981). *The Maintenance and Adaptation of Buildings.* Essex: Longman Group Limited

Chun Wei Choo (1998), *Information Management for the Intelligent Organization - The Art of Scanning the Environment*, Ney Jersey: Information Today Inc.

Chartered Institute of Building (CIOB) (1990). *Maintenance Management – A Guide of Good Practice*

ClickSoftware. (online). The Leader in Field Service Management Software and Dispatching Software. http://www.clicksoftware.com/ 30 Jan 2004

Clough P. and Nutbrown C. (2002). *A Students Guide to Methodology Justifying Enquiry*. London: SAGE Publications.

Cornford, F.M. (1935), *Plato's Theory of Knowledge*, London: Routledge and Kegan Paul Ltd.

Costa C.A., Oliveira R.C. (2002). Assigning Priorities for Maintenance Repair and Refurbishment in Managing a Municipal Housing Stock. *European Journal of Operational Research*. Volumel38. Issue2 . pp 380-391

Court, A. W. (1997). The Relationship Between Information and Personal Knowledge in New Product Development. *International Journal of Information Management*. Vol.17 No.2. pp 123-138.

Cover, R. (1998), The XMLTP.ORG – XML Transfer Protocol, http://www.oasis-open.org/cover/xmltp.html 30 Jan 2004

Cronbach, L.J. (1990), *Essentials of Psychological Testing*, New York: Harper and Row

Damelio, R. (1996). The Basics of Process Mapping. Portland: Productivity, Inc.

Davenport, T.H. and Short, J.D. (1990). The New Industrial Engineering: Information Technology and Business Process Redesign. Sloan Management Review. Summer 1990. pp 11 -27.

Davenport, T.H. (1993). Process Innovation - Reengineering Work through Information Technology. Massachusetts: Harvard Business School Press

Davenport, T.H. (1996), Knowledge Management Case Study – Knowledge Management at Hewlett-Packard Early 1996, *KM*, http://www.bus.utexas.edu/kman/hpcase.htm 30 Jan 2004

Davenport, T.H. (1997a), Knowledge Management Case Study – Knowledge Management at Microsoft 1997, *KM*, http://www.bus.utexas.edu/kman/microsoft.htm 30 Jan 2004

Davenport, T.H. (1997b), Knowledge Management Case Study – Knowledge Management at Ernst & Young 1997, *KM*, http://www.bus.utexas.edu/kman/e_y.htm 30 Jan 2004

Davenport, T. H., and Prusak L. (1998a). *Working Knowledge: How Organizations Manage What They Know*. Cambridge, Massachusetts: Harvard Business School Press.

Davenport T.H., De Long D.W., and Beers M.C. (1998b). Successful Knowledge Management Projects. *Sloan Management Review*. Vol. 39 No. 2. pp. 43-57.

Dekker R. & Winden C. V., (1998). Rationalization of Building Maintenance by Markov decision models: A pilot study. *Journal of Operational Research Society*. Vol. 49. pp.928-935

Derrington D.C., Linton F. & Brooks J. (2000). *Knowledge Management Using a Corporate Intranet*. The MITRE Corporation

Department of the Environment, Transport, Region (DETR). (2000). *Construction Statistic Annual 2000 Edition*

Department of Trade and Industry (DTI). (2000). *Small and Medium Enterprise (SME) Statistics for the UK, 1999*

Dixon, N. M., (2000). *Common Knowledge: How Companies Thrive by Sharing What They Know*. Harvard Business Press, Boston, Massachusetts.

Easterby-Smith M., Thorpe R., Lowe A. (1991) Management Research. London: SAGE Publications.

