Chapter 4
RESEARCH METHODOLOGY

4.1 Introduction

This chapter describes the methodology and methods adopted for this research. It starts by providing an introduction to general research methodologies followed by reviews of different approaches in Information Systems (IS) and Construction IT researches. The methodologies adopted for various stages of this research are then presented and justified.

The contents of this chapter are as follows. Section 4.2 presents a general overview of the research concept and methodology. The research philosophy and approach are briefly discussed in sections 4.3 and 4.4 respectively. Techniques available for the chosen research approach are also discussed. Section 4.8 explains the methodology adopted for this research.

4.2 Research and Research Methodology

Referring to English dictionaries (Chambers 21st Century Dictionary, 1999; Cambridge Advanced Learner's Dictionary, 2006; Concise Oxford English Dictionary, 2006), research can be defined as *a detailed and systematic investigation into a subject to establish facts or discover new information*. According to Greenfield (1996), research is an art aided by skills of inquiry, experimental design, data collection, measurement and analysis, by interpretation and by presentation.

There are two different types of research namely pure and applied research (Fellows and Liu, 2003). Pure research is undertaken to develop knowledge and to contribute to the body of theory which exists; while applied research seeks to address issues of applications, to help solve a practical problem. Typically, research involves solving either a close-ended or an open-ended problem. Close-ended problems are simple problems each with a correct solution. The existence of the problem, its nature and the variables involved can be
identified easily. In contrast, open-ended problems tend to be complex. The existence of the problem may be difficult to identify, the situation is likely to be dynamic and the variables are difficult to isolate.

Research methodology refers to the principles and procedures of logical thought that are applied to a specific investigation (Klein and Myers, 1999; Fellows and Liu, 2003). The ‘nested’ research methodology introduced by Kagioglou et al. (2000) provides a holistic and integrated research method. Fig. 4-1 illustrates how the research philosophy, approaches and techniques are interrelated. The research philosophy created by the outer box guides and energises the inner research approaches and techniques. The research approaches incorporate qualitative and quantitative methods. Research techniques consist of data collection tools such as literature review, interview, questionnaire survey, experiment, observation and workshop.

![Fig. 4-1: Nested Research Methodology (reproduced from Kagioglou et al., 2000)](image)

### 4.3 Research Philosophy

According to Bryman (2012), there are two main philosophical schools of thought in social research: ontological and epistemological. Ontology involves the logical investigation of the different ways in which different types of things are thought to exist and the nature of the various kinds of existences. On the other hand, epistemology deals with question of knowledge acceptability in a discipline and the methods through which knowledge is acquired. In simple terms, ontology, epistemology and methodology are the studies of what, why and how of a research project.
4.4 Research Approach

A research approach is a way of unfolding a specific style and employment of different methods in doing research. It is also being referred to as a research strategy by some authors such as Naoum (2007), who stated that the research strategy is a way in which the research objectives can be questioned. It is a strategy of enquiries which moves from philosophical assumptions to research design and data collection (Myers, 1997). The research approach or strategy can be categorised in various ways. One of the most common categorisations is quantitative, qualitative or a combination of both methods – called triangulation or mixed research methods (Fellows and Liu, 2003; Neuman, 2006). Many research projects use more than one method. The reasons for combining methods are to capitalise on the strengths of the approaches and to compensate for any weaknesses encountered (Love et al., 2002). However, the decision on which type of research strategy to follow depends on the purpose of the study and the type and availability of the information which is required (Naoum, 2007). The following sub-sections briefly review the characteristics of the quantitative, qualitative and triangulation research methods.

4.4.1 Quantitative Research

The quantitative research method is about gathering factual data and studying relationships between facts in order to find out how these relationships agree with theories of previous research findings. This approach adopts a ‘scientific method’ in which the initial study of theory and literature yields precise aims and objectives with hypotheses to be tested (Fellows and Liu, 2003). It uses empirical approaches including laboratory experiments, survey methods, formal methods (e.g. econometric) and numerical methods such as mathematical modelling (Myers, 1997). The main strengths of quantitative research methods lie in precision and control. The samples collected from quantitative research are often large and representative, hence the results can be generalised to the larger population within acceptable error limits (Bryman, 2012).

Some of the most common quantitative research techniques include experimental, surveys, co-relational and descriptive researches. Co-relational and descriptive researches are briefly explained below, whilst the rest are described in section 4.5.
Co-relational Research

The co-relation is a measure of the strength of the relationship between two variables (Bryman and Bell, 2007). This type of research examines the nature of the relationship between variables such as simple (statistical methods that yield a single number), predictive (improve capacity to anticipate events) and modelling (path analysis, graphical maps) (Locke et al., 1998).

Descriptive Research

The descriptive research method systematically identifies and records a phenomenon, process or system. Identification and recording is usually done from a particular perspective and often for a specified purpose (Fellows and Liu, 2003). Such research is commonly carried out to enable the subject matter to be categorised.

4.4.2 Qualitative Research

The qualitative research method originates from the social sciences to enable researchers to study social and cultural phenomena. Qualitative research seeks to understand how people see and interact with the world (Fellows and Liu, 2003). It is an exploration of the subject undertaken without prior formulations – the objective is to gain understanding and collect information and data such that theories will emerge (Fellows and Liu, 2003). It is, therefore, ‘subjective’ in nature and consists of “detailed descriptions of situations, events, people, interactions and observed behaviour” (Patton, 2001). Naturalistic observation, case study, ethnography and narrative report are tools used for qualitative research (Linn and Erickson, 1990; Myers, 1997).

