DEVELOPMENT OF AN E-BUSINESS CAPABILITY MATURITY MODEL FOR CONSTRUCTION ORGANISATIONS

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ABSTRACT

E-business is defined as the use of ICT and internet related technologies to create new ways of conducting business activities. It has been identified as an innovative approach for construction organisations to gain substantial benefits and to improve productivity and efficiency of processes. However, the uptake of e-business in the construction industry has been comparatively limited and ineffective. There is a need of a tool to evaluate and review construction e-business process execution and performance for further improvements. This research aims to develop a capability maturity model to systematically identify current status of e-business processes as a method of enhancing process efficiency in construction organisations. In order to achieve this aim, a multi-method qualitative research design was adopted. Initially an analysis of existing construction process maps were carried out to establish a conceptual construction process categorisation. Then two rounds of Delphi based expert forum interviews were conducted to verify the conceptual process categorisation. In the second stage of research design, an analysis of existing process maturity models were carried out to identify construction e-business process maturity characteristics. These characteristics were verified through an expert forum and further ratified using three case studies. In the third stage, Construction E-Business Capability Maturity (CeB-CMM) and its user interface were developed using verified construction process categorisation and ratified construction e-business process maturity characteristics. Finally, CeB-CMM was validated by applying it to four construction organisation using CeB-CMM user interface. This research contributed to the existing body of knowledge by developing CeB-CMM and its' user interface. Furthermore, this research established a construction process categorisation and determined the construction e-business process maturity characteristics. It is anticipated that the developed tool can be used by construction organisations as a tool to systematically evaluate their current e-business process maturity and provide them a pathway to further improve those processes.

Keywords: Construction e-business processes, Process Capability Maturity, E-business, Construction industry

DEDICATION

I dedicate this thesis

To my loving Parents, Srilal & Srima..

Hope that this achievement will complete the dream that you had for me all those many years ago when you chose to give me the best education you could.

And to my beloved Husband Roshan & Daughter Amelia..

Without whom none of my success would be possible.

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LIST OF ABBREVIATIONS

A2A	- Administration-to-Administration
A2B	- Administration-to-Business
A2C	- Administration-to-Customer
ARPANET	- Advanced Research Projects Agency Network
B2A	- Business-to-Administration
B2B	- Business-to-Business
B2C	- Business-to-Consumer
BIM	- Building Information Modelling
BIM^3	- Building Information Modelling Maturity Matrix
BPR	- Business Process Re-engineering
C2A	- Consumer-to-Administration
C2B	- Consumer-to-Business
C2C	- Consumer-to-Consumer
CeB-CMM	- Construction e-Business Capability Maturity Model
CMM	- Capability Maturity Model
DaaS	- Data Storage as a Service
DETR	- Department of Environment, Transport and Regions
DOD	- Department of Defence
DTI	- Department of Trade and Industry
EB-CMM	- Electronic Business Capability Maturity Model
E-business	- Electronic Business
EDI	- Electronic Data Interchange
e-mail	- Electronic Mail
e-MRO	- Electronic Maintenance, Repair and Operating
EQFM	- European Foundation for Quality Management
GDP	- Gross Domestic Product

HTTP	- Hypertext Transfer Protocol
IaaS	- Infrastructure as a Service
IBM	- International Business Machines Corporation
ICT	- Information and Communication Technologies
IS	- Information System
IT	- Information Technology
KPA	- Key Process Area
MS	- Micro Soft
NBIMS	- The National Building Information Model Standard
OGC	- Office of Government Commerce
PaaS	- Platform as a Service
RIBA	- Royal Institute of British Architects
SaaS	- Software as a Service
SCALES	- Supply Chain Assessment and Lean System
SEI	- Software engineering Institute
SMEs	- Small and Medium Enterprises
SPICE	- Standardised Process Improvement for Construction Enterprises
STOPE	- Strategy, Technology, Organisation, People and Environmental model
SW-CMM	- Software Capability Maturity Model
TQM	- Total Quality Management
UK	- United Kingdom
VAN	- Value-added Network
VERDICT	- Verify End-user e-Readiness using a Diagnostic Tool
WWW	- World Wide Web

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My special gratitude goes to my father and mother for their unconditional love, support and encouragement to complete my work. My brother and parents-in-law are also thanked for their encouragements throughout. And also, I express my heartiest appreciation for all I could not mention by names for every bit of their support given me even by a single word in every possible way in making this piece of work a reality.

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Above all, thank you God for guiding and strengthening me all the time to making this work a success.

DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty Ethics Committee.

I declare that the Word Count of this Thesis is 77,827 words

Name: **Vitharanage Anushi Kawshala Rodrigo**

Signature:

Date: **27-04-2015**

CHAPTER 1

INTRODUCTION

1.1 Research Background

The Construction sector is a major part of the UK economy which contributes some 7% of GDP which is worth about £110 billion per annum, comprising of three main sub sectors: commercial and social, residential and infrastructure (GCS, 2011). However, it has long been seen as inefficient and underachieving industry (Latham, 1994; Egan, 1998; Fairclough, 2002; GCS, 2011). Construction is a unique industry that generally deals with unique output, a specific building within a specific context, conditions and requirements. Each project consists of several phases and number of parties and project teams are involved. Further, the industry is highly fragmented, with over 300,000 businesses (of which 99.7% are SMEs) and over 2 million workers (GCS, 2011). This complexity of construction outputs and processes, and the nature and number of participant involved results in an extensive and complex information flow throughout construction processes (Wilkinson, 2005; Sommerville and Craig, 2006; Anumba and Ruikar, 2008; Chen, 2012). These specific characteristics demand a detailed appraisal and consideration of business activities and advanced methods for information management; where Information and Communication Technology (ICT) applications can be of great assistance (Sun & Howard, 2004).

Electronic Business (E-Business) is defined as a means of developing new ways of carrying out business activities with the use of Information and Communication Technologies (ICTs) (Li, 2007). It has become a significant source of innovation for modern businesses in every industry including Construction. E-business is an innovative approach for traditional construction organisations to gain competitive advantages and product, process and performance improvements. It has substantial benefits for every type of organisation. E-business processes can play important roles in each stage of a construction project and they have been proven to have the potential to improve many industry processes through time and cost savings (Anumba and Ruikar, 2008; Schneider, 2010; Chaffey, 2011).

Construction organisations have strategically redesigned their business processes by complementing ICTs in such a way that the processes are more efficient and effective (Love *et al*., 2004). Keraminiyage *et al*. (2008) confirm a relationship between the IT and some of the existing process improvement initiatives. Improved productivity and efficiency in the construction industry would have significant impact on the national economy (Gordon, 2003).

There have been significant evolutions in the development and application of ICTs over the past decade. Advances in hardware and networks were accompanied by a significant expansion in the e-business domain. Appropriate consideration on organisational e-business processes and practices are important to increase and sustain the benefits gained from them (Stockdale *et al*., 2006; Kang *et al*., 2013). E-business profile of a construction organisation can be defined using general construction processes. Construction process is defined as a set of activities, methods, practices and transformations that people use to construct and maintain buildings and other civil engineering structures and the associated products (Keraminiyage, 2009). Application of ICT to general construction processes creates the e-business profile of an organisation. Similarly, construction e-business process can be explained as a set of electronically supported activities, methods, practices and transformations that people use to construct and maintain buildings and other civil engineering structures and the associated products. Figure 1.1 illustrates the formation of construction e-business process profile.

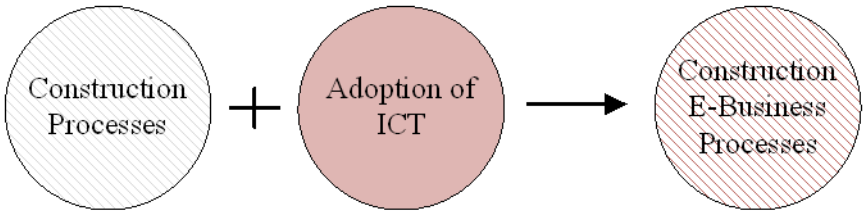

Figure 1.1: Construction e-business process profile

Successful implementation of e-business is the key to achieving optimum benefits and rewards for an organisation. Therefore careful considerations have to be taken when implementing e-business practices into businesses. The level of successful e-business implementation within the construction industry is not extensive as expected compared to other industries (Eadie *et al*, 2010; Chen, *et al*., 2011). This

creates an increasing demand for a proper analysis of construction e-business processes to ensure a productive and beneficial implementation and utilisation of ICT tools and approaches.

E-business strategy is explained as the approach by which internal and external electronic communication applications can support and influence the corporate strategy of an organisation (Chaffey, 2011). A vigorous e-business strategy will guarantee an effective execution to achieve of e-business processes within an organisation. E-business strategy endorses the configuration of business and IT infrastructure of an organisation to facilitate the maximum benefit from the technology (Beal and Mosse, 2008). It defines how organisation is operated within management, processes and systems (Zeng and Li, 2008). It is critical for organisations to scan and position their current situation, and provide a holistic approach to assist them in developing an executable e-business strategy. This requires a detailed understanding of the current status of e-business profile of the organization to set future objectives and to decide priorities. Evaluation and analysis of current e-business processes is critical and vital.

E-business capability models and e-readiness models are used as evaluation tools to determine the current status of e-business implementation of an organisation. E-readiness models gives an indication of how ready an organisation is to adopt e-business approaches with its current capabilities (Peters, 2001; Ruikar *et al*., 2006). The limitation associated with e-readiness models is that, even though they provide an indication of how able and ready an organisation is to adapt electronic processes for their day to day business activities; they do not provide possible improvements or systematic procedures for developments. On the other hand, maturity models are designed to support improvement in processes, products and delivery (Alshawi, 2007). They aim to help organisations to scale themselves and to identify next steps for developments. There are several e-business specific models that are suggested in the literature to evaluate and review e-business process execution and performance (Chen *et al*., 2006; NIBS, 2007; Succar *et al*., 2012; Eadie, 2009). However, existing models are either specific to an industry other than construction or focus mainly on only one e-business approach. There is a niche for a tool which focuses on construction e-business processes that covers the wide range of ICT tools and approaches.

1.2 Problem Statement

Considering the research background discussed above, it is apparent that there is a need to improve the efficiency and productivity of processes of construction organisations. This arise the first question "How can construction organizations' improve their business processes?". Adoption of ICT, hence e-business, is determined as the one of the best solutions to the aforementioned question as it can bring substantial benefits and competitive advantages to construction organisations while improving the productivity and efficiency of their processes.

The second question is "Why should construction organisations want to know the level of maturity of their e-business processes?". .E-business Process maturity is the extent to which an organisation is able to define, manage, measure and control its e-business processes. Knowing their e-business process maturity implies that an organisation has the potential to improve its e-business process capability which enables organisations to predict the outcome of a process before it commence. Furthermore, knowing the capability and maturity of these processes it allows them a pathway to further enhance those processes and have productivity and efficiency improvements.

The next question is "How can construction organisations know the level of maturity of their e-business processes?". In order to assess the level of maturity of construction e-business processes, a construction specific e-business capability maturity model is needed. As discussed in aforementioned section, there is a niche for a tool which focuses on assessing construction e-business process capability and maturity that covers the wide range of ICT tools and approaches.

1.3 Research Aim and Objectives

In addressing aforementioned research questions, the main aim of the research is to develop a capability maturity model to systematically identify current status of e-business processes as a method of enhancing process efficiency in construction organisations. To achieve this aim, this study looks at how the Capability Maturity Model (CMM) concept and principles could be applied with in construction e-business context. Accordingly, the following six objectives were established:

1. To explore the importance of e-business for construction organisations.
2. To review e-business evaluation tools and process improvement tools for construction organisations.
3. To identify and categorise current construction business processes.
4. To analyse e-business process capability and maturity characteristics in construction organisations.
5. To develop a model to capture the status of maturity of e-business processes in construction organisations.
6. To validate the Construction e-Business Capability Maturity Model (CeB-CMM).

1.4 Research Methodology

Research methodology for this research study was designed following the concepts of 'Research Onion' presented by Saunders *et al*. (2012) It provided six layers which can provide guidance to design the research procedures methodically and logically. These are further explained in Chapter four of this thesis in detail. In order to achieve the main aim of this research as identified in previous section 1.2, a multi-method qualitative research design was adopted to comprehensively investigate e-business implementation in construction in depth.

The research design of this research study considered in accordance with the research aim and objectives. It consisted of five stages: conceptualisation, process categorisation, e-business maturity characteristics identification, model formation and validation. Conceptualisation stage was a comprehensive literature review to explore the importance of e-business, drivers and barriers of e-business construction organisations and to review e-business implementation and evaluation tools for construction organisations. This main literature review and synthesis laid the background and rationale to the current investigation and helped to establish the research gaps. As the research progressed, it provided the basis to develop the initial conceptual framework for construction e-business capability and maturity model.

Process categorisation stage consisted of an analysis of existing construction process maps and first phase of an expert forum. Initially two existing construction process maps (Royal Institute of British Architects (RIBA) Plan of Work and Office of Government Commerce (OGC) gateway process) were reviewed to identify construction processes to establish a conceptual construction process categorisation. Next, two rounds of Delphi based expert forum interviews were conducted to verify the conceptual construction process categorisation obtained from the analysis of construction process maps.

Third stage of the research design was e-business maturity characteristics identification. Initially, an analysis of three existing maturity models was conducted in order to identify potential capability maturity characteristics to use in the construction e-business capability maturity model. Then, as the second phase of expert forum, interviews were conducted with industry and academic experts in order to verify the conceptual construction e-business process maturity characteristics. Next, three case studies were conducted with three different construction organisations to ratify construction e-business process maturity characteristics established in previous phases.

Model formation stage developed the formulating procedure of CeB-CMM with the use of process categorisation and maturity characteristics. An user interface for CeB-CMM was developed in order to facilitate an ease of use for the model. Final stage of the research design was validation stage. It focused to measure and evaluate the appropriateness and effectiveness of CeB-CMM from the industry perspective. This stage helped to demonstrate that the CeB-CMM achieved the aim of the research, to identify weaknesses and strengths of the model and to obtain suggestions and recommendations for further improvements.

1.5 Research Scope

This research focuses on e-business process capability and maturity in the construction industry, specifically developing an e-business process capability maturity model for construction organisations in the United Kingdom. In the research, e-business capability maturity is considered for construction project related processes of construction organisations. The investigation of e-business

process maturity in this research concentrates on different types of construction organisations including consultants, clients and contractors and different sizes of organisations including micro, small, medium and large.

1.6 Organisation of the thesis

This thesis includes eight chapters. Main contents of each chapter are as follows:

Chapter one of the thesis provides an introduction to this study. In this chapter, background information are discussed to articulate the significance of the research problem. It establishes the research aim and objectives, and briefly describe the research methodology designed to achieve the aim and objectives. Furthermore, the chapter presents the scope of the research and gives a detailed guide to the readers about how the thesis is organised into eight chapters.

Chapter two reviews and synthesis literature related to e-business. This chapter focuses on exploring the aspects of general e-business to determine the importance and need of e-business processes for construction organisations. This chapter demonstrates the importance of proper e-business execution and e-business strategy development for construction organisations. Further it inquires current e-readiness models and maturity models to determine the importance of having capability maturity process improvement tool to assess the current status of e-business process maturity for construction organisations.

Chapter three presents a review of relevant literature on construction process improvement and capability maturity model. It defines the meaning of process, introduce process improvement concept and approaches and investigates current process improvement initiatives in the construction industry. Further, it provides the theoretical foundation for the study by reviewing the original capability maturity model concepts and components.

Chapter four introduces the methodological considerations of the current study. It describes and justifies the philosophical stance, research approaches, methodological choices and research strategies of this study. The research design of the current study with data collection and analysis techniques are also presented

and explained. Finally, the reliability and validity measures of the research are discussed in the chapter.

Chapter five describes the framework development of CeB-CMM and establishing construction process categorisation which forms a main component of the CeB-CMM. It presents the framework of CeB-CMM describing the structure of the model. Then it presents the analysis of existing construction process maps and first phase of expert forum conducted in pursuant of the objective three of the study which is to identify and categorise construction project related processes in organisations.

Chapter six describes the process of establishing construction e-business process maturity characteristics. It describes the analysis of existing maturity models, second phase expert interviews and case studies conducted in pursuant of the objective four of the study which is to identify e-business process capability and maturity characteristics in construction organisations.

Chapter seven presents the Construction e-Business CMM which construction organisations can use to assess the state of their current e-business process maturity. The chapter describes the formulation of CeB-CMM model using the model components derived from previous chapters. It also presents the development of a user interface for CeB-CMM which enables the easy and user friendly application of CeB-CMM for construction organisations. Further, this chapter describes the validation of the CeB-CMM by applying the model into construction organisations. It discusses the findings of the validation to assess the acceptability and appropriateness of CeB-CMM to the construction organisations.

Chapter eight is the conclusion of this research study. It summarises the conclusions and contributions of the research. The chapter draws conclusions to how the research aim and objectives are addressed and achieved. It outlines the contribution of the research to the existing knowledge and identifies the limitations of the research. It also identifies the future research based on the current study.

1.7 Summary

This chapter presented an overview of the doctoral research study. It discussed the background, rationale of the research and research problem. Further, it described research aim and objectives and research methodology designed to achieve those objectives. The scope of the research and the organisation of the thesis have also been presented. The next chapter presents the first part of the literature review, establishing an understanding of e-business and importance of e-business processes for construction.

CHAPTER 2

E-BUSINESS IN CONSTRUCTION

2.1 Introduction

This chapter presents an overview of e-business and discuss its implementation in the construction industry. Further it describes the importance of an e-business strategy for construction organisations and e-business evaluation approaches. The primary focus of this chapter is to provide a comprehensive review of literature in order to establish the research context and rationale.

First section presents the definition of e-business, taxonomy of e-business and e-business enabling technologies. Second section discusses the e-business execution in the construction industry explaining the importance of e-business to the construction industry. Further it summarises construction e-business drivers and barriers and current construction e-business trends and approaches.

Third section describes the importance of an e-business strategy for a construction organisation and current e-business strategy development approaches. Fourth section of the chapter examines the e-business implementation and evaluation approaches in order to identify the limitations and gaps in prior research. Current e-readiness and e-business maturity models are presented and explained.

Finally, the chapter concludes with a discussion and a general summary which outlines the niche for this research, establishing the focus of this thesis.

2.2 Understanding E-Business

This section provides an overview of Electronic Business (e-business). It clarifies the definitions of e-business and establishes the definition for e-business within the scope of this research. Then different types of e-business enabling technologies are discussed and finally the taxonomy of e-business is presented.

2.2.1 E-Business Definition

Electronic Business (e-business) can be defined in several ways. Current literature reveals a wide range of definitions for e-business. IBM was the first group to use the term "e-business" (Gerstner, 2002; Papazoglou and Ribbers, 2006; Chaffey, 2011) to promote their services. Initially IBM (1997) introduced the term e-business as a way of transforming key business processes by using internet technologies. Four years later, IBM (2001) updated the definition of e-business with a broader indication as;

"the process of using web technology to help businesses streamline *processes, improve productivity, and increase efficiency .It is about using the internet infrastructure and related technologies to enable business anywhere and anytime" (IBM, 2001: p.5).*

In simple terms, e-business was accepted as the use of internet and related technologies to improve and transform key business processes for business benefit.

At the early stages of e-business evolvement, Department of Trade and Industry (DTI) also emphasised the full range of e-business processes in an international benchmarking study which looked into the adoption of e-business in Small and Medium Enterprises (SMEs). DTI (2000) described e-business as the integration of Information and Communication Technologies (ICTs) for business processes. ICT is explained as any technology use to support information gathering processing, distribution and use which includes hardware, software and network systems (Baynon-Davies, 2013). DTI (2004) further highlighted that when an organisation has completely integrated with e-business into its operations, its business processes has potentially redesigned around ICT or its business model has totally reinvented. This suggests that e-business enables transformations of business processes. Further, European commission (2006) also identified that e-business facilitates business process automation and integration in organisations.

Papazoglou and Ribbers (2006) described e-business as the application of information and telecommunication technologies to conducting businesses. Similarly, Li (2007) defined e-business as;

"e-business is about developing new ways of working by innovatively exploiting the new capabilities of Information and Communication Technologies in general and the Internet and related technologies in particular" (Li, 2007: p.2).

Chaffey (2011) also recognised e-business activities as;

''All electronically mediated information exchanges, both within an organisation and with external stakeholders supporting the range of business processes" (Chaffey, 2011: p.12).

These definitions set a broader boundary for e-business opportunities by outlining the innovative ways of conducting traditional business processes within organisations. This broader indication of e-business further supported by many authors (Laudon & Laudon, 2002; Aranda-Mena & Stewart, 2005 ; Anumba & Ruikar, 2008; Goncalves *et al*., 2010; Xu & Quaddus, 2010) by describing e-business as it considers all types of electronically supported business activities within an organisation. Hence, it is evident that e-business involves all types of business activities utilised with ICT within an organisation.

It is apparent that over the past years, e-business has increased from a very specific to a very broad explanation. The potential scope of e-business has broadened and the definition of e-business is not static. Different definitions can be given to e-business in different perspectives as business perspective, technological perspective or process perspective (Chen, 2012). From business perspective, e-business can be described as new ways of conducting business activities which add value to traditional processes. From technological perspective, e-business can be described as it is supported by a range of ICTs and internet related technologies. From process perspective, e-business can be described as e-business enables process transformation through automation, reengineering and integration. This thesis adopts this broader range of e-business application and summarises e-business definition as;

"E-Business is the use of ICT and internet related technologies to create new ways of conducting business activities which enables transformation of business processes with added value ".

2.2.2 Taxonomy of E-Business

E-business can be classified into different categories based on the transaction and communication relationships of businesses, consumers and administration. Several e-business categories can be identified from literature (Anumba and Ruikar, 2008; Qin, 2009; Schneider, 2010; Chaffey, 2011). Those identified categories are as illustrated in Figure 2.1 and further described in following section.