E-Construct Project (E-Construct). (online). http://www.econstruct.org/default_frame.htm 30 Jan 2004

Egbu C., and Botterill K., (2002). Information Technologies for Knowledge Management: Their Usage and Effectiveness. *Electronic Journal of Information Technology in Construction*. Vol. 7 Royal Institute of Technology, Stockholm. Sweden. http://www.itcon.org/2002/8

Elashaheb M. and Aouad G. (2003). The Development of Knowledge Management Approach for a Telecommunication Company in Libya. *Proceedings of the 3rd International Conference for PostGraduate Research Conference in the Built and Human Environment*. edited by Aouad G. and Ruddock L. 3-4 April 2003. University of Salford.

El-Haram, M.A. and Horner M.W. (2002). Factors Affecting Housing Maintenance Cost. *Journal of Quality in Maintenance Engineering*. Vol 8 No. 2. pp. 115-123.

Engelhardt, M., Skipworth, P., Savic, D.A., Cashman, A., Walters, G.A. and Saul A.J. (2002). Determining Maintenance Requirements of a Water Distribution Network Using Whole Life Costing. *Journal of Quality in Maintenance Engineering.* Volume 8 Number 2 2002 pp. 152-164

Faraj I, Alshawi M (2000). An Industry Foundation Classes Web-based Collaborative Construction Computer Environment: WISPER. *Automation in Construction.* Volume 10. Number 1. pp 79-99.

Feagin,J., Orum, A. and Sjoberg, G.(Eds.). (1991). *A Case for Case Study.* Chapel Hill, NC: University of North Carolina Press.

Finch E., (2000). Third-wave Internet in Facilities Management. *Facilities.* Volume 18. Number 5/6. 2000. pp 204-212

Galloway D. (1994). *Mapping Work Processes.* Wisconsin: ASQ Quality Press Publications

Gichuiri. J.W. (2001). *Process Modelling and Evaluation Approach in Support of Effective Management of Construction Project Information.* PhD Thesis. School of Construction and Property Management. Faculty of Business & Informatics. University of Salford.

Greenwood, R.M. (1993). Process Terminology – A Software Engineering Perspective. *IOPener,* vol 2, no 1, pp7-9.

Griffith, A. and Phillips, N (2001). The Influence of the Construction (Design and Management) Regulations 1994 upon the Procurement and Management of Small Building Works. *Construction Management and Economics.* No 19, 533-540

Griffith A. (1992) *Small Building Works Management.* London: The MacMIllan Press

Guba, E. G., & Lincoln, Y. S. (1989). *Forth Generation Evaluation.* Newbury Park: SAGE Publications.

Gupta, B., Iyer, L.S. and Aronson, J.E. (2000), Knowledge Management: Practices and Challenges, *Industrial Management and Data Systems,* 100/1, pp17-21

Handheld System (Handheld) (online). http://www.handheldsystems.com/ 30Jan 2004

Harrington H.J. (1991). Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness. London: McGraw-Hill

Headley J. & Griffith A. (1997). *The Procurement and Management of Small Works and Minor Maintenance.* Edinburgh: Addison Wesley Longman Ltd

Hendriks P.H.J. (2001). Many Rivers to Cross: from ICT to Knowledge Management Systems. *Journal of Information Technology.* Volume 16. pp 57-72

Holliday A. (2002). *Doing and Writing Qualitative Research.* London: SAGE Publications.

Horner, R.M., El-Haram, M.A. and Munns, A. (1997). Building Maintenance Strategy, A New Management Approach. *International Journal of Quality in Maintenance.* Vol. 3 No. 4. pp. 273-80

Huckvale, T and Ould, M.J. (1998). Process Modelling – Who, What and How - Role Activity Diagramming. In Grover V. and Kettinger, W.J. (ed). *Business Process Change: Reengineering Concepts, Methods and Technologies.* London: IDEA GROUP PUBLISHING.