The analysis of qualitative data is more difficult than quantitative data, requiring a lot of filtering, sorting and other manipulations to prepare them for analytical techniques (Fellows and Liu, 2003). The information gathered in qualitative research can be classified under two categories, namely exploratory and attitudinal researches (Naoum, 2007), described below:
Exploratory Research

Exploratory research is conducted for three interrelated purposes: diagnosing a situation, screening alternatives and discovering new ideas (Zikmund, 1997). A central feature of this type of research is the use of a hypothesis. Either a hypothesis is set up and then tested via research (data collection, analysis and interpretation of results) or a complex array of variables is identified and hypotheses are produced to be tested by further research (Fellows and Liu, 2003).

Attitudinal Research

Attitudinal research is used to subjectively evaluate the opinion, view or the perception of a person towards a particular object. The term ‘object’ refers to an ‘attribute’, a ‘variable’, a ‘factor’ or a ‘question’ (Naoum, 2007).

The other types of qualitative research such as the case study and action researches are discussed in section 4.5

4.4.3 Comparison of Qualitative and Quantitative Methods

The distinction between qualitative and quantitative research is not very clearly defined because it is almost simultaneously regarded by some authors as a fundamental contrast and by others as no longer useful or even simply as ‘false’ (Layder, 1993). For instance, it is possible to take a quantitative approach to many issues that are qualitative in nature (Moore, 2000). Similarly, several qualitative decisions should be made when using quantitative methods (e.g. the questions to pose, the design to implement, the measures to use, the analytical procedures to employ and the interpretations to stress) (Linn and Erickson, 1990). Table 4-1 presents a summary of the key features of quantitative and qualitative research. The key difference between the two approaches is that the quantitative research focuses on quantifying data, while the qualitative methods focus on gaining an understanding of underlying attitudes and measurements.
Table 4-1: Comparison of quantitative and qualitative research
(Adapted from Bryman and Bell (2003); Neuman (2006); (Naoum, 2007))

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Quantitative Research</th>
<th>Qualitative Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role</td>
<td>Fact-finding based on evidence or records</td>
<td>Attitude measurement based on opinions, views and perception measurement</td>
</tr>
<tr>
<td>Nature</td>
<td>Soft-science</td>
<td>Hard-science</td>
</tr>
<tr>
<td>Sample/Cases</td>
<td>Large in number, representative of the population and based on randomly selected respondents/samples</td>
<td>Small in number, non-representative of population and respondents selected to fulfil a given requirement</td>
</tr>
<tr>
<td>Data collection</td>
<td>Structured Questionnaires/Experiments</td>
<td>Unstructured or semi-structured interviews</td>
</tr>
<tr>
<td>Nature of data</td>
<td>Hard and reliable</td>
<td>Rich and deep</td>
</tr>
<tr>
<td>Data analysis</td>
<td>Statistical</td>
<td>Thematic</td>
</tr>
<tr>
<td>Role of theory in relation to research</td>
<td>Deductive; testing of theory</td>
<td>Inductive; generation of theory</td>
</tr>
<tr>
<td>Relationship between researcher and subject</td>
<td>Distant</td>
<td>Close</td>
</tr>
<tr>
<td>Relationship between theory/concepts and research</td>
<td>Testing/confirmation</td>
<td>Emergent/development</td>
</tr>
<tr>
<td>Outcome</td>
<td>Findings are conclusive, can be generalised and used to recommend a final course of action</td>
<td>Findings are not conclusive, cannot be generalised and usually exploratory and/or investigative</td>
</tr>
</tbody>
</table>

4.4.4 Triangulation Research

Triangulation involves the use of a mixture of quantitative and qualitative research tools. Although some scholars insist that either a quantitative or qualitative research approach should be used, a combination of research approaches has proven to be effective in many cases depending on the research objectives (Lee, 1991; Cavaye, 2008). The combination offers a multi-dimensional view of the subject obtained through synergy. Thus it can be very powerful to achieve insights and results to assist in making inferences and in drawing conclusions (Fellows and Liu, 2003). Triangulation also gives an added dimension and adds considerable value to the research results, providing both breadth and depth (Moore, 2000).

Typically, the triangulation process involves corroborating evidence from different sources to shed light on a theme or perspectives (Creswell, 1998). According to Fellows and Liu
(2003), as triangulated studies employ two or more research techniques, qualitative and quantitative approaches may be employed to reduce or eliminate the disadvantages of each individual approach whilst gaining the advantages of each. Quantitative data can help with the qualitative side of a study during design by finding a representative sample and locating deviant samples, while qualitative data can help the quantitative side of the study during design by aiding with conceptual development and instrumentation (Amaratunga et al., 2002).

According to Bowen (1996), there are two main categories in triangulation: simultaneous triangulation and sequential triangulation. Simultaneous triangulation uses both qualitative and quantitative methods at the same time, whereas sequential triangulation refers to the use of one method to plan the next method (i.e. both quantitative and qualitative methods are employed within one and the same study), although in different phases of the research process.

According to Easterby-Smith et al. (2002), there are four distinct categories of triangulation involving the theoretical, data, investigator and methodology triangulation as follows:

- **Theoretical triangulation** – involves borrowing models from one discipline and using them to explain situations in another discipline
- **Data triangulation** – refers to research where data are collected over different time frames or from different sources
- **Investigator triangulation** – is where different people collect data on the same situation and the results are then compared
- **Methodological triangulation** – involves using both quantitative as well as qualitative methods of data collection such as questionnaire, interview, telephone survey and field study.