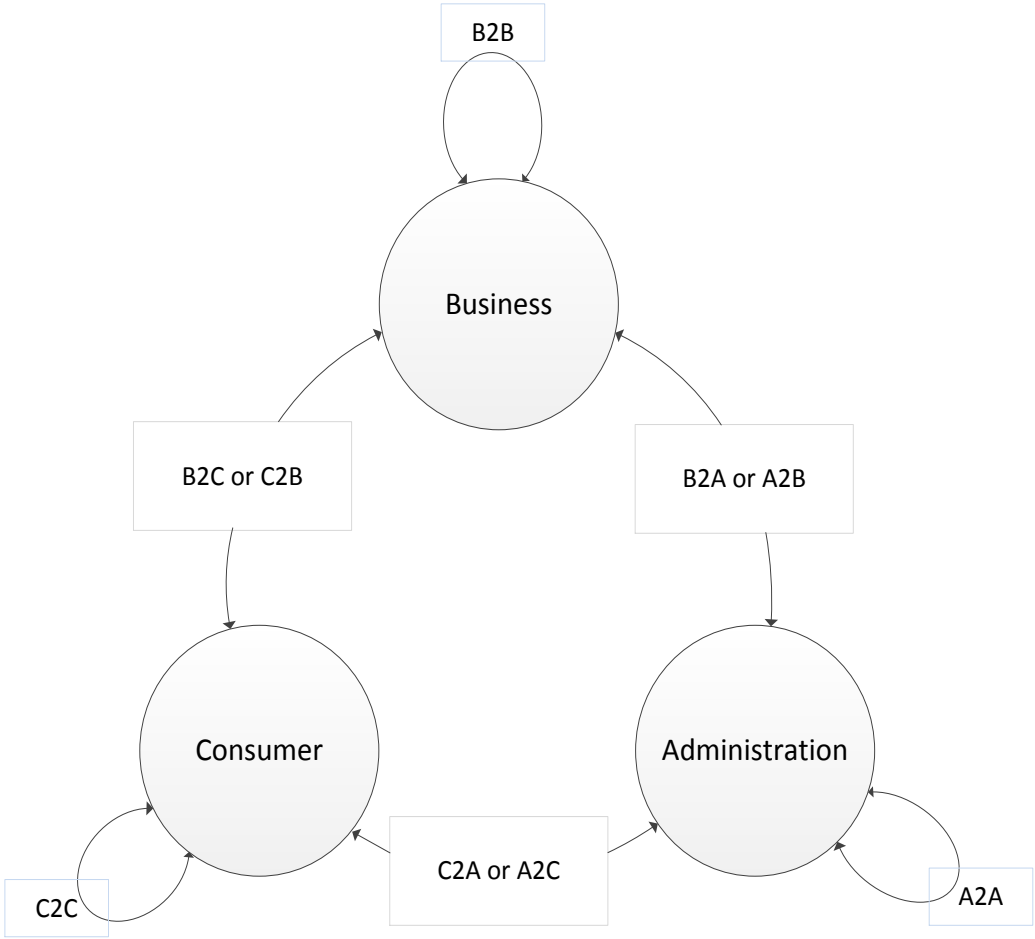

Figure 2.1: E-Business Taxonomy (Source: Ruikar and Anumba, 2008)

2.2.2.1 Business-to-Business (B2B)

Business-to-Business (B2B) refers to electronic means of carrying out business transactions between two or more businesses. It has the characteristics of carrying out business activities by Electronic Data Interchange (EDI) via Internet or any other networks between companies.

2.2.2.2 Consumer-to-Consumer (C2C)

Consumer-to-Consumer (C2C) refers to electronic exchanges of value or economic activities between consumers. Consumer e-auctions and personal blogs can be identified as examples for C2C models.

2.2.2.3 Administration-to-Administration (A2A)

Administration-to-Administration (A2A) refers to electronic exchanges between government departments. Governments departments use A2Amodels to communicate and exchange classified information through dedicated portals; nationally or internationally. National DNA database can be identified as an example for an A2A e-business model.

2.2.2.4 Business-to-Consumer (B2C) or Consumer-to-Business (C2B)

Business-to-Consumer (B2C) or Consumer-to-Business (C2B) takes place between businesses and customers. In B2C model, transactions take place between an organisation and customers, in which for example online sales and transactions are carried out using electronic means. Amazon.com and eBay can be identified as some popular examples for this category. In C2B model, consumers offer products and services to organisations. This is the reversal of traditional business model where companies offer products and services to customers. Surveys.com and SurveyMonkey online surveys can be identified as examples of C2B model, where consumers respond to organisations' surveys and get paid from them.

2.2.2.5 Business-to-Administration (B2A) or Administration-to-Business (A2B)

Business-to-Administration (B2A) or Administration-to-Business (A2B) takes place between enterprises and government bodies. B2A category refers to the electronic transactions and exchanges carried out between businesses and government bodies. An example for this type of e-business model is Accela.com, a software company which provide public access to government services for land management, asset management, licensing and case management and public health and safety. Similarly, A2B refers to the electronic means of providing business specific information such as policies and regulations to business

enterprises. Examples of this type include e-tendering portals that enable potential organisations to bid for government projects.

2.2.2.6 Consumer-to-Administration (C2A) or Administration-to-Consumer (A2C)

Consumer-to-Administration (C2A) or Administration-to-Consumer (A2C) takes place between consumers and government bodies. C2A refers electronic communications between consumers and government. These facilitate the consumers to provide information or feedback for government bodies. Electronic voting is an example for this type of e-business models. A2C refers to direct communication links between government and consumers. Examples for this type can be identified as HM Revenue and Custom website and local council and civic websites.

2.2.3 E-Business Enabling Technologies

There have been significant evolutions in the development and application of ICTs over the past decade. Advances in hardware and networks were accompanied by a significant expansion in the e-business domain. These enhancements were developed covering wide range of business applications and have clearly influenced the way in organisations adopted IT into their business environment (Alshawi, 2007). Organisations should take careful considerations on hardware, software, human resource and IT services as they persuade functional, financial and technical requirements of an organisation (Perera and Karunasena, 2008). These IT solutions are the enablers and driving forces behind the e-business adoption. Not content with these enablers can set up limits for potential competitive advantages.

Enabling technologies are defined in this segment as the technologies which enable e-business adoption and expansion. Defining adequate and suitable enabling technologies is vital for organisations as they help to embrace an expanded scope of e-business operations. The e-business enablers have revolutionised from Electronic Data Interchange (EDI) to internet and cloud computing and have greatly influenced the growth of e-business. They have changed not only the way in which businesses communicate and interact, but also

the way in which information is stored, exchanged and viewed (Ruikar, 2004). Following sections describe prominent enabling technologies for e-business.

2.2.3.1 Electronic Data Interchange (EDI)

In the 1960s, Electronic Data Interchange (EDI) over secure private networks was established in the US transport industries (Chaffey, 2011). Clarke (1998) describes EDI as exchange of structured business information in standardised electronic form using digital media between organisations. EDI provides a collection of standard formats to exchange data through an electronic messaging service (Norris and West, 2001).

Organisations have to have necessary IT applications such as private lines or value-added networks (VANs) and software which can incorporate different formats in place to utilise EDI (DTI, 2000). EDI reduces the processing time for transactions and improve the accuracy of data (O'Brien and Al-Soufi, 1994). However EDI has proven considerably expensive to facilitate technical implementation among business partners (Li, 2003; Beynon-Davies, 2004). Therefore the usage of EDI was restricted due to financial restrictions and system incompatibilities (O'Brien and Al-Soufi, 1993; Akintoye and Mckellar, 1997; Hulme, 1997).

In later years, EDI has developed through new standards and integrated with Internet to achieve Internet EDI, which can describe as the use of EDI data standards delivered across the internet (EDI Insider, 1996; IDC, 1999; Fu *et al*., 1999; Chaffey, 2011). This enabled EDI to be implemented using lower-cost transmission techniques through the public Internet and the reported cost savings were up to 90% (EDI Insider, 1996). Internet EDI also includes exchange of structured documents by email and has broadened the EDI usage even for smaller enterprises.

2.2.3.2 Email

Electronic mail (e-mail) is exchanging information using computer text-processing and communication tools (Sproull and Kiesler, 1986). Depending on the type and sophistication of technologies used, the mailed information can be a message, a document or a collection of organised messages. E-mail is recognised

as the ordinary use of network communication technologies that developed along with the Internet (Crocker, 2000). In interactions within the e-mails, users transform the data into information they find meaningful (Lee, 1994). Gimenez (2000) recognised that email communications resembles the features of both spoken and written language. Successively e-mails have become increasingly important for everyday communication within commercial organisations and many of which have developed their own in-house e-mail systems both for national and intra-national communications (Gimenez, 2000; Chaffey, 2011). Email is a simple and prominent communication mode within and outside the organisations.

E-mail is one of the main facilitator of e-business implementation for any business. However the evolution and adoption of e-mail have posed some challengers for users. Chaffey (2011) identifies risks associated with e-mails as infringing an individual's privacy and defamation to an individual or a company. Specific laws and regulations are been developed in many countries to minimise these risks and to reduce the volume of spam. Moreover use of e-mail has been criticised for overloading employees due to the requirement to respond to this information (Wilkinson, 2006; Chaffey, 2011; Hagan, 2012).

2.2.3.3 World Wide Web (WWW)

The World Wide Web (WWW) was developed in early 1990s as a tool which allows computers to connect to the Internet (Berners-Lee, 1999; Lederer *et al*., 2000). It provides a standard method of exchanging and publishing information on the internet (Chaffey, 2011). The WWW has grown phenomenally since its inception. The growth of the WWW has transformed it into a web of knowledge in which highly diverse information is linked in an extremely complex and arbitrary manner (Huberman and Adamic, 1999).

At present, WWW is the most common technique for publishing information on the internet which uses the HTTP protocol, one of the languages used over the Internet to transmit data. It is accessed through web browsers which display webpages of embedded graphics and text. The data and information on the web is defined as common formats, which allows the flexibility to use them across various applications (W3C, 2011). New generations of web technologies have

transformed the interactivity and extensibility of the web. As a result, new communication tools such as blogs and social networks were built (Chaffey, 2011). Currently, web technologies have created advanced e-business options to businesses utilising communication, collaboration, marketing and information transaction approaches (Huberman and Adamic, 1999; Lederer *et al*., 2000; Schneider, 2010; Chaffey, 2011).

2.2.3.4 Intranet

Intranet is a private network within an organisation. It uses internet standards to access and share information using web publishing technology (Vlosky *et al*., 2000; Chaffey, 2011). A key feature of an intranet is that its access is limited to employees or organisation members only. Therefore intranet can provide secured and restricted network for e-business applications that access sensitive company information which need be limited or restricted to qualified individuals.

The benefits of intranet are recognised as improved communication and information sharing, increased accuracy of information and easier organisational publishing. Intranet facilitates communications among company members and delivers information to employees, which make intranets are more useful in large organisations (Vlosky *et al*., 2000). Even though an intranet can yield benefits to an organisation by disseminating information throughout a company or cross departmental teams within a company as an internally focused network; it lacks the strategic importance of partner relationships and external expansions (Riggins and Rhee, 1998). This gap generated the need of extended intranets and the extranets and internet were emerged.

2.2.3.5 Extranet

Extranet can be described as a network which link business partners to one another over the Internet. Chaffey (2011) defined extranet is defined as a network service provided through internet and web technologies delivered by extending an intranet beyond a company to customers, suppliers and collaborators. This association is usually achieved by organisations permitting their collaborators to access certain areas of their intranet (Greengard, 1997; Vlosky *et al*., 2000). According to the characteristics of extranet, it acts as a collaborative platform for

business partners to operate their business activities and facilitate the information flow providing a collaborative environment.

The benefit of having an extranet is connecting all businesses in a company's supply chain. It brings suppliers, partners and customers in to the information loop which is significant to organisation's growing market environment (Baker, 2000). Extranets eliminate location barriers and give organisations a wider acceptance and recognition in the market (Riggins and Rhee, 1998, Baker, 2000). Easy and secure information sharing and collaboration, cost savings, increased customer service are some key potential benefits of using extranets (Vlosky *et al*., 2000; Chaffey, 2011).

Counterbalancing the benefits of extranets, there are some identified problems associated with extranets such as liability issues, confidentiality of information and security concerns (Vlosky *et al*., 2000). These concerns are common with collaboration networks as sensitive information is transmitted. Therefore it is essential to consider these issues when establishing an extranet and take necessary actions to address the potential risks involved. However, extranets offer an excellent platform for organisations to execute e-business activities facilitating their business processes.

2.2.3.6 Internet

The Internet is the most common and popular network which links and enables communication between connected computers across the globe. It consists of network infrastructure and communication links between them which are used to hold and transfer information between client personal computers and web servers (Chaffey, 2011). In simple terms the Internet is a massive network of networks and it allows a computer to communicate with another computer as long as they both connected to the Internet. Information are transmitted over the Internet via variety of languages known as 'protocols' (Beynon-Davis, 2004).

Initial concept of internet was introduced by Licklider (1962) discussing his concept of a 'Galactic Network'. He envisaged a globally interconnected set of computers through which any one from any location in the network could quickly access data and programs. Following this idea the ARPANET was created by the

Advance Research Project Agency (also known as DARPA) in 1969 linking servers by key military and academic collaborators in USA (Beynon-Davis, 2004; Leiner *et al*., 2009; Chaffey, 2011). Additional computers were linked to the network during the following years and the original ARPANET grew into the Internet.

Internet has generated a new era of collaboration and sharing information across the world. It enhanced innovations such as e-business and allowed organisation and people to create new ways of operating business activities and interactions. The introduction of WWW boosted the massive growth in business use of the Internet and currently Internet is used to enable the major value chains of organisations (Beynon-Davis, 2004, Chaffey, 2011).

Figure 2.2 shows the relationship between internets, extranets and the Internet.

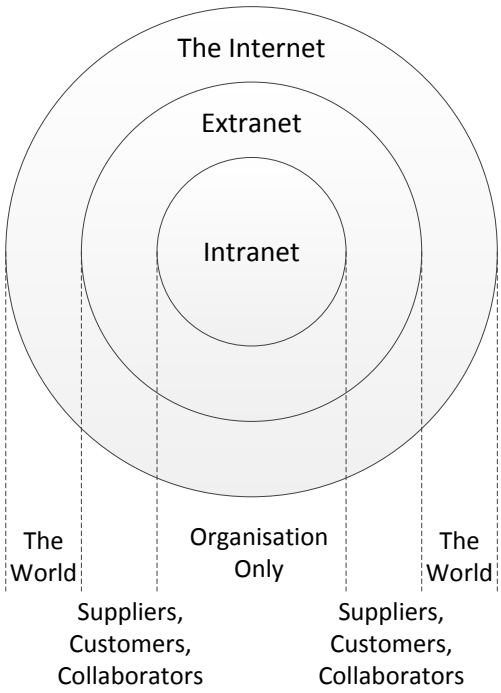

Figure 2.2: Relationship between intranets, extranets and the Internet

2.2.3.7 Cloud Computing

Cloud computing is defined as a model for enabling convenient and on demand network access to a shared pool of computing resources such as networks, servers, storage, applications and services that can be quickly discharged with minimal

management effort or service provider interaction (Mell and Grance, 2009). On demand self-service, broad network access, resource pooling, rapid elasticity and measured service are identified as essential elements of cloud computing (Dillon and Chang, 2010).

Cloud computing provides more flexibility and scalability in the use of IT. There are different types of services that can be offered by cloud services such as Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS) and Data Storage as a Service (DaaS) (Dimaiakos *et al*., 2009; Dillon and Chang, 2010; Sultan, 2010). Similarly different types of cloud deployment models have been defined such as private clouds, community clouds, public clouds and hybrid clouds (Dillon and Chang, 2010). These different forms of clouds provide wide range of IT services and facilities to organisations combining reduced capital cost reduce support cost and usage based charging (Thompson and Waller, 2011). These features generate a valuable basis for start-ups and small companies to deploy their application services on a pay-as-you-go basis (Sharma *et al*., 2010; Calheiros and Buyya, 2013). This will minimise the cost concerns for smaller companies to adopt e-business to their business practices.

The relationship between cloud computing and e-business results a positive shift in its delivery. Cloud computing comes into focus when an organisation considers e-business implementation and increase e-business capabilities. Cloud services helps to advance organisations' e-business applications with the wide range of services provided. However, cloud computing is not without its challenges. Key challenges associated with cloud services are security concerns, data management, interpretability issues (Dikaiakos *et al*., 2009; Dillon and Chang, 2010). It is important for clients to consider security measures and policies of the cloud provider before migrating to the services offered by a cloud. If these challenges are conquered, cloud computing has the potential to increase operational efficiency and reduce cost in e-business deployment.

2.2.4 E-Business Practices

The emergence of e-business has transformed the way in which organisations conduct their traditional business operations. With the growing importance of the

e-business, organisations across several industries have increasingly leveraged to electronic ways of conducting their business activities to achieve competitive advantages (Cheng *et al*., 2003). E-business has made several fundamental changes in the business environments by introducing numerous e-business applications to their day to day routines (Li, 2007). Wide range of e-business applications utilise in various disciplines are presented and explained in below Table 2.1.

Table 2.1: E-business applications in various industries and disciplines

Application	Description	References
e-commerce	Conducting sales and transactions with the use of electronic means.	Anumba & Ruikar (2002), Issa *et al*. (2003), Beynon-Davies (2004), European commission (2006), Li (2007), Chaffey (2011)
e-procurement	Obtain information about suppliers and their products using web directories and procure online.	Anumba & Ruikar (2002), Issa *et al*. (2003), Beynon-Davies (2004), Aranda-Mena & Stewart (2005), Perera *et al*. (2006), European commission (2006), Papazoglou and Ribbers, (2006), Li (2007), Eadie *et al*. (2007), Chaffey (2011)
e-advertising	Advertising companies and their products using internet.	Anumba & Ruikar (2002)
e-project management	Communication between project parties using web.	Anumba & Ruikar (2002), Issa *et al*. (2003)
e-collaboration	Using the web as a tool to facilitate online collaboration for project partners.	Anumba & Ruikar (2002), Issa *et al*. (2003), Knudsen, (2003), Aranda-Mena & Stewart (2005), Papazoglou and Ribbers, (2006)

Application	Description	References
e-tendering	Provide tendering information online with project specification and carry out the tendering process online.	Anumba & Ruikar (2002), Knudsen, (2003), Lou and Alshawi (2009)
Supply chain management	Doing the supply chain activities with the use of web and ICT.	Cheng *et al*. (2001), Issa *et al*. (2003), European commission (2006), Qin (2009), Chaffey (2011)
e-transactions and e-payments	Carrying out transactions through web and do the payments online.	Aranda-Mena & Stewart (2005), European commission (2006), Papazoglou and Ribbers, (2006)
e-logistics	Carrying out the process of delivering parts, components, materials, plant, information, energy to the point where they are needed online.	Aranda-Mena & Stewart (2005), Papazoglou and Ribbers, (2006)
Internet and email	Use of the internet and e-mail.	Issa *et al*. (2003), Aranda-Mena and Stewart (2005), Li (2007)
e-marketplace	Web site which aggregates different content and services of interest to a particular industry and makes it available for industry members.	Issa *et al*. (2003), Beynon-Davies (2004)
e-interactions	The full range of e-transactions, and in addition collaborative business processes (e.g. collaborative design) which are not directly transaction focused.	European commission (2006), Elliman and Orange (2000)
Sharing documents in a	Disseminate relevant information about	Knudsen, (2003), European commission

Application	Description	References
collaborative workspace	construction projects to the involved partners, and make possible the retrieval of vital information from the partners at all times.	(2006)
e-invoicing	Computer-mediated electronic transaction between a seller and a buyer, which replaces traditional paper-based invoicing processes.	European commission (2006), Arbin (2008), Korkman *et al*. (2010)
e-marketing	Support online marketing activities, including the communication with customers, offering products for sale, and developing new marketing strategies.	Beynon-Davies (2004), European commission (2006), Papazoglou and Ribbers (2006), Timmers (2006); Chaffey (2011)
e-sourcing	Identifying new suppliers for a specific category of purchasing using internet technology across spatial boundaries.	Walker *et al*.(2002), Knudsen, (2003), Reyes-Moro (2003), Bartezzaghi and Ronchi (2007)
e- auctions	Electronic implementation of bidding mechanisms.	Walker *et al*.(2002), Knudsen, (2003), Li (2007)
Web-based enterprise resource planning	Create and approve purchasing requisitions, place purchase orders and record the goods and services receipt using a software system based on Internet technology.	Walker *et al*.(2002), Knudsen, (2003), Papazoglou and Ribbers, (2006)
e-MRO (Maintenance, Repair and Operating)	Channels for e-MRO include direct or desktop purchasing systems (DPS), standardised catalogues (e.g. at buyer's	Walker *et al*.(2002), Knudsen, (2003), Arbin (2008)

Application	Description	References
	site), broker intermediaries (Application Service Providers, which purchases goods on the buyer's behalf within certain price limits) and supply-side shop systems.	
e-informing	Gathering and distributing purchasing information both from and to internal and external parties using web technology.	Walker *et al*. (2002), Knudsen, (2003)
e-malls	A collection of e-shops enhanced by a common umbrella.	Gre (1999), (Li (2007)
e-shops	Web marketing by an organisation or an online shop.	Timmers (2006); Li (2007)
e-government	The application of e-commerce technologies to government and public services.	Bertot *et al*. (2010); Chaffey (2011); Snead and Wright (2014)

2.3 E-Business Execution in the Construction Industry

This section provides an insight investigation of e-business execution and implementation in the construction industry. It highlights the importance of e-business within the construction context and explains the impact of e-business with its benefits and inhibitors. Simultaneously, e-business drivers and barriers in the construction industry are also discussed. Finally, this section identifies current construction e-business trends and explains prominent approaches.

2.3.1 Importance of E-Business to the Construction Industry

Construction is a unique industry. It has unique characteristics and differs from other industries in many ways. Usually other industries mainly deliver their

products from an immobile production base, with a constant workforce and a supply chain which is regular over considerable time periods. Construction does not benefit from these characteristics. It has a dynamic and unique projects, different clients and composite supply chain (Sommerville and Craig, 2006). The importance and need of e-business to the construction is associated with this unique nature of the industry. Further, fragmentation, intense of the information and issues of underperformance are some of the other characteristics of the construction sector which e-business can be a great assistance (Ruikar *et al*., 2003; Wilkinson, 2005; European Commission, 2006; Sommerville and Craig, 2006).