Hyperknowledge. www.hyperknowledge.com 30Jan 2004

Ikhwan M.A.H. & Bumey (1994). Maintenance in Saudi Industry. International *Journal of Operations & Production Management.* Volume 14. Number 7. pp. 70-80

Ingirige B., Sexton M., and Betts M.. (2002). The Suitability of IT as a Tool to Facilitate Knowledge Sharing in Construction Alliances. *International Council for Research Innovation in Building and Construction, CIB w78 conference 2002*, pp. 1-8, Aarhus. School of Architecture, 12-14 June 2002

International Alliance of Interoperability Morth America (IAI-NA). (online). http://www.iai-na.org/aecxml/mission.php. 30 Jan 2004

Internet Movie Database (IMDb) (online). http://www.imdb.com 30 Jan 2004

IML. (online). IML Ltd. Innovative Group Response. http://www.iml.ltd.uk/about_iml.htm. 31 Dec 2003

ISoft. (online). ISoft Product: Case Based Reasoning. Recall. http://www.alice-soft.com/html/prod_recall.htm 30Jan 2004

Jones O. (2000). Facility Management: Future Opportunities, Scope and Impact. *Facilities.* Volume 18. Number 3/4. pp. 133-137

Johnsson P. (1997). The Status of Maintenance Management in Swedish Manufacturing Firms. *Journal of Quality in Maintenance Engineering.* Volume 3. Number 4. pp. 233-258

Kagioglou, M., Cooper, R, Aouad, G., Hinks, J., Sexton, M. and Sheath, D. M. (1998). *A Generic Guide to the Design and Construction Process Protocol.* University of Salford.

Karake, Z.A. (1994). Relative Information Technology Index: IT Performance, Companv Confrol and Governance. *Logistics Information Management.* Vol. 7. No. 4. pp 6-14.

Kirchner S.R. (1997). Focus on: Database Integration and Management for Call Centre. *Telemarketing*, Vol. 16, No. 2 pp. 22-24

Koenig, M.E.D and Srikantaiah, T.K. (2000), The Evolution of Management, in Srikantaiah, T.K. and Koenig M.E.D. (ed.), *Knowledge Management - For the Information Professional*, New Jersey: Information Today Inc.

Lang J.C. (2001). Managerial Concerns in Knowledge Management. *Journal of Knowledge Management.* Volume 5. Number 1. pp. 43-59

Lee, R. (1987). Building Maintenance Management. London : Collins

Leibovich S. L. and Shohet I.M. (2002). Integrated Maintenance Management of Multi-System Buildings – A Case Study. *Proceedings of the 2nd International Conference for PostGraduate Research Conference in the Built and Human Environment.* 11th and 12th April 2002. Univeristy of Salford.

Lewis M.W., Steinberg L. (2001). Maintenance of Mobile Mine Equipment in the Information Age. *Journal of Quality in Maintenance Engineering.* Volume 7. Number 4. pp. 264-274

Madu C. (1990). An Economic Design for Optimum Maintenance Float Policy. *Computers and Industrial Engineering.* Vol. 18. No. 4. pp 457-469

Malhotra, Y. (1998). Knowledge Management, Knowledge Organisations & Knowledge Workers: A View from the Front Lines. http://www.brmt.com/interview/maei1.htm 15/05/2003.

Mason J. (1996). *Qualitative Researching.* London: SAGE Publications.

McDermott R. & O'Dell C. (2001). Overcoming Cultural Barriers to Sharing Knowledge. *Journal of Knowledge Management.* Volume 5. Number 1. pp. 76-85

McDermott R. (1999). Why Information Technology Inspired But Cannot Deliver Knowledge Management. *California Management Review.* Volume 41. Number 4. Summer 1999. pp 103-117

McLennan P. (2000). Intellectual capital: Future Competitive Aadvantage for Facility Management. *Facilities*. Volume 18. Number 3/4. pp 168-171.

Merriam, S. B. (1988). *Case Study Research in Education: A Qualitative Approach*. San Francisco: Jossey-Bass Publishers.