### 4.5 Approaches in Information Systems Research

Information system (IS) research is an exploration of research approaches suitable for studying the impact of information and communication technologies on groups, on organisations, between organisations, on market and on society worldwide (Galliers et al.,
2007). There has been a general shift in IS research away from the technological to managerial and organisational issues, hence there has been an increasing interest in the application of qualitative research methods (Myers, 1997). Specific research methods imply different skills, assumptions and research practices. Galliers et al. (2007) identified various research approaches in the study of IS. The approach to be adopted for conducting IS research depends on the type of investigation, data and information that are required and available (Naoum, 2007). These approaches and their typical application in IS research are discussed in the following sub-sections.

### 4.5.1 Action Research

An action research involves active participation by the researcher in the process under study in order to identify, promote and evaluate problems and potential solutions (Fellows et al., 2003). It aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework (Gill and Johnson, 2002).

According to Eden and Huxham (2005), good and effective action research should have the following outcomes:

- It should have implications that relate to situations other than the one that is studied
- It should be concerned with theory as well as being usable in everyday life
- It should lead to the generation of emergent theory
- It should have practical implications.

One of the key advantages of the action research is that the researcher’s bias is made overt when undertaking the research (White, 1985). Action research also places a great deal of responsibility on the researcher who must be aware that in certain circumstances he/she is aligning him/herself with a particular grouping whose objectives may well be at variance with other groupings (Galliers et al., 2007).

### 4.5.2 The Survey Approach

Surveys are used to gather data from a relatively large number of respondents within a limited time frame. It is thus concerned with a generalised result when data is abstracted
from a particular sample or population (Naoum, 2007). Commonly, samples are surveyed through questionnaires or interviews and they vary from highly structured questionnaires to unstructured interviews. The selection of data collection method is important because it affects the quality and cost of the data and avoids interviewer bias, but the researcher cannot control the conditions under which a questionnaire is completed. In general, an interview survey is more capable of obtaining quality data compared to a questionnaire survey. In term of cost, the questionnaire survey is cheaper. However, in terms of time, web-based surveys over the Internet or by e-mail are very fast and inexpensive and they allow a flexibility of design that can also use visual images and even audio or video in some internet versions.

According to Naoum (2007), there are two types of survey:

- **The descriptive survey** – aims to answer such questions as: How?, How many?, Who?, What is happening?, Where?, and When?. It deals with counting the number of respondents with certain opinions/attitudes towards a specific object.
- **The analytical survey** – aims to establish relationships and associations between the attributes and objects of the questionnaire.

The key advantage of the survey approach is that a greater number of variables may be studied compared to the experimental approach. The key disadvantage is that little insight is usually obtained regarding the causes or the processes behind the phenomenon being studied.

**4.5.3 The Case Study Approach**

Yin (2003) defined a case study as empirical inquiry based on observable evidence that investigates a phenomenon in a natural setting when the boundaries between the phenomenon and its context are not clear, using multiple sources of evidence. Its defining feature is the exploration of complex real-life interactions as a composite whole. According to Weiss (1998), a case study is a way of organising data so as to keep the focus on totality. One who conducts case studies tries to consider the interrelationships among people, institutions, events and beliefs. Rather than breaking them down into separate items for analysis, the researcher seeks to keep all elements of the situation in sight at once.
The strength of case studies lies in the fact that they allow for covering a large amount of ground for an acceptable cost (Fellows and Liu, 2003). In addition, it provides a means of looking in-depth at complex problems. Case studies can also help in achieving greater realism in the research. A key weakness of the case study method is that data collection and analysis process may be influenced by the researcher’s interpretation of events, documents and interviews (Drake et al., 1998).

The case study research is appropriate when addressing the ‘how’ and ‘why’ questions (Yin, 2003). Case studies are useful for revealing the details of a phenomenon, in particular the relationship between the phenomenon and its context. According to Naoum (2007), there are three types of case study design:

- **The descriptive case study** – This is similar to the concept of the descriptive survey (i.e. counting), except it is applied to detailed case(s).

- **The analytical case study** – This is similar to the concept of the analytical survey (i.e. counting, association and relationship) except it is applied to detailed case(s).

- **The exploratory case study** – This is the theoretical approach to a problem. It explains causality and tries to show linkages among the objects of the study. It asks why things happen the way they do. In other words, the researcher collects facts and studies the relationship between them.

### 4.5.4 Future Research

In this kind of research, different scenarios or futures are postulated and the different impacts of IT and IS are identified given these different situations (Galliers et al., 2007). Table 4-2 summarises various approaches to the design of future research.