Construction Process generally deals with unique outputs, a specific building within a specific context of conditions and requirements. It consists of several phases from inception to handover (DETR, 2000; RIBA 2013). There are number of parties and project teams involve in a construction project. These project participants are multi-disciplinary, multi-company and multi-location (Wilkinson, 2005). This complexity of construction outputs and processes, and the nature and number of participant involved results extensive and complex information flow through the construction process (Ruikar, 2004; Wilkinson, 2005; Sommerville and Craig, 2006). This requires a detailed appraisal and consideration of business activities and advanced methods for information management; where ICT applications can be of great assistance (Sun and Howard, 2004). Efficient management of this high volume of information can improve the productivity of the whole industry significantly (Sommerville and Craig, 2006; Anumba and Ruikar, 2008; Harris and McCaffer, 2013). Further, ICT applications can play important roles in each stages of a construction project and therefore it is vital for organisations to consider how e-business can effects and develop strategies to adopt them for their business routes.

Fragmentation is another issue of the construction industry where e-business can be of a great support. The construction industry is fragmented in its structure with very few large companies and a large number of small and medium companies (Paulson, 1995; Egan, 1998; Morton, 2008; Sommerville and Craig, 2006). The large companies tend to embrace innovative trends in the market and are better able to utilise them to achieve competitive advantages (Heyes, 2000). However many small and medium companies fight to survive in the market and have

limited resources to invest and embrace new technology advancements (European Commission, 2006). Therefore it is apparent that construction organisations have considerable e-business usage gaps from large scale to small, medium and micro level businesses. This difference reveals that there is a possible advancement of usage and it needs to be captured and managed. Narrowing this competitive gap between large and small and medium organisations through emerged e-business applications and enabling technologies will be a great benefit for the industry as a whole.

Other issue of the construction industry is that it is generally considered as generally inefficient and underperforming compared to other sectors such as manufacturing and electronics (Paulson, 1995; Wolstenholme, 2009; Cabinet Office, 2011). There are number of industry reports published, within which the construction sector has been identified as incompetent in addressing problems and need to improve performances (Latham, 1994; Egan, 1998; 2002). In his report "Accelerating Change", Sir John Egan (Egan, 2002) highlighted the need of process thinking in construction. This argument further supported by Sir John Fairclough (Fairclough, 2002) by emphasizing the importance of achieving the desired performance improvements in construction. Recently, to review the latest progress of the construction industry, another report has been produced by Constructing Excellence (2009). The result of the report indicated that, although there has been significant improvement, it has not been on the scale anticipated. Fragmentation of the industry, nature of the project participants, lack of collaboration, poor communication and process related issues were identified as the reasons for inefficiencies arise (Alexander *et al*., 1998; Howard *et al*., 2002; Wilkinson, 2005; European Commission, 2006; Sommerville and Craig, 2006). This creates an increased demand for creating new ways of conducting construction business processes utilising e-business tools and approaches.

2.3.2 E-Business Drivers and Benefits for the Construction Industry

There are ample examples of potential benefits of successful e-business implementation for organisations in the construction industry. These benefits comprise of both tangible and intangible aids (Chaffey, 2011). Tangible benefits are directly associated with monetary savings and intangible benefits are difficult

to measure from monetary values. The advantages of e-business could benefit construction businesses in various aspects including procurement, transactions, transparency, management, collaboration and communication (Anumba and Ruikar, 2008). The main benefits of implementing e-business are identified as cost savings, time savings, quality improvements and improved collaboration (Issa *et al*., 2003; DTI, 2004; European Commission, 2006; Eadie *et al*., 2007; 2010).

Construction organisations and practitioners are motivated for the adoption of e-business by substantial benefits of profitability and the generated value to businesses (Alshawi *et al*., 2008). Implementation of e-business is driven by the potential benefits and organisations which executed e-business believed that it would generate higher revenue, increased profitability and business success (Schneider, 2010). Perrott (2005) identified four categories of e-business drivers as cost-benefit, competitive pressure market advantage and value added. E-business drivers are well documented in the construction industry and Table 2.2 below presents the drivers identified from published literature (Issa *et al*., 2003; Stockdale and Standing, 2004; European Commission, 2006; Eadie *et al*., 2007; 2010).

Table 2.2: Drivers and Benefits of E-Business

E-Business Drivers
Increase transaction accuracy
Efficiency of business transaction processing
Condense business cycle times
Reduce cost
Improve customer service
Improve collaboration
Eliminate obstacles between corporate business partners or customers
Market transparency
Increase communications
Enhance customer relationship management
Increase predictability

E-Business Drivers
Increase productivity
Reduce defects
Innovation of product
Reduce capital costs
Reduce travel costs
Expansion of partnership
Improve industry standards
Expansion of geography
Reduce the cycle time of purchases
Reduce personnel cost
Decreases stocking requirements
Lower inventory management cost
Better customer relationships
Enhance new procurement concepts
Easy to handle large projects
Add value to the enterprise by increasing revenues and decreasing costs
Process, transaction and administration cost savings
Increase quality through increased accuracy
Convenience of archiving completed work
Shortened internal and external communication cycle times
Increase profit margins
Reduce in evaluation time
Gaining competitive advantages
Develop technical skills, knowledge and expertise of staff
Increase transparency
Increase quality through increased visibility in supply chain
Increase quality through increased competition

2.3.3 E-Business Barriers and Adoption Issues in the Construction Industry

Despite the fact that e-business offers more benefits to organisations, it is noticeable that e-business approaches are also associated with some barriers. Behind the rewards, there are some likely challenges as well. These barriers of e-business need to be identified and addressed in order to improve successful execution and inspire its adoption in the industry (Anumba and Ruikar, 2008). Aranda-Mena and Stewart (2005) identified and categorised construction e-business barriers according to different types and sizes of organisations. Stewart *et al*., (2004) identified barriers in organisational level and project level. Following Table 2.3 summarise the barriers of e-business identified from published literature (Stewart *et al*., 2004; Stockdale and Standing, 2004; Aranda-Mena and Stewart, 2005; Peansupap and Walker, 2006; Eadie *et al*., 2007; 2010).

Table 2.3: Barriers of E-Business

Barriers
Trust
IT skills training and literacy
Cultural change
Business process change
Goods unsuitable for e-sale
Services unsuitable for e-sale
Lose of current clients
Uncertainty of financial returns
Initial financial cost
Privacy issues
Lack of reliable measurement
Need for face to face communication
Management commitment
Maintenance running cost
Connection speed
Technological updates

Barriers
Quality and reliability of current infrastructure
User authentication and fraud
Dissatisfied with performance
Technical complexity and lack of user-friendly interfaces
Incompatibility with already existing ICT systems
Some e-business solutions are tailor-made for the existing workflow processes
Reluctant to buy-into one off system
Enforceability of electronic contracts
Proof of intent and electronic signatures
Insufficient assessment of system prior to installation
Confidentiality of information
Lack of widely accepted software solutions
Resistance to change
Security in process (Data transmission to the wrong person)
Internal and external interoperability of software
Investment in compatible systems
Lack of publicity and awareness of best practice solutions

The nature of the construction industry itself can be considered as a challenge for ICT and e-business adoption. The industry is fragmented in its structure with very few large companies and a large number of small and medium companies (Paulson, 1995; Egan, 1998; Morton, 2008; Sommerville and Craig, 2006). The large companies tend to embrace innovative trends in the market and are better able to utilise them to achieve competitive advantages (Heyes, 2000). However, the majority of more than 90% small and medium companies fight to survive in the market and have limited resources to invest and embrace new ICT advancements (European Commission, 2006). Large size of the initial IT investments are crucial for most SMEs in the industry (Elliman and Orange, 2000; Anumba and Ruikar, 2002). This e-business usage gaps from large scale to small, medium and micro level organisations have to be narrowed and managed to enable the optimal growth of ICT adoption for the industry as a whole.

In the early 2000s, infrastructure and security issues were considered as the key challenges that limited the uptake of e-business in the construction industry (Ugwu *et al*., 2000). Examples included the required frequency of system upgrades, security concerns and data reliability issues in online transactions, and interoperability of distributed software applications over the Internet. However, the technological barriers to e-business can be overcome if the infrastructure for e-business use was properly created, and security issues can be addressed through firewalls and secure encryption technologies (Ruikar and Anumba, 2008). Moreover, with the emergence of new collaborating technologies and service models like cloud platforms; the financial barriers can also be overcome.

Later, industry experts identified that the barriers to the effective adoption and use of e-business as human resources and culture (Aranda-Mena, and Stewart, 2005; Ruikar et al., 2006; Zou and Soe, 2006; Alshawi, 2007). E-business implementation affects business processes of organisations, and this impact will cause changes in organisational goals, technology, vision, training, policies, culture, mission and business strategy (Ruikar and Anumba, 2008; Chaffey 2011). Building trust and confidence in staff to commit to e-business is also crucial (Industry Canada, 2007). Therefore, to improve e-business implementation, it is important to create a positive organisational culture that informs, equips and encourage staff members to learn and adopt e-business initiatives in future (Ruikar and Anumba, 2008).

Alshawi (2007) has identified that 80%-90% of IT/IS have failed to achieve their intended business objectives in past and this has become an issue for current and future IT adoption in the industry. The main reason behind this failures are not pure technical issues of the systems; but more related to the organisational capability to successfully absorb ICT into its work practices. (Alshawi, 2007). Furthermore, he identified that there are plenty of isolated e-business initiatives with no collaborating strings in the industry due to ad-hoc IT investments. Technologies alone are not sufficient to assure the success of e-business implementation. E-business solutions must be accompanied with business processes reengineering, change management, and interaction with business partners (Chaffey, 2009; Laudon and Laudon, 2009). Potential benefits and gains

resulting from new technologies are only anecdotal until their value has been proven in actual practice.

Alshawi (2007) attributed this issue to the business-pull and technology-push paradigms. Under business pull, organisations responds to the demand of marketplace through the development of relevant ICT and innovations are initiated by relying on strong market need alone. But, for a unique industry like construction where more than 90% is small and micro firms; it is difficult to achieve innovation and performance improvement by relying on business pull alone. On the other hand, technology push provides new technology-based business opportunities that can lead to new innovations led by other industries. However, the biggest challenge is how to integrate those technologies into their current business processes to maximise benefits to the business and to minimise risk to failure. This requires organisations to achieve necessary competencies and capability levels to strategically benefit from ICT adoptions. The main elements to acquire these capabilities are identified as people, process, work environment and IT infrastructure (Chen, 2006; Alshawi, 2007). The issues surrounded construction e-business are not just technological, but also cultural, human and process related (Aouad *et al*., 2005).

Aouad and Arayici (2010) identified that the IT adoption of construction industry is lagging behind other industries such as automotive, manufacturing and service sector. Construction projects are unique and consist of many interrelated processes and sub-processes with complex information flows. Many project parties are involved in projects and the industry is highly fragmented in its supply chain. This requires a detailed appraisal and consideration of business activities and advanced methods for information management (Ng and Skitmore, 2005). Aouad and Arayici (2010) outlined these as constrains behind the reason for the slow uptake of ICT adoption in Construction. Further, they identified the role of the construction industry in the national economy and culture of the industry as other constrains for ICT adoption. As a result, changes associated with ICT adoption are less inspiring and reluctant in construction organisations (Cao *et al*., 2015). Lack of long term-strategic management thinking and absence of management techniques and methods are also dominant features of ICT adoption challenges in the construction industry (Aouad and Arayici, 2010). Gerrard *et al*.

(2010) recognised lack of expertise, lack of awareness and resistance to change as main barriers impeding the implementation of new approaches as BIM across the construction industry.

2.3.4 E-Business Trends and Approaches in the Construction Industry

E-Business applications can play important roles in each of the various stages of a construction project and they complement most of the business functions of the construction industry. Figure 2.3 below presents some of the common construction e-business trends identified by Anumba and Ruikar (2008).

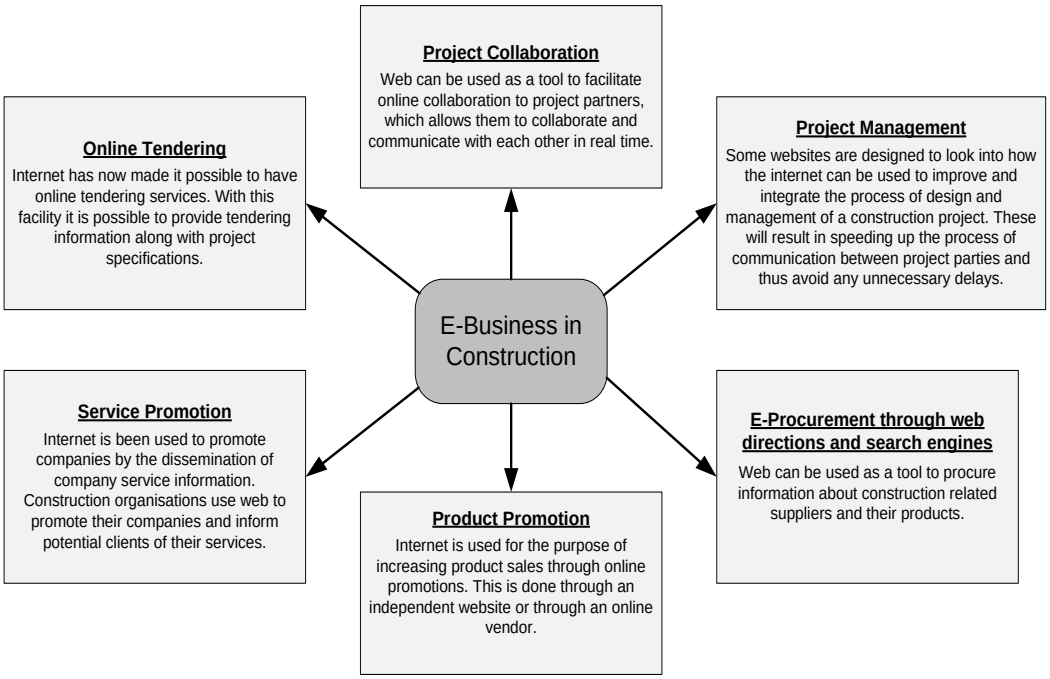

Figure 2.3: Common construction e-business trends (adopted Anumba and Ruikar, 2008)

The main purpose of e-business approaches is to facilitate organisational activities across industry boundaries to achieve economic advantages. Recent emerging enabling technologies and collaboration platforms such as cloud computing, BIM (Building Information Modelling) and web-based project management software has become a platform from which e-business can be utilised, maximised and maintained. Table 2.4 below presents some other construction e-business applications identified from the literature.

Table 2.4: Construction e-business trends and approaches

Construction e-business trends and approaches	**Referenced in**
Project management	Issa *et al*. (2003)
Accounting / finance	
Project collaboration	
Knowledge management / data warehouse	
e-commerce	
e-procurement	
Customer relationship management	
Supply chain management	
Enterprise resource planning	
Digital auctions	
e-procurement	Aranda-Mena and Stewart (2005)
e-transactions	
e-logistics	
e-collaboration	
e-procurement	European Commission (2006)
3D technologies	
Project web	
Enterprise resource planning	
Document management systems	
Document sharing	
Accounting software	
Collaborative design process	
e-invoicing	
e-integrated supply chain management	

Construction e-business trends and approaches	**Referenced in**
Automated financial processes	
e-marketing and sales	
Customer Relationship Management	
Service promotion	Anumba and Ruikar (2008)
Product promotion	
e-procurement through web directories and search engines	
Project management	
Project collaboration	
Online tendering	

Figure 2.3 and Table 2.4 confirms the wider adoption of e-business initiatives in the construction businesses. Many research studies have been carried out aiming to identify the industry specific needs to offer guidance on e-business solutions and approaches particular for construction industry (Construct IT, 2000; 2003; European Commission, 2006). Including aforementioned trends and approaches; enterprise resource planning, e-procurement, e-commerce, e-bidding, e-tendering, e-collaboration, web-based project management, Building Information Modelling (BIM), Internet and e-mail can be identified as some of the main e-business trends within construction industry (Anumba and Ruikar, 2002; Issa *et al*., 2003; Kong *et al*., 2004; Aranda-Mena and Stewart, 2005; Hadikusumo *et al*., 2005; Ruikar *et al*., 2006; European Commission, 2006; Anumba and Ruikar, 2008; Grilo, and Jardim-Goncalves, 2011; Costa and Tavares, 2012; 2014; Kassam *et al*., 2014; Wang *et al*., 2014). These e-business approaches have changed the traditional construction practices in a broader sense of people, process, communication and working culture.

2.4 E-Business Strategy for Construction Organisations

Successful implementation of e-business has received considerable attention in business management and e-business evaluation is identified as a critical aspect for effective adoption and implementation (Anandarajan and Wen, 1999). Organisations implement e-business for their business process considering strategic perspectives to optimize the benefits gained (Betts, 1999; Love *et al*., 2005). A seamless e-business strategy is vital for organisations to ensure productive and sustain implementation of e-business practices. Following section briefly introduces the concept of strategy and explains the importance of an e-business strategy. Several e-business strategy development approaches are discussed to understand the of e-business strategy development process.

2.4.1 E-Business Strategy

The concept of strategy has been initiated in the military and later adopted for use in business sector (Niklos, 2000). Chandler (1962, p. 13) defines strategy as "*the determination of the basic, long-term goals and objectives of an enterprise, and the adoption of course of action and the allocation of resources necessary for those goals*". Similarly in a later study Johnson *et al*. (2008) defines strategy as the direction and scope of an organisation over a long time which achieves rewards for the organisation through its configuration of resources. Ruikar *et al*., (2006) identifies strategy as a generic framework which provides guidance for the actions to be taken. Strategy is emphasised as an important aspect to consider in an organisation to achieve competitive advantages (Betts, 1999; Dobson *et al*., 2004; Hoskisson *et al*., 2008; Chaffey, 2011; Chen, 2013).

2.4.2 Importance of E-Business Strategy

E-business strategy is explained as the approach by which internal and external electronic communication applications can support and influence the corporate strategy (Chaffey, 2011). Several authors revealed that there is a growing tendency for incorporating e-business strategies to businesses and the importance of having an e-business strategy has been recognised by the senior managers (Deise *et al*., 2000; Chaffey, 2011). There are many rewards that an e-business can deliver to an organisation. E-business strategy can endorse the configuration

of business and IT infrastructure to facilitate the maximum benefit from the investment in technology (Beal and Mosse, 2008). If an organisation make business and IT decisions separately without having a strategy, it can lead to failures of technology investments to deliver the expected benefits (Alshawi *et al*., 2008). This highlights the need and importance of having a robust e-business strategy in businesses. At the same time e-business strategy performs as an approach to reduce the uncertainty and risk associated with changing traditional business operations to electronic means and to the Internet (Daghfous and Al-Nahas, 2006).

IT strategy has a similar intention to e-business strategy and can identify as synonyms. Yet, Chaffey (2011) stated that IT strategy was intended to support the e-business strategy. Zeng and Li (2008) differentiate the two terms as IT strategy identifies the IT infrastructure required to sustain business functions whereas e-business strategy defines how organisation is operated within management, processes and systems. This argument suggests considering IT strategy as a sub element of e-business strategy. However IT is an internal driver of e-business implementation of an organisation and the two elements are closely interconnected. It is apparent that an organisations needs to have a robust e-business strategy to obtain guidance in future direction of e-business developments and to maximize and utilise their resources.

2.4.3 E-Business Strategy Development Approaches

Robust e-business strategy ensures productive and sustain implementation of e-business practices within an organisation. Recent literature reveals different models which are developed to support e-business strategy formulation. Following section reviews several prominent e-business strategy development approaches identified from the literature.

2.4.3.1 The Roadmap for E-Business

Kalkota and Robinson (2001) developed a model called 'Roadmap for E-Business' for e-business strategy planning and implementation. Four stages of planning and formulating an appropriate e-business strategy were identified in the model as consider knowledge building and evaluate e-business capabilities, e-business

design based on organisation business goals, decide priorities for investment by developing a high level action plan (called blueprint of action in the model) and plan for technological e-business applications and finally develop e-business applications and deployment. The main focus of the Roadmap for E-Business strategy model is continuous review and prioritisation of investment in new e-business applications. It suggests the procedures for gather feedback for learning and improvement. The importance of a situation analysis based on customer demands and technological trends also emphasised within the model for organisations in traditional business sectors (Kalkota and Robinson, 2001). This model is suitable for organisations to define an evolving e-business strategy. Moreover this model helps to rapidly respond to market dynamics and innovations.

2.4.3.2 E-Business Strategy Framework

Jelassi and Enders (2009) developed 'E-Business Strategy Framework' for e-business strategy formulation and implementation based on three key dimensions of e-business strategy. Three considerations behind the framework were determining where the organisation will compete within the external micro-environment, what type of value will it create and how should the organisation be designed to deliver value. According to the E-Business Strategy Framework, an organisation should go through three phases (situation analysis, strategy formulation and strategy implementation) to plan and implement e-business strategies. Initial phase is situation analysis which includes an internal analysis to determine e-business competences and an external analysis to determine the impact of new technologies on the macro-environment and on the industry structure. Second phase is strategy formulation which analyses strategy options based on type of value they would generate for organisation. Final phase is strategy implementation which considers implementation of strategy and the managing changes of organisation structure and its relationships. However, even though e-business creates both tangible and intangible value to organisations, this framework is mainly considering only the tangible value of e-business strategy options in strategy formulation.

2.4.3.3 Strategic E-Business Framework for Construction

Chen (2012) developed the 'Strategic E-Business Framework' which offers a holistic approach for construction organisations to execute e-business strategy formulation, implementation and review. The Framework comprises of six phases as Analyse Situation, Establish Vision, Determine Critical Success Factors, Develop Action Plan, Implement Action Plan and Review Strategy. Organisation can develop a complete e-business strategy and an implementation plan by following through these six phases. Strategic E-Business Framework also includes five factors by which to categorise the main activities involved in each phase. By addressing each of these five factors, industry practitioners can make their organisations ready for implementation of e-business. Further, this framework specifies the roles and responsibilities relating to each of the defined activities, which will help organisations to utilise their available IT resources and maximise the benefits of e-business. However this framework has the limitation of lack of in-detail explanations associated with lower level actions, tools and techniques which require when implementing the framework. Further this framework does not address the feature of continuous improvement of e-business to meet the changing industry needs and to keep up-to-date with the technological developments.

2.4.3.4 UK Construction BIM Strategy and BIM Toolkit

UK Government Construction Strategy was published in May 2011 and it announced the Government's intention to require collaborative 3D BIM (Level 2), with all project and asset information, documentation and data being electronic on its projects by 2016. The objectives behind the strategy were build and operate assets more cost efficiently, reduce environmental impact and improve UK exports of professional services and construction projects (CGS, 2011).