Merriam-Webster Collegiate Dicitionary (online), http://www.m-w.com/ 30 Jan 2004

Miller, F. J. (2003). 1=0 (Information has no intrinsic meaning). http://www.sveiby.com.au/knowledgemangement.html 20/12/2003.

Mitropoulos, P. Howell. G.A.. (2002). Renovation Projects: Design Process Problems and Improvement Mechanisms. ASCE *Journal of Management in Engineering*. Volume 18. Number 4. pp 179-85.

Mohamed S. (2003). Web-based Technology in Support of Construction Supply Chain Networks. *Work Study*. Volume 52. Number 1. pp. 13-19

Nagarur N.N. and Kaewplang K.W. (1999). An Object –Oriented Decision Support System for Maintenance Management. Journal of Quality in Maintenance Engineering, Vol. 5 No. 3. pp. 248-257.

Nelson M. and Baldry D. (2000). Modelling Process Improvement in Facilities Management. Proceedings of the Bizarre Fruit 2000. *National Conference of Post Graduate Research in the Built and Human Environment*. Edited by Sun M., Aouad G. Ormerod M. and Ruddock L. 9-10 March 2000. University of Salford.

Newman, B.D. (online), What is Knowledge Management, *The Knowledge Management Forum*. http://www.km-forum.org/what_is.htm 30 Jan 2004

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, New York; Oxford: Oxford University Press

Nonaka, I., Reinmoeller, P. and Senoo, D. (2000), Integrated IT Systems to Capitalize on Market Knowledge, in von Krogh, G., Nonaka, I & Nishiguchi, T. (ed.), *Knowledge Creation - A Source of Value*, London: Macmillan Press Ltd.

Nutt B. (2000). Four Competing Futures for Facility Management. *Facilities*. Volume 18. Number 3/4. pp. 124-132

Oakley, A. (1999). People's way of knowing: gender and methodology. In Hood S., Mayall B. and Oliver S. (eds). *Critical Issues in Social Research: Power and Prejudice*. Buckingham: Open University Press, pp. 154-77.

Olomolaiye A. & Egbu C. (2004). Motivating Knowledge Workers: The Dilemma of HRM's Contribution to Knowledge Management in the Construction Industry. *The International Salford Centre for Research ad Innovation (SCRI) Research Symposium*. University of Salford. 30-31 March 2004.

Olscheske, T.J. (1999). *Knowledge Creation and Discovery Learning Teams: A Case Study Exploring the Dynamics of Knowledge Creation, Utilization, and Transfer in Biotechnology R&D Groups*. In partial fulfilment of the requirements for the degree of Doctor of Philosophy. University of Wisconsin-Madison.

Olubodun O.F. (1996). *An Empirical Approach to Evaluation of Factors in Local Authority Housing Maintenance Requirements in the City of Manchester*. PhD Thesis. T.I.M.E. Research Institute. Department of Surveying. University of Salford.

Ould M.A. and Unwin C. (ed.) (1986). *Testing in Software Development*. Cambridge: Cambridge University Press

Ould M.A. (1994). Eight Laws for Process Modelling. *IOPener*. Vol 2. No. 4. pp 9-12

Ould M.A. (1995). Business Processes – Modelling and Analysis for Reengineering and Improvement. New York: John Wiley & Sons.

Patel, M. B., McCarthy T. J., Morris, P. W. G. and Elhag T. M. S., (2000). The Role of IT in Capturing and Managing Knowledge for Organisational Learning on Construction Projects. *The Construction Information Technology, International Conference,* Kelandic Building Research Institute, Reykjavik, Iceland, June 28-30.

Perera R. S. (1997). *Case-based Estimating and Design: Towards A Collaborative Approach*. PhD Thesis. T.I.M.E. Research Institute. Department of Surveying. University of Salford

Patton M.Q. (1990). Qualitative evaluation and research methods / Michael Quinn Patton. 2nd ed. London : Sage Publication

Pintelon L., du Preez N. & van Puyvelde F. (1999). Information Technology: Opportunities for Maintenance Management. *Journal of Quality in Maintenance Engineering*. Volume 5. Number 1. pp. 9-24

Polanyi, M. (1958a), *Personal Knowledge: Towards a Post-Critical Philosophy,* London: Routledge & Kegan Paul.