**Table 4-2: Research Methods for Future Studies**
(adapted from Glenn and Gordon (2003); Galliers et al. (2007))

<table>
<thead>
<tr>
<th>Research Method</th>
<th>Description</th>
<th>Typical Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future Extrapolation</td>
<td>This method is based on the belief that the future represents a logical extension of the past</td>
<td>Trend Analysis, Time Series, Regression, Econometrics and Simulation Modelling</td>
</tr>
<tr>
<td>Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploratory Method</td>
<td>This method concentrates on structuring possible futures, typically using qualitative descriptions</td>
<td>Morphological Analysis, Relevance Trees, Mind-mapping and Future Wheel</td>
</tr>
</tbody>
</table>
Participatory Method | This method is based on expert and stakeholder opinions and insights about the future | Delphi Technique, Scanning, Focus Groups, Future Search Conferences
---|---|---
Future Modelling | This method describes the future by identifying the determining mechanisms of past events and how these influence the future | Analogy Analysis, Technological Sequence Analysis, Stakeholder Analysis and Structural Analysis
Scenario Planning Method | A key assumption is that the future is essentially unpredictable. Considering the uncertainties included in the future, modelling will not lead into one future but rather to many different futures, each of which may be described in the form of a scenario | Scenario method combines aspects of other tools with the aims of creating several scenarios
Normative Method | This method investigates how we want the future to be and how to obtain this goal | Typical method is back-casting. Objectives that are very discontinuous from the present trends are defined and then the normative method moves backwards to the present to identify the necessary steps for reaching these objectives

4.5.5 Longitudinal Studies

Longitudinal studies involve repeated measures on the same variables for the same group or groups on an extended series of occasions (Robson, 2002). Babbie (2001) defined three types of longitudinal studies which include:

- Trend Studies – examines changes within some general population over time
- Cohort Studies – examines more specific sub-populations over time
- Panel Studies – examines the same set of people over time.

Longitudinal research uses two types of time design (Fellows and Liu, 2003): discrete time design (in which cross-sectional data are collected on two or more occasions) and continuous time design (in which data are collected ‘continuously’ over a period). Quantitative methods of undertaking longitudinal research include social survey research (on a sample on more than one occasion) or content analysis of documents relating to different time periods. Qualitative methods of undertaking longitudinal research include ethnographic research over a long period, qualitative interviewing on more than one occasion or qualitative content analysis of documents relating to different time periods (Bryman and Bell, 2007).
4.5.6 Phenomenological Studies

Leedy and Ormrod (2004) defined phenomenological study as a study that attempts to understand people’s perceptions, perspectives and understanding of a particular situation. It is a research method in which human experiences are examined through detailed descriptions provided by the people being studied (Creswell, 1998).

The key focus is on the subjective experience of the individuals studied. The key advantages of this approach include:

- It recognises the fact that the researcher will interpret what is being studied in a particular way.
- It provides a means of describing the inter-relationship of many factors found in real-life.

The key disadvantage of this approach is that despite making the prejudice of the researcher known, it could still cloud the interpretation of reality and thus make the research conclusions subjective (Galliers et al., 2007).

4.5.7 Experimental Research

The experimental research method is best suited to known problems where the variables involved are identified or hypothesised with some confidence (Fellows and Liu, 2003). There are two approaches to the experimental research: laboratory experiments and field experiments. The laboratory experiment takes place in a laboratory or in a contrived setting, whereas field experiments occur in real-life settings such as in classrooms and organisations (Bryman and Bell, 2007). The key advantage of experimental research is that the researcher is able to isolate and control a small number of variables that may then be studied in more depth. The major weakness is the limited extent to which the identified relationships exist in the real world. Also, in the experimental research, there are difficulties in finding organisations or groups of people prepared to be experimented upon.
4.6 Approaches in Construction Information Technology

According to Fellows and Liu (2003), the research methods which are most applicable to construction research include action research, survey, case study, experiment and ethnographic research. However, in the past decade, the number and complexity of research methods available to construction researchers have increased sharply, particularly with the advent of IT focused research within the construction domain. Where only a few forms of inquiry were available (and acceptable within the scientific domain) previously, many options now exist (Kimmance, 2002). This proliferation allows for a wider choice to the researcher and better matching of the research tools to the demands of the research questions.

It is also important to realise that research in Construction IT differs from the study of IT as a purely technical phenomenon (Whyte, 2000). In Construction IT, the focus is not merely on technology. Issues with regards to appropriateness of the technology for various cultural and social factors specific to the construction industry should also be taken into account. In a review, Leslie (1996) critiqued that construction researchers see only the positive side of hard methodology approaches without taking into consideration the complexity of IT applications. They concentrate their researches on technical aspects forgetting how IT can be accepted and used by construction practitioners. This results in poor alignment of the technology with the construction industry’s needs. In light of the previous discussion, this research takes both the technology and application perspectives (explained in more detail in section 4.8) to ensure that technology is rightly aligned to the needs of the industry.

4.7 Scenario Planning Method

Scenario planning is considered to be an important strategic planning tool that can be used to identify risk, uncertainty and opportunity of the future proposed strategy or system (Ogilvy and Schwartz, 2006; Heijden, 2008). It is important to appreciate that scenario planning is not a prediction tool but it is an exercise that is oriented towards developing plots about some time in the future, perhaps ten or more years ahead (Drinkwater, 2003). Chermack (2004) described scenarios as narrative stories of the future that outline several possible paths through various challenges to arrive at varying future states. Likewise,
according to Ogilvy and Schwartz (2006), scenarios are descriptions of possible or probable futures. They are a vehicle for envisioning where the world could go so that we can learn in time to do something different. They are not projections, predictions or preferences. Rather they are coherent and credible stories, describing different paths that lead to the alternative futures (Davis, 2002). The underpinning philosophy of scenario planning method is that the future cannot be foreseen, but that some of the forces that will shape the future can (Heijden, 2008). When these driving forces are identified and some of the ways they are likely to interact and affect other key variables are considered, then futures built by intuition and logic can be constructed (Verity, 2000). Thus scenario planning facilitates thinking about the future so that informed decisions can be made in the present.