NBS was awarded to develop a BIM Toolkit for BIM in September 2014 ahead of the 2016 deadline for use of collaborative 3D BIM on public sector projects (NBS, 2015a). The Toolkit is a web-based resource tailor-made to guide users through the construction process which will benefit both public and private sector construction projects. NBS successfully launched the beta version of BIM toolkit in April 2015. It is a free to use toolkit which offers a straight-forward and

intuitive way of defining, managing and validating responsibility for information development and delivery through a project's lifecycle (NBS, 2015b).

NBS BIM Toolkit moved out of beta status in October 2015, ensuring its true readiness for project use (https://toolkit.thenbs.com). It defines who is doing what and when on Level 2 BIM projects and combines a standardized and digitally-enabled classification system with a level-of-definition reference library and digital plan of work tool (NBS, 2015c). The Toolkit enables clients and managers to clearly define information requirements. It supports design and construction teams to assemble a team with clearly defined roles and responsibilities to work collaboratively on construction projects. Further Manufacturers are benefited by being able to supply digital information at the point of specification. With the latest release, a range of collaborative features have also been developed in the Toolkit interface allowing members of a project team to view and comment on tasks they have been assigned (NBS, 2015c).

2.5 E-Readiness and Maturity Models

The implementation of e-business has broadened the boundaries and capabilities of organisations bringing in opportunities to achieve competitive advantages, productivity improvements and efficiency savings. The effective implementation and use of e-business is vital for any organisation to achieve potential benefits and rewards. There are several approaches initiated by researchers to encourage and support e-business adoption. This section presents and discusses strategy development approaches, e-readiness models and maturity models focused on successful e-business implementation and evaluation.

2.5.1 E-Readiness Models

E-readiness is defined as "*the ability of an organisation, department or workgroup to successfully adopt, use and benefit from information and communication technologies*" (Ruikar *et al*., 2006: p.99). In other terms, it is how able and ready an organisation is to adapt electronic processes for their day to day business activities. Implementation of e-business in an organisation involves modifications in its current practices, systems, processes and workflows. Therefore, organisations need to take measures on their organisational e-readiness

to successfully adopt and use e-business tools. Evaluating and measuring organisational e-readiness is important to companies to ensure a productive and beneficial implementation of e-business tools within their businesses.

There are several attempts of measuring organisations' e-readiness and an increasing number of readiness assessment tools have been developed over last few years. These e-readiness models and tools have been developed to assess how ready an organisation, an industry or an economy is to adopt ICTs and e-business (Peters, 2001). Existing e-readiness tools use various approaches for readiness assessment, including different methods for measurement, different underlying goals and focuses and different definition of e-readiness. Some of the e-readiness models are reviewed in following Table 2.5.

Table 2.5: E-Readiness Models

Model Name	**Description**	**Reference**
Readiness Assessment Tool	Measure and analyse the worldwide growth of the internet	Mosaic Group (1998)
E-commerce Readiness Initiative	Focuses on government policies for e-commerce	APEC (2000)
Network Readiness Index	Defines e-readiness as the degree to which a community is prepared to participate in the networked world	Kirkman *et al*. (2002)
SCALES (Supply Chain Assessment and Lean Evaluation System)	Assess the readiness to adopt different concepts and approaches	K3 Business Technology Group (2006)
STOPE (Strategy, Technology, Organization, People and Environment) model	Asses general ICT readiness investigating strategic issues, technology issues, management issues, organisational issues, people issues and environmental issues	Al-Osaimi *et al*. (2006)

VERDICT (Verify End-user e-Readiness using a Diagnostic Tool)	Internet based prototype application that assesses the overall e-readiness of end user companies and profiles by considering management, process, people and technology aspects	Ruikar *et al*. (2006)
IS/IT Readiness Model	Assess readiness of an organisation for an IS/IT project in terms of people, processes, technology and environment.	Alshawi (2007)

Key construction specific e-readiness models are examined in detail in the following section.

2.5.1.1 Verify End-user e-Readiness using a Diagnostic Tool - VERDICT

Ruikar *et al*. (2006) presents Verify End-user e-Readiness using a Diagnostic Tool (VERDICT) as an e-readiness assessment model which can be used to measure the readiness of construction organisations for e-commerce. VERDICT is internet based prototype application that assesses the overall e-readiness of end user companies and profiles by considering management, process, people and technology aspects. VERDICT model is developed based on the principle that for any company to be e-ready, its management, people, process and technology have to be e-ready (Ruikar *et al*., 2006). Organisations cannot use VERDICT to measure their overall e-readiness; but can use it to periodically review their progress in achieving e-readiness by using the four categories as key performance indicators. Figure 2.4 presents a typical table summarising average scores in each category with traffic light indicators of VERDICT.

Category Name	Average Score	Traffic Light Indicator
Management	3.33	Amber
People	3.62	
Process	3.83	Green
Technology	4.46	

Figure 2.4: Typical table summarising average scores in each category with traffic light indicators of VERDICT (Ruikar *et al*., 2006)

The scores of each category are averaged and presented with traffic light indicators of red, green and amber lights to visually indicate their e-readiness in each category. Red indicates that several aspects within a particular category need urgent attention to achieve e-readiness. Amber indicates that certain aspects within a particular category need attention to achieve e-readiness. Green indicates that the end-user organisation has adequate capability and maturity in these aspects and therefore is e-ready. In addition to this traffic light indicators, VERDICT gives an indication of critical issues that companies need to address to achieve e-readiness and points out organisations' strengths and weaknesses regarding its readiness for using e-commerce tools. Further, being Internet-based, the system is platform-independent and provides all the benefits of using the Internet such as flexibility, accessibility, portability, device independence and economical. However, VERDICT does not define measures for organisations to address the issues of highlighting areas and the necessary procedures for them to go through to make improvement in such areas.

2.5.1.2 IS/IT Readiness Model

Alshawi (2007) developed 'IS/IT Readiness Model' to assist organisations in the construction industry to successfully implement information technology and information systems. The Model describes the readiness of an organisation for an IS/IT (Information System/Information Technology) project in terms of four

categories; people, processes, technology and environment. IS/IT Readiness Model illustrates these four elements in detail using a criteria describing the attributes related with each of them. Attributes of the people category are head of IS/IT function, staff and skills. Process category considers general practices and technology category considers systems in terms of hardware, software, communication and networks as attributes. Environment category consists of culture, leadership and structure attributes. Under each category these attributes are described as they might occur in each of the six maturity levels. However, how organisations can improve their organisational readiness from the lowest to the highest level has not been addressed in the model. The structure of the IS/IT Readiness Model is presented in Figure 2.5.

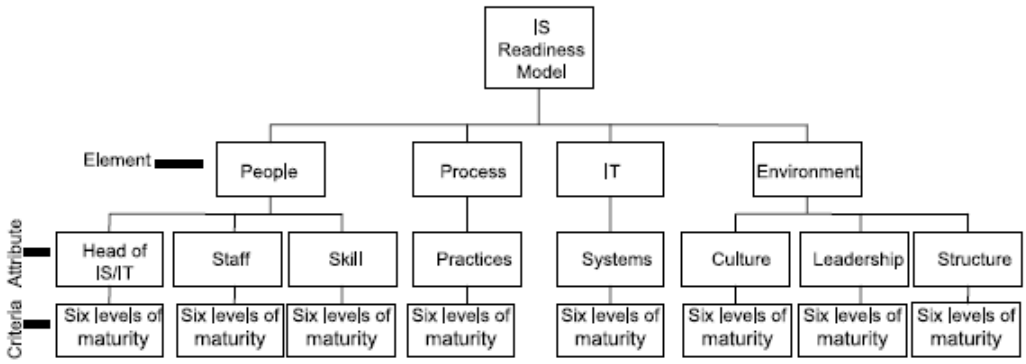

Figure 2.5: The structure of the IS/IT Readiness Model (Alshawi, 2007)

2.5.2 E-Business Maturity Models

Maturity is defined as the degree to which organisational processes and activities are executed following principles of good practice (Alshawi, 2007). Maturity concept encourages repeatable and predictable outcomes within a process or practice in an organisation. The fundamental concept behind maturity is that mature organisations carry out processes systematically while immature organisations does not have systematic processes and their success relies on individual efforts and unstructured approaches (Becta, 2005). As a result, mature organisations consistently accomplish schedules and goals and achieve right outcomes in an efficient manner (Harmon, 2004).

Early maturity model approaches were emerged from the area of software engineering (Humphrey 1989). They were developed targeting the need to measure and control processes more thoroughly. The first maturity model in the software development field was the Capability Maturity Model (CMM) of Carnegie Mellon University (Paulk *et al*., 1993). Maturity models are designed to support improvement in processes, products and delivery (Alshawi, 2007). They aim to help organisations to benchmark themselves and to identify next steps for organisational development. Maturity level indication gives an evidence of the effectiveness and efficiency of an organisation and probable quality of its outcomes. Maturity model concept has been widely adopted by organisations in several disciplines worldwide. Thus, many maturity models have been developed and used by organisations over the past several years. Key maturity models developed within e-business and construction contexts are presented in the following section.

2.5.2.1 E-Business Capability Maturity Model (EB-CMM)

E-Business Capability Maturity Model (EB-CMM) was developed by Chen *et al*. (2006) focusing cosmetic and drug industry. They applied the concepts of original CMM and CMMI for electronic business practices in the cosmetic and drug industry. EB-CMM has both capability and maturity representations and they represent the different focus on process and organization.

EB-CMM is comprised with 6 maturity levels and 7 capability levels. Maturity levels are named as Initial, Internal, Integrated, Defined, Quantitatively Managed and Optimising. Capability levels of the model are Incomplete, Performed, Internal, Integrated, Defined, Quantitatively Managed and Optimising. In the model capability representation describes how an organisation does regarding a particular process area and maturity representation describes the entire organization performance on certain e-business related process areas. The model provides what-to-do implementation suggestions for organizations to electronically perform certain core activities for certain process category. Maturity levels and their process areas of EB-CMM are presented in below Figure 2.6.

ML	Level Name	PA	Process Area and the Description
2	Internal	OP	**Order processing:** Managing and tracking orders in order to know the status.
		DM	**Document management:** Electronically managing ad-hoc business documents using IT tools.
		NM	**Network management:** Establishing internal/external network infrastructure.
		ISS	**Information and systems security:** Ensuring secure use of internal information, information system and network environment.
		TS	**Technical solution:** Providing candidate IT solutions evaluation.
		SD	**System development:** Describing and managing IT system implementations.
		RSKM	**Risk management:** Identifying and managing potential problems before an IT solution is implemented.
3	Integrated	OLAP	**OLAP, on-line analytical processing.** Performing online multi-dimensional data warehousing analysis.
		INE	**Integrated network between enterprises:** Establishing and integrating business networks between enterprises.
		ICRM	**Integrated customer relationship management:** Establishing and integrating front-end and back-end sales and customer information for offering better, more flexible customized serviced or products.
		EDI	**Electronic data interchange:** Establishing and integrating standards and platforms for information exchange automation.
		EAI	**Enterprise application integration:** Integrating internal or external information systems
		EKMS	**Electronic knowledge management and sharing.** Establishing online information indexing and knowledge querying services
		IISS	**Integrated information and systems security:** Establishing security mechanisms between systems or between organizations.
		IOPF	**Integrated order processing and forecasting:** Integrating sales information among players for better business forecast.
4	Defined	WFM	**Workflow management:** Defining, managing, and automating business processes.
		OCE	**Organizational culture and environment for EB:** Developing and maintaining EB implementation culture and environment.
		EPF	**Electronic process focus:** Understanding current situation of EB process, planning EB process improvement.
		EPD	**Electronic process definition:** Establishing and maintaining EB process assets for managing existing and composing new EB processes.
		DAR	**Decision Analysis and Resolution.** Establishing evaluation criteria for stakeholders to make valid decision.
5	Quantitatively Managed	QEBP	**Quantitatively EB Performance.** Establishing and maintaining key performance indices for measuring ad-hoc EB processes.
		QSQM	**Quantitatively system quality management:** Establishing and maintaining key performance indices for measuring the performance of ad-hoc information system.
6	Optimizing	CAR	**Causal analysis and resolution:** Analyzing the root causes of EB problems, taking corrective actions and preventing from recurrence.
		OID	**Organizational innovation and deployment:** Choosing innovative information technologies for continually optimizing electronic business performance.

Figure 2.6: Maturity levels and their process areas of EB-CMM (Cheng *et al*., 2006)

This model can be identified as a generic e-business capability maturity model for organisations in the cosmetic and drug industry. However the applicability of this model to the construction discipline is debatable as construction is a unique industry and as it has distinctive characteristics from other industries. Therefore in order to consider EB-CMM in construction context, the internal components and process areas have to be carefully investigated and the applicability of EB-CMM process areas for construction organisations have to be confirmed.

2.5.2.2 National Building Information Model Standards' Capability Maturity Model

The Unites States National Building Information Model (NBIM) Standard proposed a CMM for use in measuring the degree to which a building information

model implements a mature BIM Standard (NIST, 2007). The idea was to allow BIM users to plot their current position and to set goals for their future operations (NIBS, 2007). NBIMS' CMM is available for use as a standardised tool to assist users with BIM evaluation and development. There are two versions of NBIMS' CMM. Firs version is a tabular version identifying eleven areas of interests measured against ten levels of increasing maturity. The areas of interest include; data richness, life-cycle views, change management, roles or disciplines, business processes, timeliness/response, delivery method, graphical information, spatial capability, information accuracy, and interoperability/IFC support (NIBS, 2007).

Maturity Level	A Data Richness	B Life-cycle Views	C Roles Or Disciplines	G Change Management	D Business process	F Timeliness/ Response	E Delivery Method	H Graphical Information	I Spatial Capability	J Information Accuracy	K Interoperability / IFC Support
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	No CM Capability	Separate Processes Not Integrated	Most Response Info manually re-collected - Slow	Single Point Access No IA	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Aware of CM	Few Bus Processes Collect Info	Most Response Info manually re-	Single Point Access w/ Limited IA	2D Non-Intelligent As Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Aware of CM and Root Cause Analysis	Some Bus Process Collect Info	Data Calls Not In BIM But Most Other Data Is	Network Access w/ Basic IA	NCS 2D Non-Intelligent As Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Aware CM, RCA and Feedback	Most Bus Processes Collect Info	Limited Response Info Available In BIM	Network Access w/ Full IA	NCS 2D Intelligent As Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Information	Includes Constr/Supply & Fabrication	Partial Plan, Design&Constr Supported	Implementing CM	All Business Process(BP) Collect Info	Most Response Info Available In	Limited Web Enabled Services	NCS 2D Intelligent As-Builts	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative Information	Add Limited Operations & Warranty	Plan, Design & Construction Supported	Initial CM process implemented	Few BP Collect & Maintain Info	All Response Info Available In BIM	Full Web Enabled Services	NCS 2D Intelligent And Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data w/ Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	CM process in place and early implementatio	Some BP Collect & Maintain Info	All Response Info From BIM & Timely	Full Web Enabled Services	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	CM and RCA capability implemented	All BP Collect & Maintain Info	Limited Real Time Access From BIM	Web Enabled Services - Secure	3D - Current And Intelligent	Part of a more complete GIS	Full Computed Areas &	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Management	Full Facility Life-cycle Collection	All Facility Life-Cycle Roles Supported	Business processes are sustained by CM using RCA and Feedback	Some BP Collect&Main t In Real Time	Full Real Time Access From BIM	Netcentric SOA Based CAC Access	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Management	Supports External Efforts	Internal and External Roles Supported	Business processes are routinely sustained by CM, RCA and Feedback loops	All BP Collect&Main t In Real Time	Real Time Access w/ Live Feeds	Netcentric SOA Role Based CAC	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

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Figure 2.7: Tabular BIM Capability Maturity Model (NIBS, 2007)

Second version is an Interactive Capability Maturity Model (I-CMM). It is a multi-tab Microsoft Excel workbook based on initial tabular model (NIBS, 2007). Following Figure 2.8 presents the I-CMM. The administration portion of the I-CMM provides categories for scores levels within the model. These categories range from 'Minimum BIM' to 'Platinum'. The scoring levels within the I-CMM reflect the maturity level of an individual BIM as measured against a set of weighted criteria agreed to be desirable in a BIM.

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The Interactive BIM Capability Maturity Model

Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
Data Richness	84%	Data Plus Expanded Information	4.2
Life-cycle Views	84%	Add Construction/ Supply	2.5
Change Management	90%	Limited Awareness	2.7
Roles or Disciplines	90%	Partial Plan, Design&Constr Supported	4.5
Business Process	91%	Some Bus Process Collect Info	2.7
Timeliness/ Response	91%	Data Calls Not In BIM But Most Other Data Is	2.7
Delivery Method	92%	Limited Web Enabled Services	4.6
Graphical Information	93%	3D - Intelligent Graphics	6.5
Spatial Capability	94%	Basic Spatial Location	1.9
Information Accuracy	95%	Limited Ground Truth - Int Spaces	2.9
Interoperability/ IFC Support	96%	Most Info Transfers Between COTS	4.8
		Credit Sum	**40.0**
		Maturity Level	Minimum BIM

National Institute of BUILDING SCIENCES
Facilities Information Council
National BIM Standard

ADMINISTRATION	Points Required for Certification Levels		
	Low	High	
	40	49.9	Minimum BIM
	50	59.9	Minimum BIM
	60	69.9	Certified
	70	79.9	Silver
	80	89.9	Gold
	90	100	Platinum
Remaining Points Required For:		Certified	20.0

Figure 2.8: Interactive BIM Capability Maturity Model

The goals of both tabular and interactive versions of CMM are to help users gauge their current maturity level, as well as plan for future maturity attainment goals through a commonly accepted, standardized approach.

2.5.2.3 Building Information Modelling Maturity Matrix (BIM^3)

Succar *et al*. (2012) presents Building Information Modelling Maturity Matrix (BIM^3) which includes a set of maturity levels which indicate the evolutionary improvement of processes, technologies and policies within each BIM Stage. Maturity index of BIM^3 was developed by analysing and integrating several models from different industries. It has five maturity levels named Initial/Ad-hoc, Defined, Managed, Integrated and Optimises. Its maturity levels reflect the extent of BIM abilities, deliverables and their requirements as opposed to minimum abilities reflected through capability stages. Succar (2009) introduces BIM^3 as a knowledge tool which incorporates many BIM framework components for the purpose of performance measurement and improvement. The components of BIM Maturity Matrix are represents in following Figure 2.9.

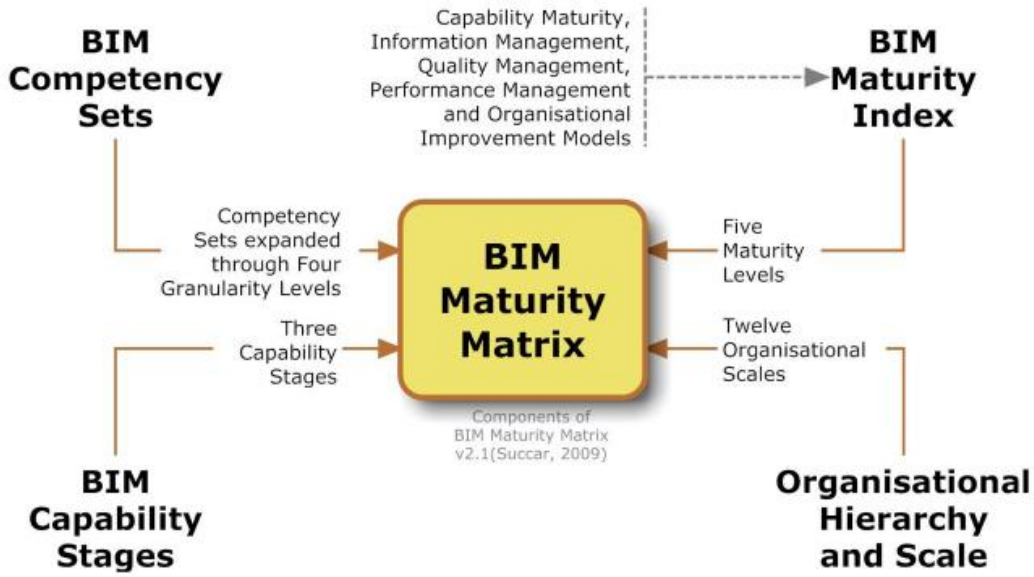

Figure 2.9: Components of the BIM Maturity Matrix (Succar, 2009)

The BIM Maturity Matrix incorporates maturity index for a set of competencies, capability stages and organisation scales. Competency areas include Technology, Process and People which expand through four granularity levels. Three capability stages are presented as Modelling, Modelling based collaboration and Network based integration. Organisation scales include in the model are micro, meso and macro. Industry practitioners can use the BIM Maturity Matrix to increase their capability across a range of technology, process and policy steps. It provides an assessment tool to measure BIM capability and maturity at selective organisational scales and granularity levels. Organisations can use BIM^3 to continuously assess and improve their BIM performance.

2.5.2.4 VDC Scorecard

The Centre for Integrated Facility Engineering (CIFE) of Stanford University developed the VDC Scorecard to provide a holistic, quantitative, practical and adaptive approach to evaluate and track Virtual Design & Construction (VDC) performance. It evaluates the maturity of VDC in practice based on an industry performance rating framework, and measures the degree of VDC innovation in planning, adoption, technology, and performance. AEC professionals can use the evaluation framework to track and assess VDC performances of their projects (*Kam et al*., 2013a).

The VDC Scorecard is an evaluation framework that can comprehensively describe VDC implementation using the overall score, 4 Scorecard Areas, 10 Scorecard Divisions, and 56 Scorecard Measures. The structure of VDC scorecard is presented in following Figure 2.10.