Polanyi, M. (1958b), *The Study of Man*, London: Routledge & Kegan Paul

Polanyi, M. (1967), *The Tacit Dimension*, London: Routledge & Kegan Paul

Popper, K.R. (1979), *Objective Knowledge - An Evolutionary Approach*, Oxford: Oxford University Press

Pressman, R.S. (2000). *Software Engineering – A Practitioner's Approach.* London: Mc Graw-Hill Publishing Company.

Punch, K. F. (1998). *Introduction to Social Research: Quantitative and Qualitative Approaches.* London: Sage.

QFM – Service Works Ltd (online). http://www.serviceworksglobal.com/products/property.html 30 Jan 2004

Robson, C. (1993). *Real World Research.* Oxford: Blackwell Publishers.

Ruggles, R. (1997), *Knowledge Tools – Using Technology to Manage Better,* Working Paper, Center for Business Innovation, Ernst & Young LLP

Russel, L. (online), Help for the Help Desk: Growing and Sharing Knowledge, *Help Desk Software Resource,* http://www.helpdesk-online.com/oldsite/sept07/article3.asp 30 Jan 2004

Sahasrabudhe, V. (2000), Information Technology in Support of Knowledge Management, in Srikantaiah, T.K. and Koenig M.E.D. (ed.), *Knowledge Management - For the Information Professional,* New Jersey: Information Today Inc.

Salford University. (1999). *Research Methods.* A Module of the Masters Programme in the School of Construction and Property Management. Salford: University of Salford.

Scharmer, C.O. (2000), Organization Around Not-Yet-Embodied Knowledge, in von Krogh, G., Nonaka, I & Nishiguchi, T. (ed.), *Knowledge Creation - A Source of Value,* London: Macmillan Press Ltd.

Seeley I. H. (1976). *Building Maintenance.* London: The MacMIllan Press

Seeman, P. (1997), *Managing Knowledge at Hoffmann-LaRoche,* Center for Business Innovation, Ernst & Young LLP

Shen Q. (1997). A Comparative Study of Priority Setting Methods for Planned Maintenance of Public Buildings. *Facilities.* Volume 15. Number 12-13. pp. 331-339

Shohet, I. M. and Bar-On, D. (2003). Performance-based Healthcare Facilities Maintenance in Israel. *Business Briefing: Hospital Engineering and Facilities Management.* Healthcare and Pharmaceutical. Business Briefing. http://www.bbriefings.com/cdps/cditem.cfm?NID=13 , 30 Nov 2003

Sidney, R. (1992). Planned Preventative Maintenance and the Maintenance Contractor. *Property Management*. Vol. 10 No. 1. pp 29-32

Silverman D. (2001). *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction*. 2nd ed. London: SAGE Publications.

Skyrme, D.J. (online), Knowledge Management Solution - The IT Contribution, *David Skyrme Associates Limited*, http://www.skyrme.com/pubs/acm0398.doc 30 Jan 2004

Small C.T. and Jean T. (2000). Knowledge Management Model Guides KM Process: The EDGE Newsletter. http://www.mitre.org/news/the_edge/april_00/4_00.pdf (view as html) 30 Jan 2004

Smith E.A. (2001). The Role of Tacit and Explicit Knowledge in the Workplace. *Journal of Knowledge Management*. Volume 5. Number 4. pp. 311-321

Srikantaiah, T.K. (2000), Knowledge Management: A Faceted Overview, in Srikantaiah, T.K. and Koenig M.E.D. (ed.), *Knowledge Management - For the Information Professional*, New Jersey: Information Today Inc.