The scenario planning is not a single well-defined methodology but rather a set of principles for strategic analysis and planning that may be applied using a combination of various qualitative and quantitative research methods and techniques (Sideris, 2002). Disciplines and practices that have influenced scenario planning include mental models, cognitive mapping, systems analysis, stakeholder analysis, conceptual thinking, decision analysis, facilitation techniques, oral tradition and storytelling (Davis, 2002).

The main generic steps in developing scenarios can be referred to Drinkwater (2003), Wilkinson (2006), Ogilvy and Schwartz (2006) and Godet (2001). The scenario planning method developed by Godet (2001) called the Structural Scenario Method is primarily driven by formal techniques, which are employed to reveal hidden relationships between variables, actors and hypotheses. Whereas, the approach by Ogilvy and Schwartz (2006) is more informal: based on the key factors, the driving forces and the alternative visions gathered by a team of experts.

### 4.8 Research Methods Adopted

This section discusses the methodologies adopted for the research in order to achieve the aim and specific research objectives. Figure 4-2 illustrates the key steps in the research process, while Table 4-3 presents the tools used in various research steps. These are discussed in more detail in the following sections.
Context-Aware Services Delivery in the Construction Supply Chain

Fig. 4-2: Key research steps
Table 4.3: Tools used in various research tasks

<table>
<thead>
<tr>
<th>Research Tools</th>
<th>Technology and Literature Review</th>
<th>Survey and Case Study</th>
<th>Scenario Generation</th>
<th>Scenario Validation</th>
<th>Context Modelling</th>
<th>System Design</th>
<th>Prototype Development</th>
<th>Prototype Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Document Analysis</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Structured Interviews / Questionnaire</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Scenario Planning Method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity Theory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Context Tool-Kit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid Prototyping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

4.8.1 Technology and Literature Review

An essential early stage of virtually all research is to search for and to examine potentially relevant theory and literature (Fellows and Liu, 2003). Theory and literature are the results of previous research projects. Theory is the established principles and laws (such as Einstein’s theory of relativity). Literature in this context, concerns findings from research which have not attained the status of theory; often it represents findings from research into particular applications of theory. A literature review is based on the assumption that knowledge accumulates and that people learn from and build on what others have done (Neuman, 2006).

According to Neuman (2006), there are four main goals of the literature review:

- To demonstrate a familiarity with a body of knowledge and establish credibility
- To show the path of prior research and how a current project is linked to it
- To integrate and summarise what is known in an area
- To learn from others and stimulate new ideas

In order to address the first and second objectives of the research, technology and literature reviews involved a state-of-the-art developments and trends in context-aware computing.
and construction supply chain. Primary data were sourced from academic journals, conference proceedings, articles, books and from various on-going researches. These are summarised and presented in Chapters 2 and 3. The technology and literature reviews were based on ‘personal document analysis’, a qualitative analysis approach to review and analyse current theories and literature (Keppel, 1991; Dainty et al., 1997). The technology and literature reviews also addressed “how” and “why” questions related to the relevance of various digital technologies to support context-aware application in construction.

4.8.2 Survey

The survey method was adopted to learn the magnitude of which information and communication technologies are being used at construction sites and investigate the construction industry’s readiness to adopt new technology. This method was chosen because it provided an opportunity to discuss key topics with the construction practitioners. It is an appropriate method to discover the current construction practices and to gather their opinions regarding technology. The questionnaire was designed objectively to investigate the level of acceptance of using wireless communication network technology in improving logistics services within the construction supply chain network as a whole and the magnitude of which technology was being used at construction sites. Relevant questions relating to the use of communication and information tools, construction logistics services and digital technologies were developed utilising both closed questions and open-ended questions. For close-ended questions, a five-point Lickert scale was used (e.g. 1 – unnecessary, 2 – somewhat unnecessary, 3 – neutral, 4 – recommended, and 5 – strongly recommended). Closed-ended questions limit the respondents’ answers to the survey and allow more questions to be answered, while open-ended questions give freedom to respondents to give recommendations for improvement and address certain issues. Chapter 5 further elaborates on the survey method and presents the findings from the survey.

4.8.3 Case Studies

Case studies were adopted to investigate the current industrial practice in construction logistics management for the purpose of generating scenarios for future construction supply chain. They were also essential in identifying key problem areas, the approaches to address these problems, how ICT was being used in project management processes and
how these could improve problems in logistics management on site. Site logistics was chosen as it is the backbone of construction supply chain. The case study results had also been used to establish the needs for developing context-aware application in the construction supply chain.

**Multiple Case Studies**

Multiple case studies approach was used in this research to investigate contemporary phenomena within six construction projects. This involved the comparison of current practices of logistics services management between six construction projects to establish key problem areas and examine the implementation of ICT in logistics services management processes and the potential of digital technologies (such as Wi-Fi tags and PDA) in logistics services management in construction projects. The needs for developing context-aware application in the construction supply chain were also investigated.

**Defining the unit of analysis**

The selection of the ‘unit of analysis’ adopted for the case studies can be referred to in Chapter 5.

**Case selection**

According to Creswell (1998), a case is defined by the setting of the project, the people who manage the project, the events that occur and the processes that develop over the project. Six construction projects were selected based on the following criteria:

- Adequate access to explore the relevant logistics management issues to be investigated.
- The willingness of organisation’s individuals to participate and share their experience in managing logistics on the construction site.