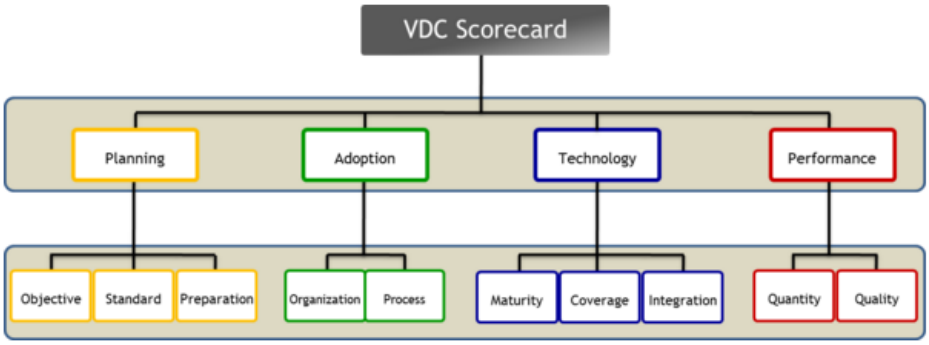

Figure 2.10: VDC Scorecard (CIFE, 2013)

As shown in above figure, the four scorecard areas are Planning, Adoption, Technology and Performance. The Planning Area covers the creation of objectives and standards as well as the availability of technological and fiscal resources that will promote the projects' business goals. The Adoption Area assesses the organizational and procedural aspects of social methods for adopting technology while the Technology Area assesses the product, organization, and process models implemented across five maturity levels. The quantitative and qualitative success in achieving these objectives is measured in the Performance Area (Kam *et al*., 2013b). These main areas are further divided into 10 divisions such as Objectives, Standard, Preparation, Process, Organization, Maturity, Coverage, Integration, Quality and Quantity. Under each division, there is a total of 56 measures that will be evaluated quantitatively or qualitatively.

The Scorecard uses a percentile scale that has been covered with a 5 performance levels for each of the 56 measures and supplemented with an assessment of the certainty in the score. The levels are Conventional Practice, Typical Practice, Advanced Practice, Best Practice, and Innovative 36 Practice. When combined with the percentile scale, the levels allow VDC practitioners and researchers to see how they compare relative to the rest of the industry (Kam *et al*., 2013b).

2.5.2.5 E-procurement Capability Maturity Model

Eadie (2009) developed an e-procurement capability maturity model for construction organisations. The concept for this maturity model also borrowed from original SW-CMM. Initially construction related e-procurement drivers and barriers were identified for the development of the model. Then factor analysis was used to produce a set of Key Process Areas (KPAs) for the model from drivers and barriers. The KPAs were then subjected to a mapping process linking them to maturity levels to develop a CMM to analyse the e-procurement capability of construction organisations. The maturity levels and key process areas of e-procurement CMM are presented in Table 2.5.

Table 2.6: Maturity levels and key process areas of e-procurement CMM

Maturity Levels	E-Procurement CMM KPAs
Level 1 - Initial	No KPAs
Level 2 - Repeatable	Quality Management System Cost Management System Time Management System Operational Analysis
Level 3 - Defined	Intergroup Coordination Integrated Teaming Requirements Development Integration Management system Organisational Environment
Level 4 - Managed	Organisational Change Management System Knowledge Management System
Level 5 - Optimising	Governance Management System

The e-procurement CMM comprises of five maturity levels and 12 key process areas. This model can be used to measure the capability and maturity of e-procurement process in construction organisations.

2.5.3 Discussion

E-business is an innovative approach for traditional construction organisations to gain competitive advantages and product, process and performance improvements. It has substantial benefits for every type of organisations. Successful implementation of e-business is the key to achieve optimum benefits and rewards for an organisation. Therefore careful considerations have to be taken while implementing e-business practices into businesses.

E-business strategy plays an important role to ensure a productive and beneficial e-business implementation in an organisation. Robust e-business strategy will guarantee an effective execution to achieve desired goals. It is important for organisations to scan and position their current situation, and provide a holistic approach to assist them in developing an executable e-business strategy. This demands a thorough understanding of the current e-business condition of the organisation to set future objectives and to decide priorities. Evaluation and analysis of current e-business is critical and vital.

E-readiness models and capability maturity models are used as evaluation tools to determine the current status of e-business implementation of an organisation. E-readiness models gives an indication of how ready an organisation is to adopt e-business approaches with its current capabilities. The restriction of e-readiness models is that they do not provide potential enhancements or methodical guidelines for improvements. Maturity models bridge this gap by providing an indication of e-business maturity of an organisation which leads to an understanding of current status of their e-business capabilities together with systematic approach procedures for higher maturity levels. Thus, maturity models can be used as the initial prior step for developing an e-business strategy for an organisation. Moreover, e-business capability maturity models are process focused and process improvements leads performance improvements of organisational practices.

There are few construction specific e-business models developed in previous researches as described in Section 2.5.2. Currently available e-business capability maturity models are either specific to an industry other than construction or focus mainly on only one e-business approach. There are CMMs developed for specific

e-business approaches in construction organisations as e-procurement and BIM. However, there is no CMM available for construction organisations which covers wide range of construction e-business processes. As defined in the initial section of this chapter, e-business shelters a wide range of business processes carried out with the use of ICTs. There is a need for a construction specific e-business CMM which focuses on different types of construction e-business processes.

Development of a construction specific e-business CMM demands a comprehensive understanding of construction processes and capability maturity concepts. It is important to explore construction process improvement concepts and existing approaches to gain an in-depth understanding of the context. Next chapter describes the concepts of process definition, process thinking and process improvement in construction and comprehensively discusses the fundamental concepts and structure of capability maturity model.

2.6 Summary

This chapter reviewed the literature to gain an understanding of e-business with its taxonomy and enabling technologies. Importance and need of e-business for construction is discussed and established explaining the drivers and barriers of construction e-business. Current construction e-business trends and approaches are investigated and the importance of robust e-business strategy for a construction organisation is highlighted.

Further, current e-readiness models and e-business capability maturity models also reviews in this chapter to establish the research focus and need. It has been established that the e-business capability models is an effective solution for current construction organisations. Existing models are investigated, but there is a visible gap that need to be filled with a full potential construction e-business process improvement strategy. This sets out the theoretical gap addressed within this thesis. Next chapter discusses construction process improvement concepts and capability maturity model fundamentals.

CHAPTER 3

CONSTRUCTION PROCESS IMPROVEMENT AND CAPABILITY MATURITY MODEL (CMM)

3.1 Introduction

Previous chapter reviewed the literature regarding e-business and importance of implementing e-business processes in construction organisations. Further it discussed several e-business process improvement approaches and established the need for an e-business capability maturity model for construction.

Development of a construction specific e-business CMM demands a broad understanding of construction process thinking concepts and capability maturity concepts. Thus, this chapter describes process improvement concepts and approaches in the construction industry and fundamental principles and the internal structure of the initial CMM.

First section of this chapter discusses the importance of process thinking and process improvement initiatives in construction industry. It introduces the process definitions, process classifications, different process improvement approaches, construction process maps and process capability maturity models.

Second section of this chapter explains the fundamental principles of the original CMM and its structural components. Understanding of the basic concepts and values of CMM will assist in borrowing and customising the underline principles of original SW-CMM for the development of an e-business CMM.

3.2 Process Improvement in Construction

There has been a long stream of reports published which identify the need of performance improvement in the construction industry (Latham, 1994; Egan, 1998; 2002; Fairclough, 2002). Many authors recommends that the industry should pay greater attention to processes and organisations should move towards a focus of ‘process thinking’ in order to achieve desired improvements. (Latham,

1994; Egan, 1998; 2002; Atkin *et al*, 2003; Harris and McCaffer, 2013). The following section explains the basic concept of processes and process improvement principles. Further it presents construction process maps and process capability maturity models in order to understand the current status of the process improvement initiatives within the construction industry.

3.2.1 What is a process?

There are various interpretations of a process. The term is defined differently depending on the sector and purpose in which they are functioning. In general, Oxford Dictionary (2014) defines process as '*a series of actions or steps taken in order to achieve a particular end*'. The basic endeavour of a process is to convert inputs into value added outputs (Vonderembse and White, 1996; Koskela, 1992; Cooper, 1994).

In organisational context, SEI (2007) explains a process as a set of activities performed to achieve a given purpose. Davenport and Short (1990) highlight two main characteristics of a business process as they have customers and they cross organizational boundaries and are generally independent of formal organizational structure. Further they define a business process as the logical organisation of people, materials, energy, equipment and procedures into work activities designed to produce a specified end result. A business process transforms a set of inputs into outputs which fulfil customer requirements in the form of products, information or services (Oakland, 2014). It can also be identified as a collection of activities which are performed together to create a value to the customer (Hammer and Champy, 2001; Cooper, 2005).

Ould (1995) identifies some essential features of a business process as follows.

- A process involves activity. People or equipment do things.
- A process also generally involves more than one person or piece of equipment. A process is about groups, it concerns collaborative activity.
- A process has a goal. It is intended to achieve something and produce some results.

Considering aforementioned definitions, organisational processes can be explained as a group of related activities which create value to the customers by converting a series of inputs into specific outputs utilising resources such as people and equipment. And a business process is initiated by and provide results to a customer who may be internal or external to the company.

3.2.2 Process Classification

Business processes in an organisation may have different focuses and forms. Childe *et al*., (1994) presents a process classification which was established by the CIM-OSA Standard Committee in 1989. According to the categorization, business processes are divided into three broad types of processes as:

- Management Processes
- Core (Operation) processes
- Support Processes

Management processes as those which are concerned with strategy and business planning and control. These processes may include all high-level strategic-planning activities. They focus on overall managing activities of an organisation which consider ideas about direction based upon business and environmental information and transform these into a set of strategies, operational goals and performance measures. Core processes concentrate on nourishing clients. They respond to the needs of the client and generate client satisfaction by directly adding value to the output. Support processes act in support of manage and core processes. They might add value indirectly by supporting a core business process or they might add value to the business directly by providing a suitable environment.

The relationship of these three types of processes are illustrated in Figure 3.1.

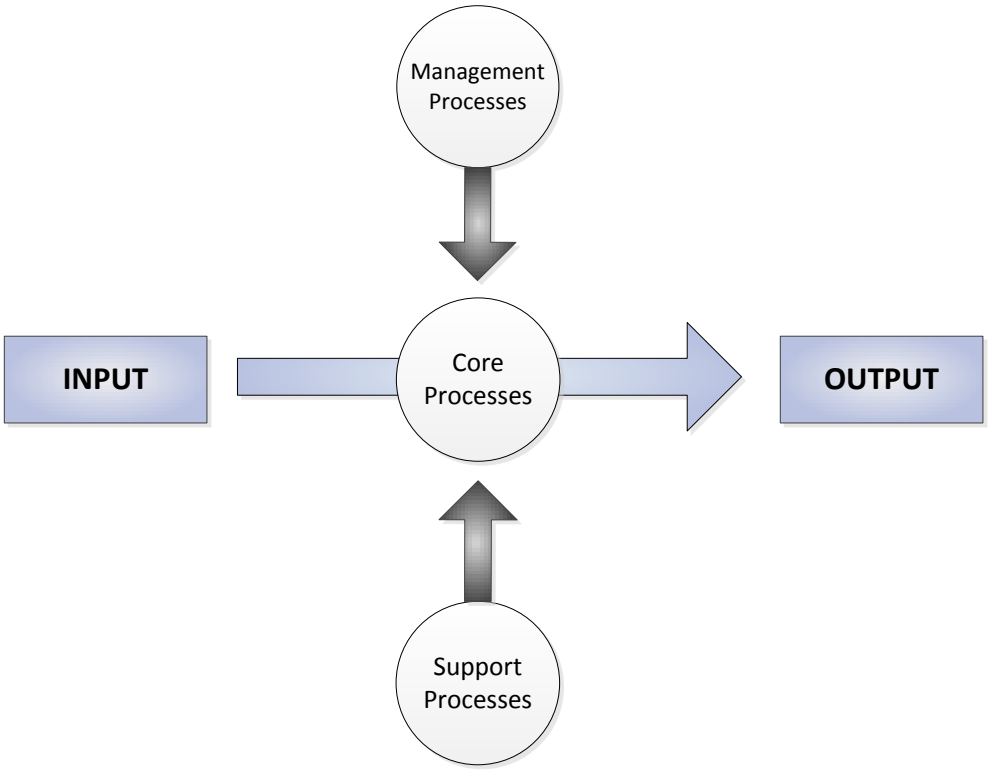

Figure 3.1: Different types of Processes

3.2.3 Process improvement

Process improvement plays an important role in achieving performance improvements in an organisation. Improved processes create improved outcomes or services. There are several process improvement approaches varying from revolutionary approaches to evolutionary approaches. These approaches have different characteristics in terms of the degree of change (radical or incremental), the scope of the exercise (internal or external), the potential risks and benefits (Childe *et al*., 1994).

3.2.3.1 Business Process Re-engineering (BPR)

Business Process Re-engineering (BPR) is one such revolutionary (radical) process improvement strategy initially introduced by Hammer (1990) and Davenport and Short (1990). They outlined a new approach to manage processes to achieve radical improvements in performances and to achieve competitive advantages (O'Neill and Sohal, 1999). According to Hammer and Champy (2001), driving forces behind BPR can be identified as diverse customers, intensified competition and persistent market change.

The aim of BPR is to facilitate the match between market opportunities and business capabilities ensuring commercial growth (O'Neill and Sohal, 1999). BPR demands thinking beyond of existing practices and radical redesigning of business processes to achieve dramatic improvements in performance (Hammer and Champy, 2001). Talwar (1993) explains BPR as rethinking, restructuring and streamlining of the business structure, processes, working methods and management systems through which value is created and delivered. Similarly, Lowenthal (1994) describes BPR as the fundamental rethinking and redesign of operating processes and organisational structure to achieve dramatic improvements in organisational performance.

The various definitions of BPR suggests that the radical improvement of processes is the goal of BPR. However, advocates do not refer specific tools and techniques used in reengineering business processes as BPR's essential components. Therefore, authors and consultants have pursued many different tools and techniques for BPR such as process visualization (Barrett, 1994), process mapping (Cypress, 1994), change management (Mumford and Beekma, 1994), benchmarking (Chang, 1994) and process and customer focus (Vantrappen, 1992; Chang, 1994).

Owing to radical changes to processes proposed through BPR, it often claims to produce significant level of improvements. Although BPR is not without its detractors, there are criticisms of BPR as a process improvement strategy. Considering the nature of the construction industry, Love and Li (1998) identify BPR as a difficult approach to apply in construction due to the ad hoc manner of the industry and complex supply chain arrangements. Due to these complex relationships, BPR might impose negative effects on organisational processes, which would not be apparent for some time after implementation (Dosi *et al*., 1998). Further, there are number of barriers and reasons of BPR failures documented in literature such as failure to reflect organizational culture, management practices, business strategy and people (Davenport, 1993; O'Neill and Sohal, 1999; Mohsen, 2000; Hammer and Champy, 2001; Smith, 2003; Mohsen, 2004; Oakland, 2014).

3.2.3.2 Total Quality Management (TQM)

TQM is an approach to improving the competitiveness, effectiveness and flexibility of an organisation by placing the customer as the focal point of business operations (O'Neill and Sohal, 1999; Oakland, 2014). The primary purpose of TQM is to achieve excellence in customer satisfaction through continuous improvements of products and processes (Ahmed, 1993). The heart of TQM is the concept of management and improvement of the processes to provide quality and excellence products or services to the customers. Oakland (2014) states that TQM approaches develop an understanding of the processes which are operated, and attempt to make the customer as the target of improvement activities. The principles of TQM create the basis for developing an organisation's system for planning, controlling, and improving quality (Deming 1993).

The initial thoughts of TQM concepts were emerged during 1970s in Japanese manufacturing industry and then applied across the world in other disciplines due to TQM paybacks such as increased productivity, decreased product cost and improved product reliability (Arditi and Gunaydin, 1997). As a result, a huge interest was aimed towards establishing quality management frameworks to create organizational wide approach for quality by integrating it to organizational strategy. This trend was followed in Europe in early 1990s by the launch of the European Quality Award by the European Foundation for Quality Management (EFQM). This EFQM framework is considered as the first framework to include business results and to really represent the whole business model (Oakland, 2014). Figure 3.2 presents the EFQM model in action.

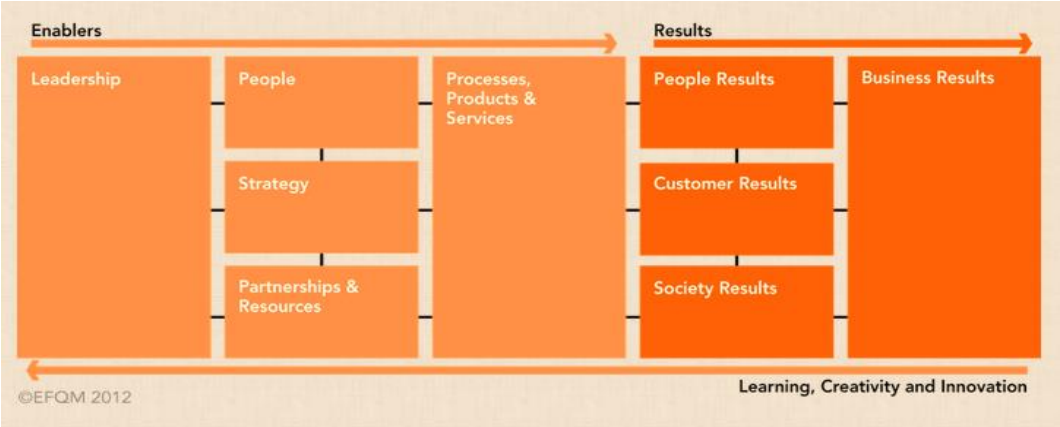

Figure 3.2: The EFQM model (EFQM, 2012)

The EFQM model is a generic model for quality management which can apply in all types of organisations (Nabitz *et al*., 2000). As shown in Figure 3.2, the model presents nine dimensions called 'criterias' which are grouped into 'Enablers' and 'Results'. The nine criterias are Leadership, People, Strategy, Partnerships and resources, Processes, products and services, People results, Customer results, Society results and Business Results. The model is based on the premise that enablers direct and drive results. (EFQM, 2012). It means that an organisation with well-developed enablers will have excellent quality results.

Considering the understanding of TQM concepts developed through the years; Oakland (2014) also establishes a quality management model giving a broad perspective to TQM by linking TQM approaches to the direction, policies and strategies of an organisation.

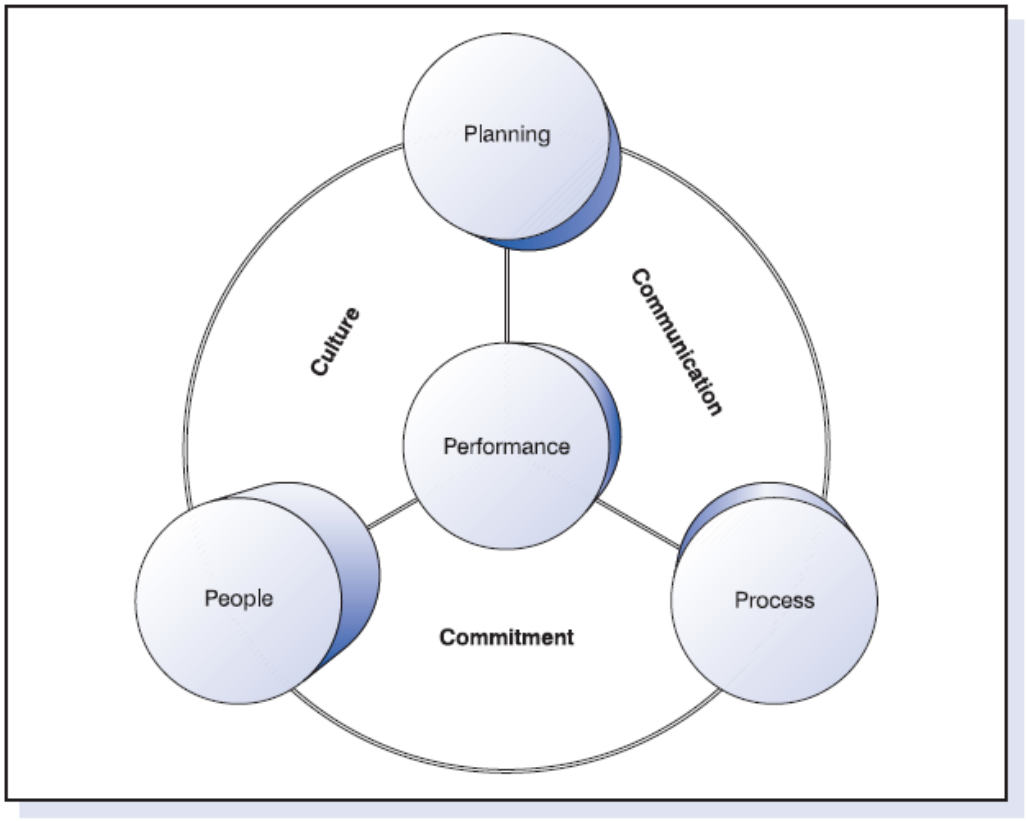

Figure 3.3: The TQM model (Oakland, 2014)

The TQM model (Figure 3.3) comprises with 'four Ps' and 'three Cs'. The 'four Ps' of the model are Planning, Process, People and Performance. They provide the 'hard management necessities' for organizational success. The 'three Cs' are Culture, Communication and Commitment. These are 'soft outcomes' in the

model. The TQM model drives organisations to move forward successfully when 'three Cs' are integrated into the 'four Ps' (Oaklan, 2014).

3.2.4 Process Improvement Initiatives in Construction

The understanding and importance of process improvement as a path of achieving performance improvements has led the development of process improvement initiatives in the construction industry. These initiatives cater the industry as valuable management tools for construction organisations to improve their processes. Following section discusses process mapping models and capability maturity models developed in the construction industry as process improvement tools.

3.2.4.1 Construction Process Models and Maps

Process models and maps can use as a management tool to understand the processes and their values. Lathem (1994) states that reducing variations in the project process can improve performances. Process models and maps can optimise predictability of the processes which leads performance improvements by reducing variations. Over past years, a number of construction process mapping initiatives have been launched in the UK. Following section reviews main process models and maps launched in construction industry.

Royal Institute of British Architects (RIBA) Plan of Work

The first development RIBA plan of work was began in 1964 as a standard method of operation for the construction of buildings. Since its first development, it has been accepted as a consistent model for the building, design and construction process in the UK. It has been widely used not only as a process map but also as a management tool, and provides important work stage reference points for contractual and appointment documents and best practice guidance (RIBA, 2013). RIBA plan of work has been amended and updated over time to reflect expansions in design team organisations, modifications in regulatory systems and innovations in procurement arrangements. The latest version, RIBA 2013 has been recently released and it supersedes the previous versions of RIBA plan of work.