Stake, R. E. (1981). *Case Study Methodology: An Epistemological Advocacy*. Minneapolis: Minnesota Research and Evaluation Centre.

Strauss. A., & Corbin, J. (1994). Grounded Theory Methodology: An overview. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research*. California: SAGE Publications.

Sulaiman M.J. (1997). *INTESITE: Intelligent Site Layout Planning within an Object Oriented Integrated Construction Environment*. PhD Thesis. School of Construction and Property Management. Faculty of Business & Informatics. University of Salford.

Sun M, K.N. Ali, P.S Barrett (2003a). An Integrated Management System for Reactive Building Maintenance Project. *10th ISPE International Conference on Concurrent Engineering: Research and Applications*. Carlton Madeira Hotel, Madeira Island – Portugal. 26 - 30 July, 2003

Sun M., Barrett P., Petley G., Ali K.N., Kagioglou M. (2003b). *More productive Minor Construction Projects through Information Technology (MoPMIT)*. Salford: Salford Centre for Research and Innovation.

Swan J., Newell S., Scarbrough H. and Hislop D. (1999). Knowledge Management and Innovation: Networks and Networking. *Journal of Knowledge Management*. Volume 3. Number 4. pp. 262-275

Technological Business Solution (TBS) Ltd. (2000). Interview with Steve Reynolds (TBS). 11 August 2000

Torrance V. (1997). Building Process Summary. *Automation in Construction.* Volume 6. 11-16

TouchStar (online). http://www.touchpc.com/ 30Jan 2004

Tsang A.H.C. (1995). Condition-based Maintenance: Tools and Decision Making. *Journal of Quality in Maintenance Engineering.* Volume 01. Number 3. pp. 3-17

Underwood J. & Alshawi M. (2000). Forecasting Building Element Maintenance within an Integrated Constuction Environment. *Automation in Construction.* Volume 9. pp 169-184

Vanier, D. (2001). Why Industry Needs Asset Management Tools. *Journal of Computing in Civil Engineering.* Vol. 15. No. 1. pp 35-43.

Virtual Private Network (VPN). (online). AVAYA. www.vpnet.com. 30Jan 2004

Wang S. W. & Xie, J. L., (2002), Integrating Building Management System and Facilities Management on the Internet. *Automation in Construction.* Vol. 11. No. 6. pp 707-715

Watson I. and Brandon P. (1992). Strategic Maintenance Prediction: An expert system for Facilities Managers. *Facilities Management: Research Direction.* Edited by Peter Barrett. Salford: University of Salford pp 225-237

Wiig, K.M. (1997), Roles of Knowledge-Based Systems in Support of Knowledge Management, in Liebowitz, J. and Wilcox, L.C. (ed.), *Knowledge Management and Its Integrative Elements*, Florida: CRC Press LLC.

Willmott Dixon Plc. (2000). Interview with Mr. Daren Murphy. 16 January. 2001

Wilson, T.D. (2000). Recent Trends in User Studies: Action Research and Qualitative Methods. *Information Research.* Vol. 5. No. 3. http://informationr.net/ir/5-3/paper76.html 30 Jan 2004

Winegardner K.E. (online). *The Case Study Method of Scholarly Research.* The Graduate School of America. https://cpub.brown.edu:8543/cpubsh/Raymond_Hyatt-SO0105_S02/materialadd2.pdf. (view as html). 22 March 2001.

Wordsworth P. (2001). *Lee's Building Maintenance Management.* 4th Edition. Oxford: Blackwell

Yin, Robert K. (2003a). *Applications of Case Study Research.* 2nd ed. London: SAGE Publications.

Yin, R. (2003b). *Case Study Research: Design and Methods.* 3rd ed. Newbury Park, California: SAGE Publications.

Yu B. and Wright D.T. (1997). Software Tools Supporting Business Process Analysis and Modelling. *Business Process Management Journal.* Vol. 3. No. 2. pp. 133-150.