**Data collection**

Data were collected by interviewing the project or logistics manager in each project. A set of questions were designed as a tool to gather opinions and responses from the managers about current problems and aspects that needed to be improved in logistics management of
construction projects. The questions were organised under broad headings including: key problems in site logistics management practices, approach to addressing problems, information and communication tools, digital technologies and logistics management system.

**Data analysis**

Analysis of the collected data involved both single case and cross-case analysis. Single case analysis produced individual case reports and cross-case analysis made a comparison of the ‘embedded unit of analysis’ across the cases. The results were used to generate realistic scenarios to support the development of context-aware application for managing construction supply chain.

**Interview Technique**

Interviews lasted from two to three hours, which included face-to-face interview session and site visit to observe the logistics activities which mainly involves materials delivery, handling and storage. Semi-structured interviews allow the interviewer freedom to explore the expert’s views or opinions while maintaining a level of comparability between interviewees. The interviews consisted of three parts. Part 1 aimed to capture the general information about the site managers and the project that they were in charge of. Part 2 aimed to look at the current problems and ICT implementation in logistics management practices and Part 3 aimed to investigate the needs for context-aware application for logistics management. Interview questions were designed to facilitate opinions and responses from the experts.

The case study method was chosen to gain insight into the current practices in managing site logistics in different projects to discover the common traits shared by them. It is suitable for learning about little known situations and it afforded an opportunity to investigate and achieve deeper insights into the areas examined. The case study method had been used by Kasim (2007) to study the material management practices for the purpose of developing a real-time materials tracking system which is a lot similar to this research. The case studies and their findings are presented in Chapter 5.
4.8.4 Scenario Planning Method

The encompassing theme of this research is the emerging field of context-aware computing and its future applications for the construction industry. From this viewpoint, various Future Research methods (as discussed in section 4.5.4) are considered to be very relevant to achieve the research objectives (as presented in Chapter 1). Of the various future research methods discussed in Table 4-2, scenario planning and participatory methods are considered to be the most relevant for this research. The emerging nature of context-aware technology and the huge amount of uncertainties with regards to its application in the construction industry (such as application scenarios, business models, technology robustness, interoperability and costs) undermine the basic assumption of the future extrapolation method (i.e. the future represents a logical extension of the past) and future modelling method (i.e. the future can be modelled based on the events of the past). Due to the high level of uncertainties involved with regard to context-aware technology applications in the construction industry, this research effort relies on the scenario planning assumption that there is no single best answer since the future is uncertain and unpredictable (Heijden, 2008). The scenario planning method is considered to be the most appropriate for uncertain, complex and fast developing situations where the future cannot be predicted accurately enough to identify a single forecast and it cannot be reasonably expected to be a continuation of present and past trends (Dyson, 1990; Godet, 2001). Also, scenarios are known to offer greater advantages over other forecasting methods when uncertainty is high and historical relationships shaky (Fahey and Randall, 1998). The key disadvantage of scenario planning approach is that developing initial set of scenarios is a lengthy and time consuming process. The scenario planning method has been previously discussed in section 4.7. Participatory methods (as described in Table 4-2) are also considered relevant for this research because it is important to have the construction industry experts’ and end-users’ perspectives and insights about future context-aware services delivery.

**Justification for Adopting Scenario Planning Method**

This research adopted the scenario planning method as the basis for understanding user needs and for system design. This section explains different reasons for choosing scenario planning methods for this research:
Scenarios open up new areas of thinking: Telling stories have always been considered a good way to get a group of people to think “out of the box” and to synthesise their inspiration and experience into a logical whole. A key assumption in scenario planning is that there is no single best answer but a broad space of future possibilities (Heijden, 2008). Unlike forecasts, which box-in the-future, scenarios open up new areas of thinking and perspectives so that the whole exercise can also be seen as one of stimulating creative foresight, even if no one scenario applies perfectly (Sideris, 2002).

Scenario planning is suited for complex and uncertain situations: One key challenge facing this research is the fast pace of technological development and the complexity of context-aware wireless Web applications. Scenario planning is particularly well suited to address high levels of complexity and uncertainty (Dyson, 1990). According to Schoemaker (1995) in the study of emerging technologies, there are three particular challenges: uncertainty, complexity and paradigm shift that can hardly be answered by other forecasting techniques.

It is easy to communicate a scenario: A context-aware service is a multi-disciplinary product of research from different fields including computer science, telecommunications, system design and ergonomics. Very often, different disciplines involved in the value chain (e.g. technology providers and end-users) use different terminologies and often ideas are not well understood by end-users. The construction industry experts have the most comprehensive knowledge about the construction industry dynamics (i.e. the construction industry pull). However, as a result of increasing the convergence and greater pace of technology growth, it is possible that these experts are not fully aware of the possibilities offered by emerging and converging technologies (i.e. the technology push). In order to investigate future context-aware services for the construction industry, it is important to have a deeper understanding of both the technology push and the industry pull, as the industry pull will define whether a technology push will succeed or not. For these reasons, visual description of technology implementation scenarios in real construction situations were chosen as the best method to test scenarios with industry experts at an early stage, prior to the system development.
• **Appropriate for use in the system development process:** Scenarios can be very effectively used in the system development process for many purposes (Weidenhaupt et al., 1998). These include:
  - To provide a long-range vision that stimulates ideas and directs short range goals
  - To focus the development perspectives on the users’ point of view
  - To provoke and capture design decisions
  - To involve users in design decisions and requirements analysis
  - To validate the system specification and requirements analysis
  - To serve as trial and evaluation experiments.