RIBA (2013) admit that the major strength of the previous version, RIBA Outline Plan of Work 2007 was the simplicity of its stages and the clarity of the stage descriptions. Although the RIBA Plan of Work 2013 appears fairly different from the RIBA Outline Plan of Work 2007, its use of stages and task descriptions has not altered fundamentally. Further, RIBA (2013) identifies the significance of its latest version on previous versions by acting across the full range of sectors and project sizes, mapping for all forms of procurement, integrating design processes, mapping Building Information Modelling (BIM) processes and providing flexibility in relation to town planning procedures. It has been developed as an online flexible tool which facilitates the customisation of plan of work according to the relevant procurement route, programme and planning activities.

The RIBA Plan of Work 2013 organises the process of briefing, designing, constructing, maintaining, operating and using building projects into eight key stages and defined by the numbers 0-7 as illustrated in Figure 3.4.

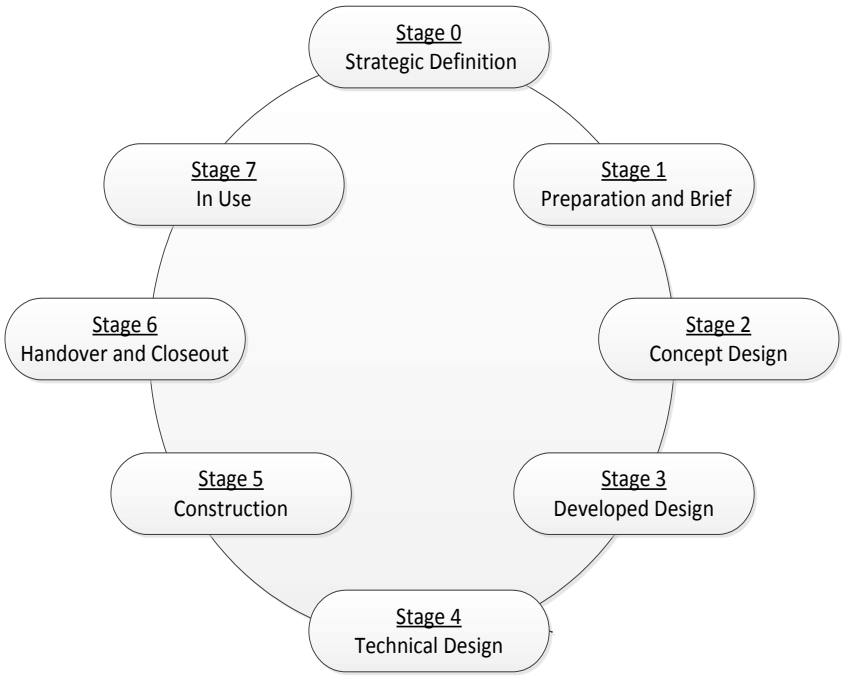

Figure 3.4: Stages of RIBA Plan of Work 2013

RIBA plan of work 2013 defines eight task bars in addition to work stages. These task bars replace the 'Description of key tasks' in the previous version RIBA 2007. Some task bars are fixed, some are variable and others are selectable. The fixed bars ensure the consistency and variable and selectable bars provide

flexibility to customise the work stages according to specific practice or project desires.

Office of Government Commerce (OGC) gateway process

The Office of Government Commerce (OGC) is an independent office of HM Treasury established in 2000. The initiative of the OGC was launched according to the recommendations of the Gershon report which was based on a review of civil Procurement in Central Government (Gershon, 1999). The report identified the need of a common strategic framework for all government departments to conduct their procurement activities. As a result of the Gershon Review, the government established the giving it responsibility for formulating an integrated procurement policy and strategy (NAO, 2004). In 2010, OGC had to face a huge transformational change. All the responsibilities of OGC were moved to the Cabinet Office, which formed a part of the Efficiency and Reform Group (ERG).

OGC provides policy standards and guidance on best practice in procurement, projects and estate management. OGC has developed a number of initiatives to help departments to procure programmes and projects. These have included Gateway Reviews, the Successful Delivery Toolkit, Successful Delivery Skills Programme and the creation of Centres of Excellence within each department (NAO, 2004).

OGC Gateway Review Process is a framework that increases the likelihood of early identification of threats to the successful delivery of major projects. The OGC Gateway Process examines a programme or project at critical stages in its lifecycle to provide assurance that it can progress successfully to the next stage. It is designed to be applied to delivery programmes and procurement projects, including those that procure services, property/construction, IT-enabled business change and procurement using framework contracts (OGC, 2007a-f).

OGC Gateway Review for building projects consist of gateway reviews and decision points. According to OGC, project reviews are carried out under OGC Gateway Reviews 1 to 5. Usually a project will undergo all five of these Reviews during its lifecycle, three before commitment to invest, and two looking at service implementation and confirmation of the operational benefits. Project Reviews

may be repeated as necessary depending on the size, scope and complexity of the project (OGC, 2007a-f).

OGC gateway review consists of six gateway reviews as shown in the Figure 3.5.

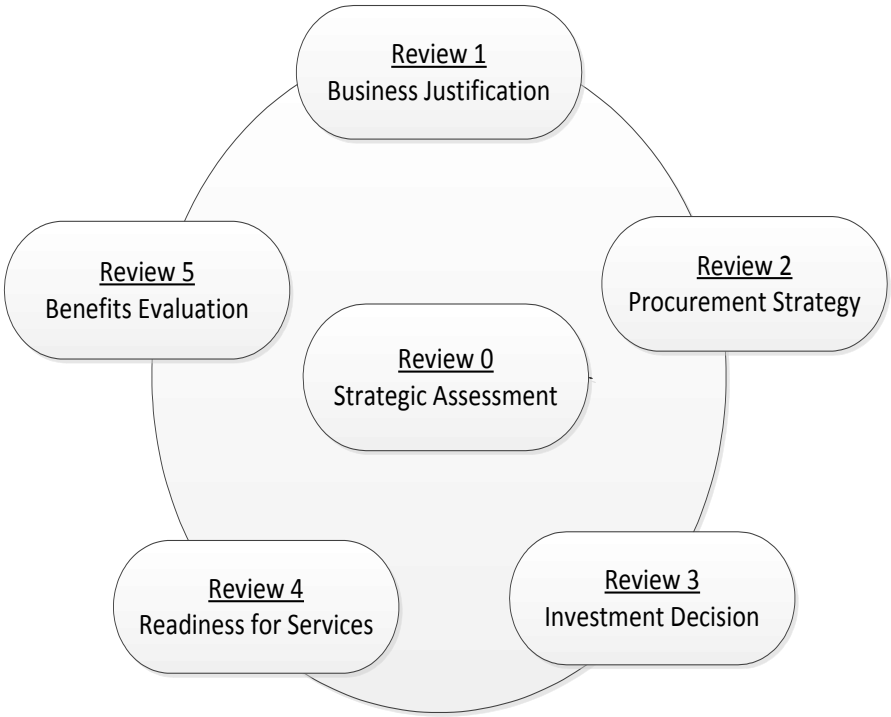

Figure 3.5: OGC gateway review

Generic Design and Construction Process Protocol

Generic Design and Construction Process Protocol is another process map developed for the construction industry. It is a result of a research project which was conducted by research expert team at Salford University and a number of companies, representing different levels of the construction supply chain. The main aim of the research project was to develop an improved design and construction Process Protocol by analysing the current practices in the construction industry and drawing comparisons with similar practices in the manufacturing industry (Kagioglou *et al*., 1998).

The Process Protocol is a framework model that is capable of representing the diverse interests of different parties involved in the construction process (Kagioglou *et al*., 2000). Process Protocol provides the base for different

organisations involved in a project to work flawlessly by establishing common set of definition, documentation and procedures (Cooper *et al*., 1998).

The Process Protocol identifies various phases of a construction project that need to be undertaken to achieve a successful project execution. Process Protocol is divided into a series of major phases defined as pre-project, pre-construction, construction and post-construction. These four major phases are separated from each other through 'hard gates'. Within each of these major phases, there are sub phases that can be operated concurrently or together to make the process more efficient in smaller scale projects. There are ten sub phases and sub phases inside each major phase are separated from each other through 'soft gates'.

3.2.4.2 Standardised Process Improvement for Construction Enterprises (SPICE)

Standardised Process Improvement for Construction Enterprises (SPICE) is an attempt to use the process capability maturity concept within the construction industry. The capability maturity model development was initiated in Carnegie Mellon University by developing first Capability Maturity Model (CMM) in the software development industry (Paulk *et al*., 1993). CMMs are designed to support improvement in processes, products and delivery. The basic viewpoint behind process capability maturity is that a when an organisation becomes mature, the processes also mature and become more predictable and reliable (Stewart and Spencer, 2006). Mature organisations carry out processes systematically while immature organisations does not have systematic processes and their success relies on individual efforts and unstructured approaches (Becta, 2005). Capability maturity models help organisations to benchmark themselves and to identify next steps for organisational development. Maturity level indication gives an evidence of the effectiveness and efficiency of an organisation and probable quality of its outcomes.

The SPICE project carried out developed by a research expert team of Salford University, following the fundamentals of the original Software Capability Maturity Model (Sarshar *et al*., 1999; 2000). Initially the process capability maturity characteristics of lower maturity levels of construction organisations were explored based on the CMM maturity levels one to three (Sarshar *et al.*,

2000; Jeong *et al.*, 2006). Later the process capability maturity characteristics of lower maturity levels of construction organisations were established (Keraminiyage, 2009).

SPICE has borrowed basic concepts from CMM and established a construction specific CMM. SPICE model comprises of maturity levels and key process areas similar to CMM. The five maturity levels of SPICE are illustrated in Figure 3.6.

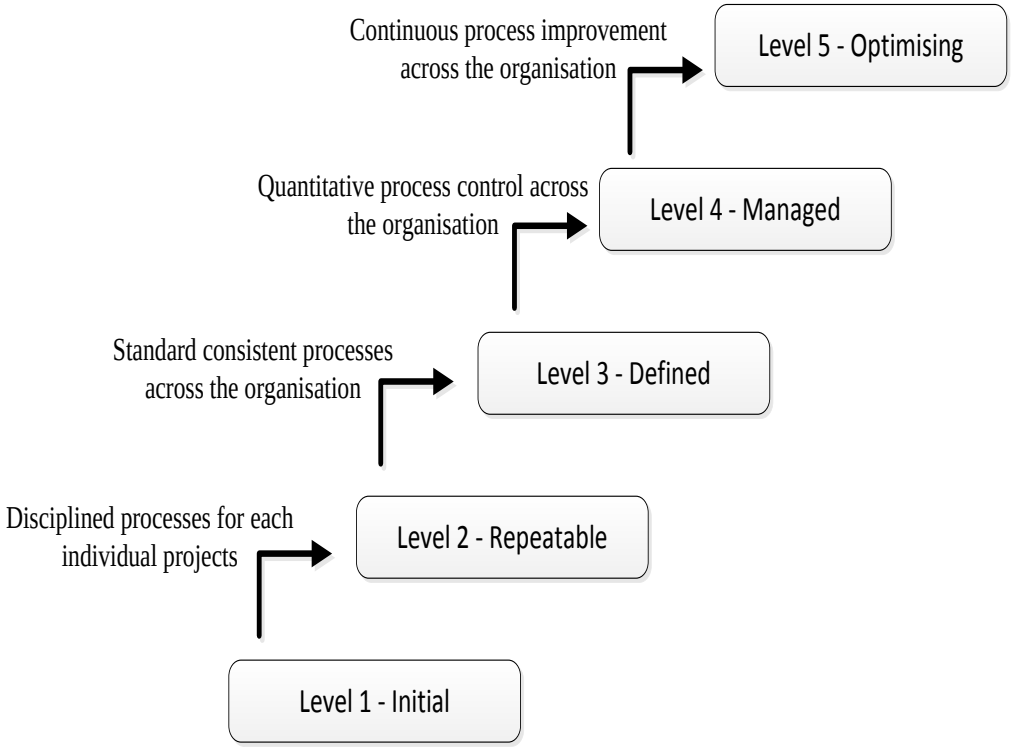

Figure 3.6: SPICE maturity levels (Sarshar *et al.*, 2000)

Each maturity level of SPICE is comprise of key process areas. The ability to perform a key process area is measured against key enablers named Commitment, Ability, Evaluation, Verification and Activities. An organisation should successfully perform all key process areas belong to a particular maturity level in order to achieve the level of maturity. The maturity levels are sequential and organisations cannot skip maturity levels while progressing (Sarshar *et al.*, 1998; 2000).

3.3 The Capability Maturity Model (CMM)

The importance and suitability of adopting the maturity model concept for this research was established in Chapter 2. Capability Maturity Model (CMM) was initiated in the software industry and has been widely applied as a process improvement initiative in many other disciplines such as systems engineering (Bate *et al*., 1995), facilities management (Amaratunga *et al*., 2002), financial management (McDonald, 2002), e-learning (Marshall and Mitchell, 2004), e-procurement (Perera *et al*., 2006; Eadie *et al*., 2007) and construction (Sarshar *et al*., 1999; Keraminiyage, 2009). This section explains the history of Capability Maturity Model (CMM), its fundamental components, other versions of CMM, limitations of CMM and the applicability of CMM concepts within the construction context.

3.3.1 History of the CMM

In late 80s, the software industry realised that there were some dissatisfy assurances about productivity and quality gains from new software methodologies and technologies. In many occasions, projects were frequently excessively late and over the planned budget. Furthermore, there were many raising issues about product quality. Investigations into this issue showed that the fundamental problem was the inability to manage the software process and the benefits of better methods and tools cannot be achieved through undisciplined and chaotic projects (Paulk *et al*., 1993). Further it was suggested that in order to accomplish the possible improvements, the software organisations should achieve and manage mature organisation-wide software process.

In early 90s, The first Capability Maturity Model (CMM) was developed in the software development industry by the Software Engineering Institute (SEI) at the Carnegie Mellon University as a framework to inspect capability maturity of software providers (Paulk *et al.*, 1993). Original CMM was based on the 'process maturity grid' developed by the Humphrey (1987) and it was evolved by alterations and transformations in the structure of the model. This was initiated by United States' Department of Defence (DOD) as a framework to scrutinize the capability maturity of software suppliers who supply software products to the

DOD and US government. Subsequently CMM principles were applied as a process improvement tool in software organisations and it is now one of the most widely adopted process improvement initiatives within many industries such as software, manufacturing, drug and cosmetic, etc. Software CMM (SW-CMM) provides a staged based step-by-step framework which permits businesses to assess where they are positioned within the framework and then provides guidelines on what are their process improvement priorities (Hutchinson and Finnemore, 1999).

3.3.2 Fundamental Concepts of the CMM

CMM is composed focusing fundamental concepts underlying software process. It defines the software process and explains the basic concepts such as process capability, process performance and process maturity. Table 3.1 below summarises and explains these basic concepts within SW-CMM.

Table 3.1: Fundamental concepts of SW-CMM (Paulk *et al*., 1993)

Concept	Explanation
Software process	Set of activities, methods, practices and transformations that people use to develop and maintain software and the associated products. As an organisation matures, software process becomes better defined and more consistently implemented throughout the organisation.
Software process capability	The range of expected results that can be achieved by following a software process. Provides one means of predicting the most likely outcomes to be expected from the next software project the organisation undertakes.
Software process performance	Represent the actual results achieved by following a software process. Within each context which the project is conducted; actual performance of the project may not reflect the full process capability of the organisation.
Software process maturity	The extent to which a software process is explicitly defined, managed, measured, controlled and

Concept	Explanation
	effective. Maturity implies a potential for growth in a company. It indicates the richness of organisation software process and consistency with which it is applied in projects throughout the organisation.

3.3.3 The CMM Structure

Advocates of CMM realised that to achieve capability and maturity in organisations, they need to eliminate barriers systematically and structure process improvement initiatives in a methodical way and to achieve long-term rewards from process improvement efforts, it is necessary to design an evolutionary path that increases an organisation's software process maturity in stages (Paulk *et al.*, 1993). CMM provides a road map for continuous process improvement and guides advancement and identifies deficiencies in the organisation.

CMM demonstrates a staged approach with five maturity levels that have to follow to achieve continuous process improvements. CMM maturity levels are interconnected and each maturity level comprise with Key Process Areas (KPAs), common features and key practices. Each KPA is organised by common features which address implementation or institutionalisation of software process. The common features contain key practices which, when collectively achieved, accomplish the goals of KPAs. The internal structure of CMM is further explained in Figure 3.7 below.

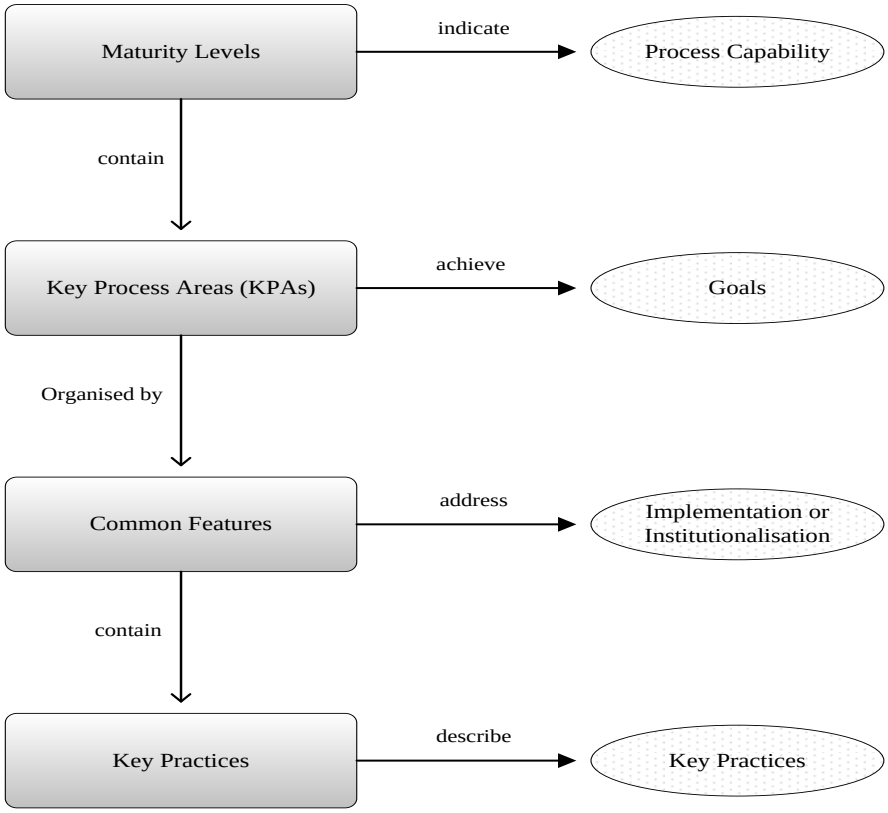

Figure 3.7: Structure of SW-CMM (Paulk *et al.*, 1993)

3.3.3.1 Maturity Levels

A maturity level is described as a precise evolutionary stage toward attaining a mature software process (Paulk *et al.*, 1993). In CMM, maturity levels define an ordinal scale for measuring the maturity of an organisation's process and each level indicates a level of software capability. Achieving each maturity level results an increase in the process capability of the organisation. Types of process capabilities being institutionalised by the organisation at each level of the maturity framework illustrate in Figure 3.8.

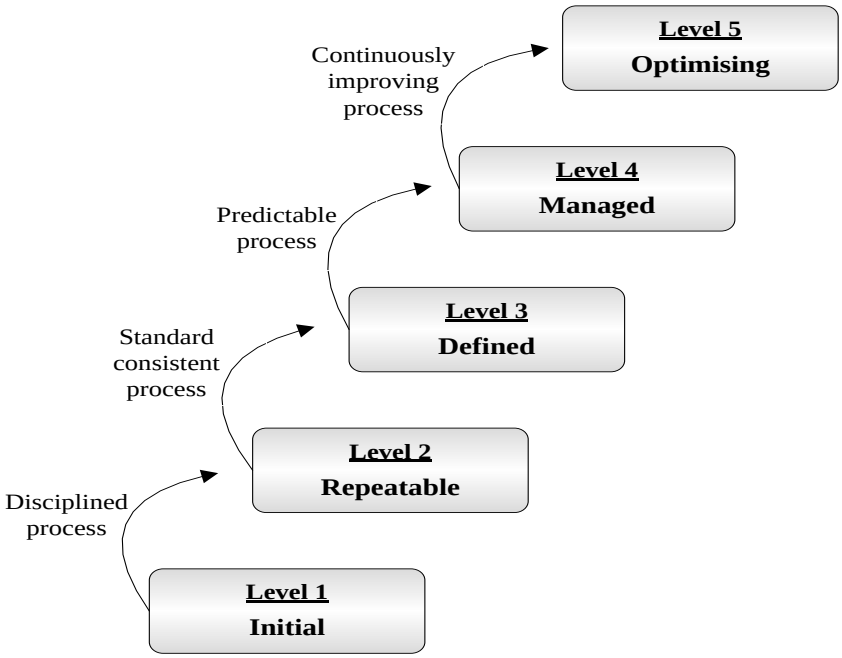

Figure 3.8: Five maturity levels of SW-CMM (Paulk *et al*., 1993)

Table 3.2 below summarises the characteristics of each maturity level which emphasise the primary process changes made at each level.

Table 3.2: Characteristics of each maturity level of SW-CMM (Paulk *et al.*, 1993)

Maturity Level	Maturity Level Definition	Maturity Level Characteristics
One	Initial	Software process is characterised as ad-hoc. Few processes are defined. Inconsistencies in process operations. Lack of reflective practices.
Two	Repeatable	Basic project management processes are established to track cost, schedule and functionality. Necessary process discipline is in place to repeat earlier successes on projects with similar applications.
Three	Defined	Process for both management and engineering activities is documented, standardised and integrated into a standard software process for the organisation. All projects use an approved, tailored version of the organisation's standard software process for

Maturity Level	Maturity Level Definition	Maturity Level Characteristics
		developing and maintaining work.
Four	Managed	Details measures of the software process and product quality are collected. Both the process and products are quantitatively understood and controlled.
Five	Optimising	Continuous process improved is enabled by quantitative feedback from the process. And from piloting innovative ideas and technologies.