In this research scenarios were used to study the construction industry’s needs and as a key input to system design process.

• **Previous applications in similar research:** Previously, scenario planning techniques had successfully been used in future study exercises in mobile computing and their use is recommended for research in this area (Sideris, 2002). Aziz (2005) adopted scenario planning technique in his research to study the potential of context-aware application for construction mobile workers. Some of the other previous projects in the realm of mobile computing, which had employed scenario planning are described as below:
  - In the MobiCom Project, scenario planning techniques were used to develop scenarios for Mobile Commerce in 2006 (Aarnio et al., 2002).
  - In the 4GW project (Karlson et al., 2003), scenario techniques were used for studying next generation wireless applications.
  - In Telecom 2010 (Flament et al., 1998) scenarios were created to generate awareness of plausible futures and to identify reasonable research assumptions.

The application of the scenario planning method in the above projects also demonstrated the applicability of research methodology for mobile IT research.
Scenario Generation Process

Several methods for scenario generation have been suggested by different authors and there is no single way of constructing a scenario nor can the same method be applied similarly in all cases (Masini and Vasquez, 2000). The scenario generation method used in this research is mostly based on the works of Ogilvy and Schwartz (2006). The first step in the scenario generation approach is to identify the factors and trends that will influence the future. As identified by Fahey and Randall (1998), the identification of the key factors and trends can generally be done in two ways:

- **Future Forward Method**: This approach is based on the future extrapolation methods. Based on the events of past and present, the future is modelled.
- **Future Backward Method**: This involves imagining the future or aspects of the future and then deducing the underlying factors or forces driving that development.

For this research, the “Future Backward Method” was chosen. There were essentially two reasons for choosing this method. Firstly, given the emerging nature of context-aware computing research, it was not possible to develop future scenarios based on the existing applications. Secondly, the “Future Backward Method” allows more room for creativity and visionary thinking. Cole et al. (1978) described three possible sources of the initial set of scenarios:

- **Analyst Input**: The analyst doing the study generates the scenarios based on their experience and research.
- **Expert Input**: Expert informants contacted by the analyst contribute ideas in various ways such as via free-form discussions, interviews, Delphi procedures, workshops, or other techniques.
- **Analyst and Expert Input**: This method combines both analyst and expert informant input.

The third method (analyst and expert input) was adapted for this research. The aim was to use previous scientific research as a basis for scenario generation process. The literature reviews (Chapters 2 and 3) were used to systematically gather information about the state-of-the-art in context-aware computing and construction supply chain. Lessons learned from
the case study interviews with construction experts were also used to help shape the scenarios. Also, previously published literatures with regards to information requirements of mobile construction workers were reviewed. Thus, a combination of analyst and expert input and the study of context-aware computing and construction supply chain (presented in Chapters 2 and 3) were used to develop realistic construction scenarios, in which the capabilities of various technologies were mapped to the needs of construction supply chain services delivery.

In this study, four different scenarios were generated to reflect the actual CSC activities and services. They are as follows:

- **Construction Logistics Supply and Delivery Services** – to demonstrate the activity among CSC partners in the delivery of a product and services according to project work schedule.
- **Materials Supplier Search Services** – to demonstrate the context-aware application in procurement activity to secure component or product and services from substitute suppliers. This case also involves B2B (Business to Business) in assisting to manage the complexity of procurement process.
- **Design, Planning and Project Management Collaboration Services** – to demonstrate the capability of context-aware application in supporting collaboration activity in construction that consists of tasks such as information sharing, design and engineering planning and collaborative decision making.
- **Business to Business (B2B)** – to demonstrate the capability of context-aware application in executing materials quotation search from a number of suppliers and specialist contractors to solve a new building design issue.

The time horizon chosen for the scenarios is ten years. This time frame is considered realistic due to the following reasons:

- The existing uncertainties involved with various enabling technologies (such as the Semantic Web, Web Services and Mobile Communications).
- Existing infrastructure is insufficient.
- Time is needed to diffuse the technological innovations and convince industry to adopt new technology.
- Context-aware software does not support the full CSC activities.

This long term focus is also important to ensure that the industry takes the right steps, in the short term, to develop the required infrastructure and effectively adapt to the emerging technologies, in the long term. The scenario planning process together with the generated scenarios are presented in Chapter 6.

4.8.5 Scenario Validation

In order to have a more credible and concrete validation of scenarios and to elicit different perspectives, interviews were conducted with industry experts. The key objective of scenario validation was to pose the question of the next generation context-aware mobile applications in the construction sector and to identify the industry’s needs and application areas with the maximum potential. For validation purposes, face-to-face loosely structured interviews were arranged with several industry experts. Section 6.5 further elaborates on the scenario validation method.

4.8.6 Context Modelling

Contexts associated with the scenarios generated in Chapter 6 were modelled using Engeström’s Activity Theory tool. The development of context models involved the process of mapping and classifying contexts that are relevant to CSC activities. The outcomes from the context models are database schemas to represent services to be provided by the proposed context-aware applications for CSC. Activity theory has been discussed in Chapter 3 and the justifications for adopting the Activity Theory method for context classification and modelling have been given in section 3.5. The application of Activity Theory in modelling contexts is explained in detail in Chapter 7.

4.8.7 System Design

important elements for developing context-aware system that can be used as models towards building a comprehensive context-aware system framework. The context-aware architecture framework was designed by extending Dey’s (2000) Context Toolkit and integrating it with WASP (Web Architecture for Services Platform). The process for system architecture framework design and context-aware information system conceptual model are discussed and presented in Chapter 8.

4.8.8 Prototype Development

A prototype is an approximation of a system that exhibits the essential features of the final version of the system (Avison and Fitzgerald, 2002). The prototyping method was formally introduced to the information systems community in the early 1980s. The early prototyping process was for the developers to design and build a scaled-down functional model of a desired system, which allows the developer to demonstrate the working model to the user. This results in comments and feedback on its suitability and effectiveness. Then, the developer continues to develop the prototype based on the feedback received until both the developer and user agree that the prototype is satisfactory. The prototyping method has gained its popularity because of its ability to capture user requirements in concrete form. In fact, the method is often used for designing decision-support systems when neither the decision maker nor the system designer understands the information requirements well. It is often used along with traditional system development methods to speed up the system development process.

Prototyping is an aid to designing a context-aware information system. It is particularly useful in this research because:

- The application area (mobile context-aware computing and construction supply chain) is not well defined in the industry.
- The organisation is not familiar with the technology (hardware, software, network, communications and designs) required for the application.
- The communications between researcher and users are limited and of indifferent quality.
- The cost of rejection by users would be very high and it is essential to ensure that the final version has correctly identified the users’ needs.
The basic idea of prototyping is to build a complete, working, physical model of the proposed system so that they can be quickly tested and evaluated (Alavi, 1984). This model is reviewed by all interested parties to confirm the key aspects of the project before actual work begins. Then, a number of suggestions for changes are made. Once the review is complete, work can begin on the real project. For information system development, the working model of the system is constructed to verify the accuracy and completeness of the system. The focus in developing a prototype is to gain clarity on how the system must operate to meet user needs such as user-friendliness and user interfaces.

Prototyping can be a series of screen sketches, a storyboard (i.e. a cartoon-like series of scenes), a PowerPoint slide show, a video simulating the use of a system, a lump of wood (e.g. Palm Pilot), a cardboard mock-up or a piece of software with limited functionality written in the target language or in another language (Sharp et al., 2011). The prototype development and implementation are presented and explained in detail in Chapter 9.

4.8.9 Prototype Evaluation

Evaluation plays an important part in systems development (Gediga et al., 1999). It involves the assessment of all data collected during the monitoring process (both quantitative and qualitative) with a view to determining the success, usefulness and value of the innovation to the construction industry. Evaluation is also about using the information to make changes and improvements.

Evaluation sessions were conducted to determine the appropriateness of the prototype system in improving logistics management practices on construction site. The prototype system was evaluated using questionnaire survey techniques: closed and open-ended questions. Closed questions limit the respondent’s answer to the survey and allowed them only to choose either a pre-existing set of answers (i.e. yes/no, true/false), or rating scale response action (i.e. 1 – strongly agree, 2 – agree, 3 – disagree, 4 – strongly disagree), or multiple choice with an option for ‘other’. Neuman (2006) stated that the main limitation of the close-ended questionnaire technique is that the researcher cannot visually observe respondents’ reactions to questions, physical characteristics or the setting. Closed-ended and open-ended questions give freedom to the respondents and encourage them to explain their answers and reactions to the question with a sentence, a paragraph or even a page or
more depending on the survey. According to Fellows and Liu (2003), open-ended questions enable respondents to answer to whatever extent the respondent wishes. The evaluation process of the prototype system is explained in detail in Chapter 9.

4.8.10 Summary of Research Methods Adopted

In this section, the research methods adopted have been presented. In summary, the methods adopted for this research are:

- Literature and technology reviews
- Survey using questionnaires
- Case studies using semi-structured interviews
- Scenario generation using Scenario Planning method
- Scenario validation using loosely structured interviews
- Context modelling using Activity Theory framework
- System development by extending Context Toolkit
- Prototype development using screen-only prototyping strategy
- Prototype evaluation using questionnaire.

The research methods adopted to achieve the research objectives are summarised in Table 4-4.

<table>
<thead>
<tr>
<th>Research Objectives</th>
<th>Literature Review</th>
<th>Survey and Case Study</th>
<th>Scenario Generation</th>
<th>Scenario Validation</th>
<th>Context Modelling</th>
<th>System Design</th>
<th>Prototype Development</th>
<th>Prototype Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review context-aware computing and Web Services in other industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review supply chain management in the construction - establish contexts</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigate requirements for integrating Web Services and Context-Awareness with supply chain management</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop integrated framework for supply chain interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Implement and evaluate prototype system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
4.9 Summary

This chapter has reviewed, described and presented the research philosophies, methodologies and methods available to address the research objectives. The general research methodologies have been presented in order to provide the background for the methods adopted in this research. The key research steps and tools used have been presented. The methods adopted for each research task have also been discussed. This includes a technology and literature review on context-aware technologies and construction supply chain, case studies on current logistics practices, development of futuristic context-aware scenarios in the construction industry context, validation of these scenarios with the construction industry and technology experts, context modelling based on scenarios, development of the prototype system based on scenarios and context models and evaluation of the prototype system.

The next chapter presents the results of the survey and case studies.
References


Myers, M. D. (1997): "Qualitative Research in Information Systems." *MISQ Discovery MIS Quarterly* (21:2), 241-242 27/03/2012: 27/03/2012