3.3.3.2 Key Process Areas

KPAs can be identified as key features of an organisation's processes which need to improve at a time to achieve a new maturity level. Each KPA classifies a group of associated activities to reach a set of goals essential for enhancing process capability. They compile key practices which are essential features that much exist in order to accomplish relevant process area (Bate *et al.*, 1994). Following Figure 3.9 illustrates the KPAs which are associated with each maturity level in the SW-CMM.

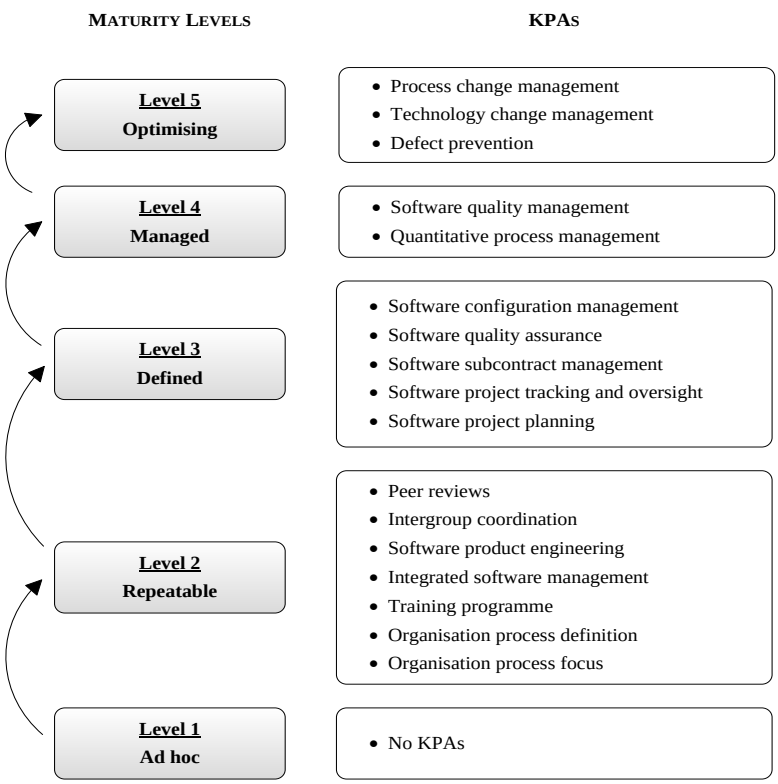

Figure 3.9: Key Process Areas associated with each maturity level of SW-CMM (adopted Paulk *et al.*, 1993)

3.3.3.3 Goals

The goals summarise the key practices of a key process area. These can be used to determine whether an organization or project has effectively implemented the key process area. The goals indicate the scope, boundaries and intention of each key process area (Paulk *et al*., 1993).

3.3.3.4 Common Features

The common features are elements that indicate whether the implementation and institutionalisation of a key process area is effective, repeatable, and lasting. There are five common features named Commitment to Perform, Ability to Perform, Activities Performed, Measurement and Analysis, and Verifying Implementation.

3.3.3.5 Key Practices

The key practices describe the infrastructure and activities that contribute most to the effective implementation and institutionalisation of the key process area. They describe what is to be done to accomplish the goals of KPAs.

3.3.4 Weaknesses of CMM

Despite the fact that CMM offers more benefits to process improvements in organisations, it is noticeable that it does not perform perfect all the time. Beside the rewards, CMM was criticised for its weaknesses by some detractors (Weinberg, 1993; Jones, 1994 and Bach, 1994). Jones (1994) presented his own model which developed independently from CMM for by indicating that CMM ignores factors such as individual contribution of engineers towards software productivity. Similarly Batch (1994) pointed out that CMM considers the processes but ignores people. Further he claimed that CMM does not have formal theoretical basis and has only vague empirical support. Besides, there are some possible constraints such as need of specialised personnel, might leading to lack of management commitment, might not feasible for small organisations as CMM is basically designed for large organisations and wrong motive as organisations might have to work on process areas having less important for organisation, but necessary for a maturity level (Shaikh *et al.*, 2009).

Organisation willingness to change and commitment of staff and top management can be identified as essential attempts to overcome the challenges which organisations might face in adopting CMM. Appropriate training and guidance should be provided if required regarding the awareness about e-business and process improvement benefits. Stelzer and Mellis (1999) also identifies staff involvement and setting relevant and realistic objectives as success factors for organisational change in process improvement. In addition accessing appropriate resources, tools and technologies is vital in order to develop and use the CMM concept productively. However, CMM is acknowledged and widely applied for many process improvement initiatives in many other disciplines.

3.4 Summary

Chapter two established the need to develop an e-business capability maturity model for construction. It demands a comprehensive understanding of construction processes and capability maturity concepts. Therefore, this chapter explored construction process improvement concepts and existing approaches to gain an in-depth understanding of the context. Further this chapter described the

concepts of process definition, process thinking and process improvement in construction and comprehensively discusses the fundamental concepts and structure of capability maturity model. It established the foundation for the empirical investigations to achieve the invented research objectives. Next chapter explains and justifies the research methodology adopted within this research.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter focuses on establishing the appropriate research methodology adopted to meet the research aims and objectives set out in the chapter one. It describes and justifies the research design of current study from inception to completion. The rationale behind select particular methods for this research study is explained throughout the chapter.

The chapter begins by introducing research process onion (Saunders *at al*., 2012) which provides guidance on systematic selection and determination of research methodological aspects. Next research philosophies and paradigms are discussed by establishing this study's philosophical position. This philosophical consideration is followed by the selection process of suitable research approach and research strategy for this study. Then the research methods used for the current investigation were explained and justified. The chapter continues with explanations of data collection and analysis techniques. Finally the reliability and validity issues are discussed. The chapter concludes with a summary of the contents of this chapter and an indication of next chapter of the research.

4.2 Research Process 'Onion'

Research process is dynamic. It should be embodied with a rigorous methodological framework and a research design. Research methodology represents the principles, procedures and logical development of the research process (Fellows and Liu, 2008). Deciding on the appropriate research methodology is vital and decisions should be made by carefully considering the various aspects within the context. It is important to look into the philosophical aspects, evaluate various research strategies and identify their limitations to acknowledge the most appropriate framework for a particular study.

Saunders *et al.* (2012) presents 'The Research Onion', comprising of six layers which can be followed to design the research procedures methodically and logically. This was initiated in business and management disciplines and widely accepted in research domain of many other disciplines. The essence of the research onion approach is to peel away the various layers of the onions to arrive at the core. The layers of 'research process onion' are presented in Figure 4.1.

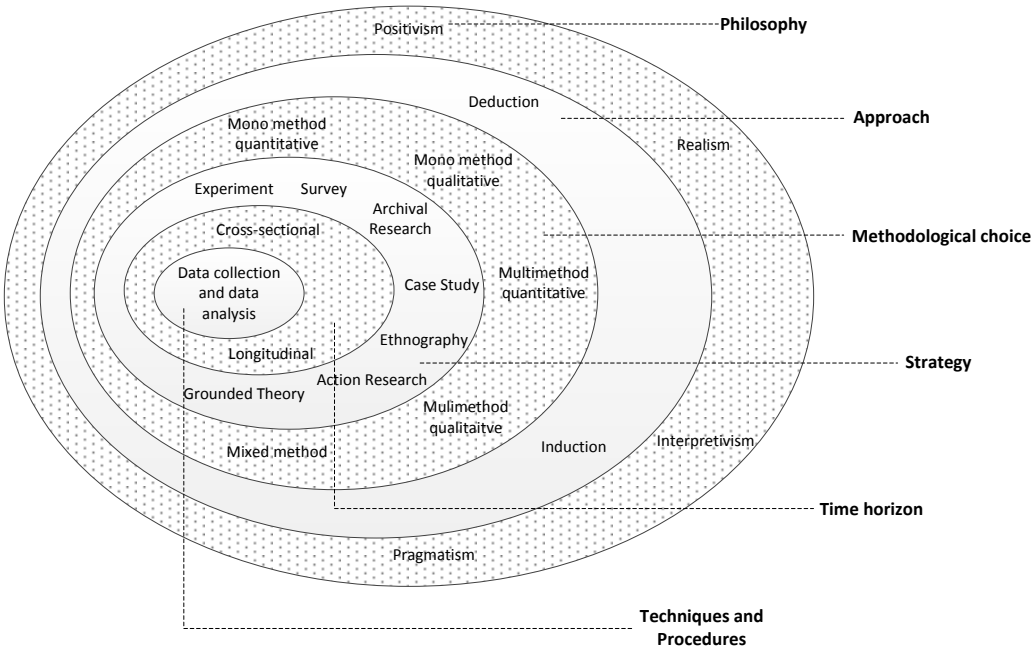

Figure 4.1: The Research Process 'Onion' (Adapted from Saunders *et al.*, 2012)

According to the research onion, methodological reflections for research design have to be considered beginning from outside layers of the onion. That means initially research philosophy should be understood and identified. Thereafter each layer has to be peeled away until the final layer of data collection and data analysis is reached. This approach provides a rigour and methodical way of determining elements of the research design. This 'research process onion' approach has been followed as a guide to review and define different research elements of the current research study as explained in the following sections.

4.3 Research Philosophies and Paradigms

Research philosophy can explain as assumptions about the way in which the researcher views the world and researcher's basic beliefs about the world. Assumptions regarding the nature of the realities and knowledge inevitably shape the understanding of the research questions, selection of research methods and interpretation of research findings (Crotty, 1998).

Understanding the philosophical background of research is important to establish develop the research design based on the philosophical standpoint. Easterby-Smith *et al*. (2012) identified the importance of having an awareness of the philosophical issues in a research stating that understanding the philosophical issues clarifies the research design and helps the researcher to identify the most appropriate research design under the given circumstances of the research in concern. By supporting this view, Williman (2011) commented that it is important for researchers to reflect upon philosophical stance and defend them in relation to the alternatives that they could have adopted in research design.

Research philosophy shapes by assumptions of ontological, epistemological and axiological foundations. There are philosophical paradigms which describes several perspectives of these assumptions. Following section describes research paradigms associate with ontology, epistemology and axiology philosophical assumptions to understand and determine the philosophical stance of the current study.

4.3.1 Ontology: The nature of reality

Ontology represents the nature of the knowledge to be discovered is and assumptions about reality (Miles and Huberman, 1994; Grant and Giddings, 2002; Fellows and Liu, 2008; Creswell, 2014). Guba and Lincon (1994) stated that if the knowledge is about the 'real world' then ontology is about 'how things really are'. Usually ontology deals with the question of ''what is the nature of being'' or ''what knowledge is'' (Miles and Huberman, 1994; Saunders *et al*., 2012).

There are two main ontological considerations as 'objectivism' and 'subjectivism' (Saunders *et al*., 2012). Bryman (2012) called these two ontological positions as objectivism' and 'constructionism'. Objectivism is an ontological assumption

which implies that reality is external to and independent of social actors (Saunders *et al*., 2012). It represents the situation that social phenomena exist externally as a meaningful beyond our reach or influence (Crotty, 1998; Bryman, 2012). In simple terms, objectivism holds that reality has a predetermined nature and structure.

The other ontological assumption, subjectivism (also known as constructionism) implies that social phenomena are created through perceptions and consequent actions of social actors (Saunders *et al*., 2012). It is argued that social phenomena are not only created through social interactions but also they are in a constant state of revision and continually being accomplished by social actors (Bryman, 2012; Saunders *et al*., 2012). In simple terms it believes that reality is created by the perceptions and social interactions or the reality as being socially constructed. As human interactions are a continual process, the reality is in a continuous state of revision. This means that it is necessary to study about the situation in order to understand what is happening or to understand the reality occurring behind what is happening.

4.3.2 Epistemology: What is considered acceptable knowledge?

Epistemology describes how we know reality and assumptions about how knowledge should be acquired and accepted (Miles and Huberman, 1994). It is concerned with the inquiry of what is or what should be regarded as acceptable knowledge in a discipline (Williman, 2006; Bryman, 2012). In other terms epistemology considers what constitutes acceptable knowledge in the field of study and how knowledge is acquired (Creswell, 2014). The view about the social reality usually determines what can be regarded as legitimate knowledge. Hence, the ontological foundations govern and shape the epistemological foundations (Williams and May, 1996).

Saunders *et al*. (2012) identifies four paradigms as 'positivism', 'realism', 'interpretivism' and 'pragmatism'. Positivism takes the position that there is truth, which is real and natural; thus the investigator should not influence the reality or should not be influenced by the reality (Fellows and Liu, 2008). Therefore positivism demands pure objectivity. It is argued that positivism is a position that

adopts the philosophical stance of natural sciences (Bryman and Bell, 2003; Saunders *et al*., 2012; Bryman, 2012).

Interpretivism is the contrasting epistemological paradigm to positivism. Interpretivism believes that the reality is not objective or external, but socially constructed and given meaning by people (Easterby-Smith *et al*., 2012). Therefore interpretivism demands subjectivity. Interpretivism emphasis the different between investigating about people and the objects; thus it is necessary for the researcher to understand the difference between humans and grasp the subjective meaning of the observed social actions (Bryman, 2012; Saunders *et al*., 2012).

Realism is also identified as a position that relates to natural science enquiry. The thinking of realism is that there is a reality quite independent of the mind. In essence, realism is what we sense as reality; that objects have an existence independent of the mind (Saunders *et al*., 2012). Realism believes the reality is objective and reality exists independently of human thoughts and beliefs, but is interpreted through social conditioning (Bryman, 2012; Saunders *et al*., 2012).

Pragmatism believes that knowledge arise out of actions, situations and consequences (Saunders *et al*., 2012; Creswell, 2014). Pragmatism claims that concepts are only applicable where they support actions; hence the most significant determination of your position on each segment is the research question and one position may be more appropriate than another for answering a particular question (Saunders *et al*., 2012). It means that if the research question does not suggest a definite philosophy, it is possible to work with different philosophical positions within pragmatism view. Therefore researchers have a freedom to choose the methods and techniques that best address their needs and purpose of the investigation (Creswell, 2014).

4.3.3 Axiology: What is the role of values?

Axiology explains which researcher values go into it and assumptions about value system (Miles and Huberman, 1994). Generally axiology deals with the question of "what is the role of values?" (Saunders *et al*., 2012). Considerations on axiological assumptions are essential because the role that researcher's own values play in research process is important to the results to be credible.

Positivism paradigm carries the axiological assumption that researcher is value free and is independent of the data and maintain an objective stance. Interpretivism paradigm considers the axiological assumption that researcher is value bound. Further, researcher cannot be separated from what is being researched so maintain a subjective stance (Saunders *et al*., 2012).

4.3.4 Philosophical Stance of the Current Study

According to the research philosophical paradigms described in above sections, the appropriateness of each position was compared against the scope of this study. Following sections describe the ontological, epistemological and axiological paradigms of the current study to establish the most appropriate philosophical stance.

4.3.4.1 Ontological Stance

As described in section 4.3.1, otology is concerned with the assumptions of the nature of reality and knowledge. Therefore the nature of knowledge that this research inquiry is associated with has to be considered to determine the ontological stance of the current study.

Looking at the current investigation from an ontological perspective considers "what is the nature of e-business capability and maturity?". As discussed throughout the literature review, the meaning of e-business is not static. It evolves with time responding to emerging and innovation technologies. Moreover, the nature of the e-business capability and maturity changes constantly within the domain according to the social factors such as business processes and technological advancements. Those changes mean that the e-business implementation and maturity depend on actions, situations and consequences. Hence, this research accepts that the reality, e-business capability and maturity, remains subjective and represents the operational context of the organisation. Therefore, the ontological position of objectivism, which suggests that knowledge is unique and considered as the universal truth, is somewhat controversial in the current study.

Ontologically, researcher believes e-business and its capability and maturity are not independent from organisations. They are embedded with the organisation

culture and people. These beliefs equal with the subjectivism philosophical position. Thus, the ontological position of the current study is subjectivism (also known as constructionism).

4.3.4.2 Epistemological Stance

As discussed in section 4.3.2, epistemology considers what constitutes acceptable knowledge in the field of study and how knowledge is acquired. There are four epistemological paradigms as positivism, realism, interpretivism and pragmatism.

Epistemologically, researcher assumes that e-business capability maturity characteristics are socially constructed and embodied within organisations. Different organisations have their own views, objectives and capabilities regarding to e-business maturity. Therefore this study doesn't belong to positivism or realism paradigms which hold that reality is objective and observable phenomena provide credible data and facts.

This investigation leans towards interpretivism where it believes that the knowledge is not objective or external, but socially constructed and given meaning by people. Further, researcher accepts that subjective meanings and social phenomena constitutes acceptable knowledge and focus upon details of situation and subjective meanings help to understand the reality behind the details and actions.

4.3.4.3 Axiological Stance

As discussed in section 4.3.3, axiology considers which researcher values go into the investigation. The intent of the current study is to investigate and interpreted the subjective reality regarding e-business capability maturity in construction organisations. Therefore, axiologicaly this study assumes researcher is value laden.

4.4 Research Approaches

Research approach is a term frequently used in social sciences, but one which can lead into confusion because it has been used within research methodology literature to represent different aspect and meanings. As described in the section 4.2, 'research process onion' (Saunders *et al*., 2012) has been followed as a guide

to review and define different research elements of the current research study. Therefore, current study defines 'research approaches' according to Saunders *et al*. (2012) as the extent to which the researcher is clear about the theory at the beginning of the research. Further they identify three main research approaches to consider in research studies as 'deduction', 'induction' and 'abduction'.

4.4.1 Deduction

Deduction approach engages the verification or expansion of a theory which is subjected to a rigorous test through a series of propositions (Saunders *et al*., 2012). In this approach, researcher deduces hypothesis based on theoretical considerations in relation to a particular domain and then subjects them to empirical scrutiny (Bryman, 2012). Similarly, Williman (2006) suggested that, deductive process is followed when the conclusions are derived logically from testing a set of hypothesis which derived based on theory. Deductive process initially conducts a search to explain causal relationships between concepts and variables which drive the establishment of testable research hypothesis (Saunders *et al*., 2012).

Bryman (2012), outlines six sequential steps through which deductive research progresses as shown in Figure 4.2.

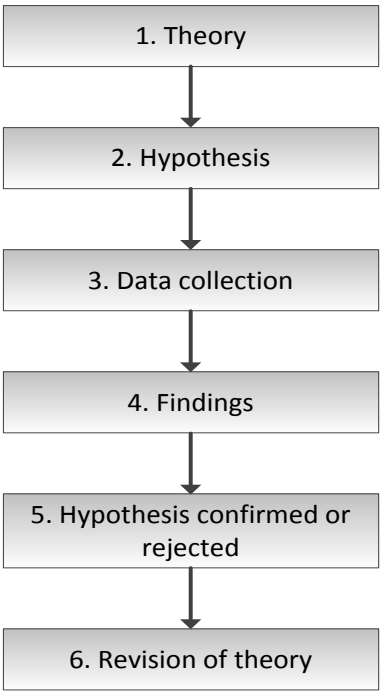

Figure 4.2: The process of deduction (Source: Bryman, 2012)

Deduction approach is considered as usually associated with positivist views and quantitative research (Bryman, 2012; Saunders *et al*., 2012). Moreover, Saunders *et al*. (2012) identifies generalisation as an additional characteristic of deduction. However, a carefully selected, sufficient sized sample is necessary for the generalisation.

4.4.2 Induction

Induction is in contrast and an alternative approach to deduction. The purpose of inductive approach is to get a better understanding of the nature of the problem and the results of data collection and analysis would be formulation of a theory or a conceptual framework (Saunders *et al*., 2012). Hence, in induction approach, theory would follow data, vice versa as with deduction. Development of a strong understanding of the social world is considered as the strength of this approach. Induction approach is concerned with small numbers of subject matters and more likely to associated qualitative data (Easterby-Smith *et al*., 2008; Bryman, 2012; Saunders *et al*., 2012).

Figure 4.3 captures the essence of the difference between deductive and inductive approaches.

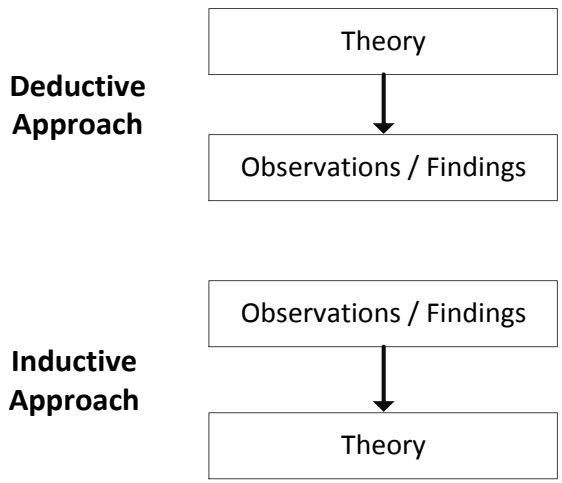

Figure 4.3: Relationship between theory and research in deductive and inductive approaches

As shown in Figure 4.3, the essence of the difference between two approaches is set in the relationship between the theory and research. Next section compares the appropriateness of these two approaches in the current investigation and establishes the research approach of the study.

4.4.3 Research Approach of the Current Study

According to the explanations on two main research approaches in previous sections 4.4.1 and 4.4.2, this section establish research approach of the current study. As described before, if a researcher adopts a clear theoretical position and identifies causal effects which is then tested through the collection of data, that research study is theory driven and follow a deductive approach. Conversely, if a researcher explores and develops a theoretical explanation as the data are collected and analysed, that research study is data driven and follow an inductive approach.

In the current investigation, researcher seeks to gain an understanding of construction e-business maturity characteristics within construction organisations, rather than trying to identify causal effects. Furthermore, the main aim of this study is to building an e-business capability maturity model for construction organisations through the use of secondary research and empirical investigations. It was focused to obtain an in depth understanding of the e-business implementation within construction specific environment and construction e-business capability maturity characteristics were expected to emerge from the data collection and analysis. Thus, this is a data driven theory building approach rather than a theory testing approach. All of these features of the current investigation favour the induction approach, compared to the deduction approach.

The nature of the research topic can also use as a parameter to determine the research approach for a research study. A research topic with a wealth of literature available to determine hypothesis may more suitable for deductive approach. Conversely, with a new debatable research topic with little existing literature available, it may be more appropriate to follow inductive approach as it demands in-depth context specific understanding (Bryman, 2012; Saunders *et al*., 2012; Creswell, 2014). Although e-business implementation and maturity have been explored in other areas and domains, research of capability maturity of e-business within the context of construction industry is quite new. Hence construction e-business capability maturity is recognised as a relatively new domain with little previous literature available. This novel nature of the current investigation further reinforced the suitability of inductive approach for the current research.

However, considering the time constrains associated with the current investigation as a PhD study, applicability of pure inductive approach is debatable. Saunders *et al*. (2012) explains that deductive researches are quicker to complete as data collection is often based on 'one take'. Further he explained that inductive researches are much more prolonged as the ideas and in-depth understanding have to emerge gradually based on a longer period of data collection and analysis. In addition, deduction has the advantage of categorising as a lower-risk strategy when compared to induction. Induction approach is associated with the risk that no useful ideas, data patterns or theory will emerge (Saunders *et al*., 2012). To minimise these issues, this research adopted some deductive elements such development of conceptual fundamentals and frameworks (refer section 4.7). Saunders *et al*., (2012) recognise that the usage of combined deduction and induction is possible and advantageous. Yin (2009) also accepts establishing theoretical propositions prior to inductive strategies such as case studies. This research study utilises both deductive and inductive characteristics, but inductive approach is dominant.

4.5 Methodological Choice

Methodological choice outlines the considerations on selecting a mono method or multiple methods of qualitative or quantitative research design (Saunders *et al*., 2012). Figure 4.4 illustrates the different methodological choices for research design.

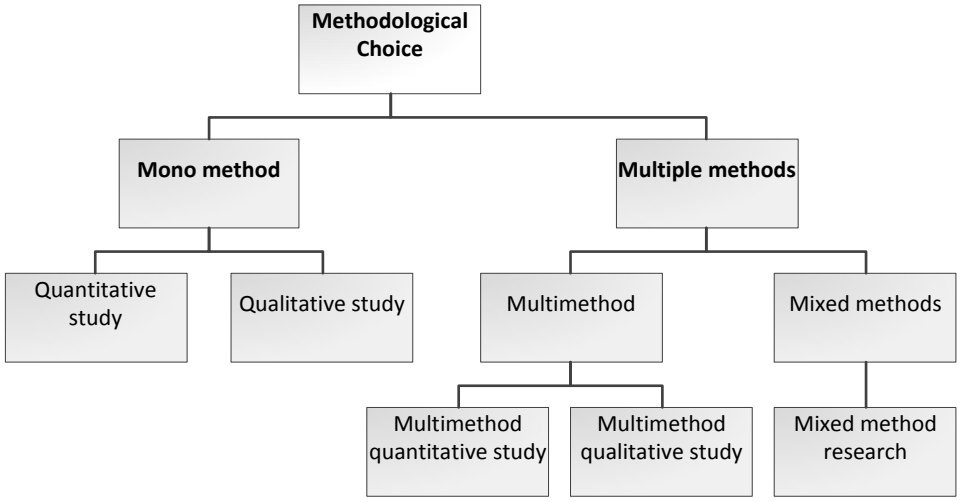

Figure 4.4: Methodological Choice (Source: Saunders *et al*., 2012)

The most common way of differentiating quantitative and qualitative research is to distinguish between numeric data and non-numeric data. Principally, the term 'Quantitative' is often used to represent data collection techniques and data analysis techniques which generate numerical data (Saunders *et al*., 2012). In contrast to quantitative, the term 'Qualitative' is often used to represent data collection techniques and data analysis techniques which generate non-numerical data.

Many researchers (Grant and Giddings, 2002; Bryman, 2012; Saunders *et al*., 2012; Hammersley, 2013; Silverman, 2013) argued that this distinction is narrow and problematic as in reality many research designs may combine both types of data. Further they explained that these can be used as two ends of a continuum and the methodological choice of a research has to consider through philosophical lens. With this broader perspective, following sections interpret quantitative and qualitative choices through their association to philosophical assumptions, research approaches and research strategies.

4.5.1 Quantitative Research Design

Quantitative research is usually connected with positivism and embodies a view of reality as an external objective reality (Fellows and Liu, 2008; Bryman, 2012; Saunders *et al*., 2012; Creswell, 2014). It generally demands a deductive approach to the relationship between theory and research which focuses on using data to test a theory (Bryman, 2012; Saunders *et al*., 2012; Creswell, 2014). However, it may also integrate to an inductive approach where data are used to develop the theory (Saunders *et al*., 2012). Quantitative research gathers factual data to study relationships between variables which are measured numerically and analysed using statistical techniques (Fellows and Liu, 2008; Saunders *et al*., 2012). This type of research often adopts experimental and survey research strategies (Saunders *et al*., 2012). These research strategies will be discussed in-detail in section 4.6.

4.5.2 Qualitative Research Design

Qualitative research is usually associated with interpretivism and embodies a view of social reality (Fellows and Liu, 2008; Creswell, 2009; Bryman, 2012; Saunders

et al., 2012). This type of research mainly emphasises an inductive approach to the relationship between theory and research which focuses on using data to generate theory (Bryman, 2012; Saunders *et al*., 2012; Creswell, 2014; Silverman, 2014). However, deductive approach is adopted by some qualitative research strategies when testing a theoretical perspective using qualitative procedures (Yin, 2009; 2011). Quantitative research seek to gain an understanding participants' perceptions and meanings and the relationship between them (Fellows and Liu, 2008; Saunders *et al*., 2012). Action research, case studies, ethnography, grounded theory and narrative research are identified as the principle strategies used with qualitative research (Saunders *et al*., 2012). These research strategies will be discussed in-detail in section 4.6.

4.5.3 Multiple Method Research Design

The different bundles of choices associated with multiple method research are illustrated in Figure 4.4. Multiple method research may use deductive approach, inductive approach or combination of both (Saunders *et al*., 2012). In this type of research, theory may be used to provide direction and to limit scope for the research (Tashakkori and Teddie, 2010). Multiple method research provides a richer approach to data collection and analysis and overcome weaknesses associated using only one method (Bryman, 2012). Multi method research designs are divided into two categories as 'multimethod' and 'mixed method' (refer Figure 4.4). Multimethod research uses more than one data collection technique, but restricted within either quantitative or qualitative. Mixed method research uses more than one data collection technique and combines both quantitative and qualitative procedures.

4.5.4 Methodological Choice of the Current Study

With reference to the above discussions on methodological choices, suitable research design for the current study is discussed in this section. To determine the nature of this research design, fundamental differences between quantitative research designs and qualitative research designs are compared and summarised in the following Table 4.1.

Table 4.1: Fundamental differences between Quantitative Research Designs and Qualitative Research Designs (Adapted from Bryman, 2012)

	Quantitative Research	**Qualitative Research**
Ontological orientation	Objectivism	Subjectivism
Epistemological orientation	Positivism	Interpretivism
Research Approach	Deductive	Inductive
Common Research Strategies	Experiments and Survey	Action research, Case study, Ethnography, Grounded theory and Narrative research

As discussed in previous section 4.3.4, the philosophical stance of this research holds subjectivism and interpretivism orientations. In terms of research approach, the current study favours inductive approach (refer section 4.4.3). Accordingly, with reference to the Table 4.1, the nature of current investigation takes qualitative interpretation. Due to the philosophical beliefs and the research problem being answered, quantitative orientation or quantitative data collection methods were deemed inappropriate. Further, research strategies adopted for the study also compliments the qualitative view (refer section 4.6.8).

In terms of mono method and multiple methods choice, this research implements multimethod choice (refer Figure 4.4). As detailed within section 4.7, multiple data collection techniques have been used within archival analysis, expert interviews, case studies and validation interviews. By considering these aspects, methodological choice of the current study is classified as multimethod qualitative study.

4.6 Research Strategies

Research strategy can be identified as a key consideration of research design. Saunders *et al*. (2012) explains research strategy as a plan which researcher is following to find answers to research question. Denzin and Lincon (2011) identify research strategy as the methodological link between research philosophy and subsequent choice of data collection and analysis methods. It comprises of an all-inclusive method with the logic of design incorporating specific approaches to collect and analyse data (Yin, 2009). Some of common research strategies used in

research can be identified as action research, experiments, ethnography, archival research, survey, case studies and grounded theory. They are discussed in the next sections to gain understanding of their values and features to select the appropriate strategies for the current study.

4.6.1 Selecting Suitable Strategies for Research Inquiries

Yin (2009) provided a classification on selecting an appropriate research strategy for a research inquiry. He suggested three conditions to distinguish different research strategies as:

- Type of the research question posed,
- The extent of control that the researcher has on events, and
- Whether the focus is on contemporary or historical events.

Table 4.2 displays these three conditions and how each of them is related to different research strategies.

Table 4.2: Appropriate situations for Different Research Strategies (Source: Yin, 2009)

Strategy	Form of Research Question	Requires Control of Behavioural Events?	Focus on Contemporary Events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival Analysis	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No
Case Study	How, why?	No	Yes

Independent to the above classification, Saunders *et al*. (2012) suggested guiding the choice of research strategy according to the research questions and objectives, the extent of existing knowledge, the amount of time and resources available and the philosophical underpinnings. To select the most appropriate strategies for the

current inquiry, this section considers and discusses the characteristics of research strategies discussed in previous sections in relation to the current study. In this way, it was possible to evaluate research strategies for the study and decisions were made with a justification in relation to criteria considered.

4.6.2 Eliminating Action Research Strategy for the Current Study

Action research is a developing and repeating process of investigating which is designed to inquire organisational problems through a collaborative approach (Shani and Pasmore, 1985; Reason, 2006; Coghlan and Brannick, 2010). Reason and Bradbury (2008) describes action research as a process concerned with emergent practical knowledge which seeks to bring together action and reflection, theory and practice. The main purpose of an action research strategy is to promote organisational learning through identifying issues, planning action, taking action and evaluating action (Saunders *et al*., 2012).

Action research starts with a research question and with a specific context, and then works through several stages. Each stage involves a process of diagnosing problems, planning, taking action and evaluating; hence the focus of the research may change as the research develops (Saunders *et al*., 2012). Some of the practical issues of this strategy are identified as identifying an accepting context, emergent nature, researcher's role as a facilitator and the stages of iterations (Saunders *et al*., 2012). These practical concerns demands long time scale and skills of the researcher to handle intense situations.

As discussed in the Chapter one, this research is built upon the research question of "How can construction organisations identify their current status of ICT (Information and Communication Technology) implementation to achieve high capability and maturity in e-business?". The aim of this study is to develop a capability maturity model to systematically identify current status of ICT implementation of project related processes in construction organisations. It is intended to understand construction e-business maturity characteristics within construction organisations, but not intended to interfere with the problem environment to change the focus and behaviour of the participants. Therefore, the action research strategy was not suitable for this research investigation. Further, considering the time constrains and resources associated with the current

investigation as a PhD study, use of a demanding strategy like action research in terms of intensity involved and the resources and time requires is questionable.

4.6.3 Eliminating Experiments Strategy for the Current Study

Experiment is a form of research strategy which predominantly relates to natural sciences (Saunders *et al*., 2012). The purpose of an experiment is to learn the relationship between independent and dependent variables (Hakim, 2000; Connaway and Powell, 2010). In experiments, researcher make observations and obtain measures at pre-test and post-test phases of the procedures (Creswell, 2014). Predictions of the experiments are called as hypotheses (null hypothesis and alternative hypothesis), and are tested statistically. The feasibility of using an experimental strategy mainly depends on the nature of research question as experiments use predictive hypotheses rather than open research questions (Saunders *et al*., 2012).

According to Fellows and Liu (2008), experiments are suitable for testing causal relationships and for issues in which the variables involved are known or hypothesised. Experiments target to produce objective results which are valid and capable of replication by other researchers (Gray, 2009). These characteristics suggest that experiments match deductive approach. However, Experiments may demand limited resources, but the time consumed is not predictable (Saunders *et al*., 2012).

As discussed above, the feasibility of using an experimental strategy mainly depends on the nature of research question as experiments use predictive hypotheses rather than open research questions. Also, even though experiments are suited for ‘how’ type research questions, the control of behavioural events are required to conduct experiments (refer Table 4.2). As discussed under the philosophical nature of this study (refer section 4.3.4), there is a high level of uncertainty of some of the variables and certain conditions which could be hypothesised within this study. Therefore, experiment research strategy was not suitable for the current study.

4.6.4 Eliminating Ethnography Strategy for the Current Study

Ethnography is used to study about groups. This strategy suggests that the researcher has to become a part of social phenomenon being invested to gain insights of behavioural patterns (Fellows and Liu, 2008). This type of strategy is particularly appropriate when researcher is seeking into a new research domain. Ethnography can provide valuable understanding which can guide later research in a new research domain; therefore, depth of the investigation becomes the norm with a moderately small numbers of cases being studied (Robson, 2011). The difficulties associated with ethnography strategy are gaining access to social setting which the researcher is interested and the role of researcher as a participant, observer or both (Bryman, 2012; Saunders *et al*., 2012). When using ethnography strategy, the research process needs to be flexible because the researcher needs to be prepared for changes in circumstances (Claire, 2003).

In essence, ethnography strategy is considered to observe and gain insights of behavioural patterns while being a part of social phenomenon being invested. This inquiry relates to e-business processes within construction organisations. It is intended to investigate the interactions between e-business processes with people, technology and environment of construction organisations. However, it does not focus to observe behavioural patterns or the psychology of the participants. Thus, the necessity of adopting ethnography strategy was not appropriate for this investigation.

4.6.5 Eliminating Archival Research Strategy for the Current Study

Archival research uses archives as the main source of data. An archive is a term which can lead to confusion because it tends to have multiple meanings. Bryman (1995) argued that, although the term 'archival' is used to describe historical documents or records, it can refer to recent documents as well. Supporting this explanation, Saunders *et al*. (2012) defines archival research as a strategy which makes use of administrative documents as the principle data source. Archival research strategy offers secondary data analysis as the original data were collected with a different perspective (Saunders *et al*., 2012). However, archival research use and analyse these data because they are relate with day-to-day activities (Hakim, 2000). Therefore, they can consider as part of reality being studied. An

archival research strategy favours research questions which focus on the past and changes over the time to be answered. However, it is highly influenced and constrained by the nature of archival information available (Saunders *et al*., 2012).

According to Yin (2009), archival analysis is suitable for 'who', 'what', 'where', 'how many' and 'how much' type research focus questions (refer Table 4.2). This strategy favours research questions which focus on the past and changes over the time to be answered. However, it is highly influenced and constrained by the nature of archival information available. Considering the current study, there are no appropriate archival records available to investigate e-business capability maturity characteristics in construction context. Hence, archival research strategy was not indicated for the current study. However, as discussed in section 4.7, this research borrows some characteristics from archival research strategy and carried out an analysis of construction process maps and existing maturity models to investigate theoretical propositions informing a conceptual framework which guided the primary data collection. Construction process maps and existing maturity models were analysed instead of archives.

4.6.6 Suitability of Surveys vs. Case Studies for the Current Study

After eliminating the choices of aforementioned research strategies for the current investigation as justified, the choice of choosing appropriate strategy considered other remaining strategies of surveys, case studies and grounded theory.

Survey strategy is commonly associated with deductive approach (Saunders *et al*., 2012). Generally, surveys are used to determine the present status of a particular phenomenon (Connaway and Powell, 2010). They are also considered as more appropriate for investigation individual factors and for exploratory analysis of relationships (Yin, 2009). Surveys commonly use questionnaire as they allow the collection of standardised data from a substantial population in an economical way (Saunders *et al*., 2012). Survey strategy is suitable to gather contemporary data from a large number of individuals without geographical boundaries (Gray, 2009). Surveys are based on statistical sampling and the information gathered from individuals of the sample is used to describe the characteristics of defined population (Thomas, 1996). Sampling is identified as the most crucial part in surveys (Gray, 2009; Thomas, 1996; Connaway and Powell, 2010; Robson, 2011;

Bryman, 2012). Researcher has to ensure that the sample is representative and response rate is respectable (Birley and Moreland, 1998; Bryman, 2012; Saunders *et al*., 2012).

Case study strategy explores a research topic within real life context. It encourages in-depth investigation of a phenomenon within a research subject (Fellows and Liu, 2008). Within a case study, the margins between the phenomenon being studied and the context within which it is being studied are not always apparent (Yin, 2009). Case study provides an in-depth exploration and understanding from different perspectives of the complexity and uniqueness of s particular project, institution, programme or a system in real life context (Simons, 2009). This approach is suitable when the focus of a study is on comprehensively exploring and understanding rather than confirming and quantifying (Kumar, 2011). Yin (2009) differentiates four case study strategy designs as single case, multiple cases, holistic case and embedded case.

When comparing surveys verses case studies, survey strategy is predominantly used to determine the present status of a particular phenomenon and usually associated with a deductive research approach. Further, Surveys commonly use questionnaire to gather information from individuals of the sample and used them to describe the characteristics of defined population. According to Yin (2009), survey strategy can be considered with ‘who’, ‘what’, ‘where’, ‘how many’ and ‘how much’ type research focus questions (refer Table 4.2). Case study strategy explores a research topic within real life context and encourages in-depth investigation of a phenomenon within a research subject. It can be considered with ‘how’ and ‘why’ type research focus questions (refer Table 4.2).

Figure 4.5 compares the breadth and depth of a research study relate to survey questionnaire, interviews and case studies. This optimisation among breadth and depth can also be considered as a criterion to find the most appropriate strategy among surveys and case studies.

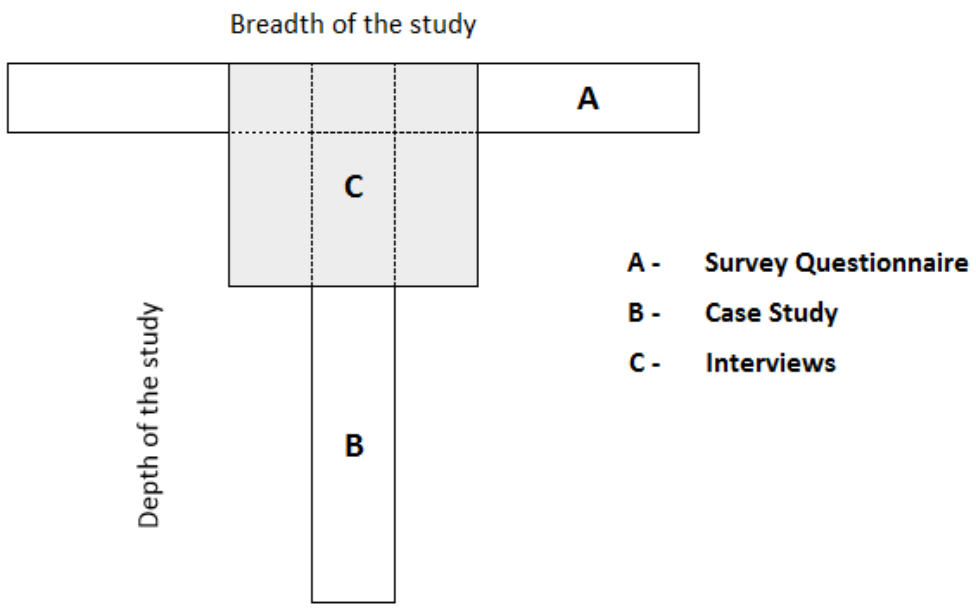

Figure 4.5: Depth and Breadth of the study related to Survey questionnaire, Interviews and Case studies (Source: Fellow and Liu, 2008)

As described under research approach in section 4.4, this research favours and leans towards inductive approach to develop an e-business capability maturity model for construction organisations. The nature of the current investigation demands comprehensive in-depth understanding of the phenomenon being inquired and focus of the research question is 'how' type investigation. By considering these characteristics of survey strategy was deemed inappropriate for the current investigation. These values of the current study made case study the preferred strategy to consider for this investigation.

4.6.7 Suitability of Grounded Theory Strategy for the Current Study

The term 'Grounded theory' is use to describe several perspectives of research. It has been used to describe as a strategy (as a way to conduct research), as a method of inquiry (data collection and analysis technique) and as the result of a research process (Bryant and Charmaz, 2007; Corbin and Strauss, 2008; Birks and Mills, 2011; Saunders *et al*., 2012). Grounded theory was developed by Glaser and Strauss (1967) as means for systematic discovery of the theory from the data of social research. It is a bottom-up approach of gathering, synthesising, analysing and conceptualising qualitative data to construct theory (Birks and Mills, 2011;

Kendall and Kendall, 2014). The name 'Grounded theory' comes from the assumption that theory is grounded in data. Explanations of the theory are grounded in the details, evidence and examples of data (Melon, 1986).

Grounded theory is suitable when little is known about the area of study and theory generation is the anticipated outcome (Birks and Mills, 2011). A domain where little is known about a particular topic is deserving of research effort with grounded theory strategy as it results in generating new knowledge in the form of theory. This strategy is usually referred to follow an inductive approach and researcher collects and analyse data developing analytical codes emerged from the data in order to recognise theoretical categories (Strauss and Corbin, 1998; Saunders *et al*., 2012). This process is considered as time consuming, intensive and reflective (Saunders *et al*., 2012).

When assessing the grounded theory strategy for current research, some of the characteristics seem appropriate for this investigation. As this research is described as a theory building attempt rather theory testing attempt (refer section 4.4 and 4.5), grounded theory can be applied to generate theory on construction e-business capability and maturity. Further, as discussed in section 4.4.3, construction e-business capability maturity is recognised as a relatively new domain with little previous literature available. This novel nature of the current investigation further reinforces the suitability of grounded theory as a strategy for this investigation. However, as further explained in section 4.4.3, this research is considered with time constrains and applicability of pure inductive approach was debatable. Therefore this research adopted some deductive propositions such as development of conceptual fundamentals and frameworks. With those elements of this research study, the usability of pure grounded theory was not promised.

However, the use of case study strategy was preferred while sharing some characteristics of grounded theory strategy. Additionally, some research elements such as analysis of existing theoretical materials and expert interviews were introduced to tighten up the research design. Use of these mixed strategies in the research design is explained in detail under section 4.7.

4.7 Research Design of the Current Study

Research design is the plan for getting from the research question to the conclusion and it describe researcher's attempt to answer the research question (Tan, 2002; Saunders *et al*., 2012). Figure 4.6 outlines the research design adapted to the current study. This section describe the major elements of the current study's research design including the literature review, analysis of construction process maps, analysis of existing maturity models, expert interviews, case studies, validation exercise and data analysis techniques used.

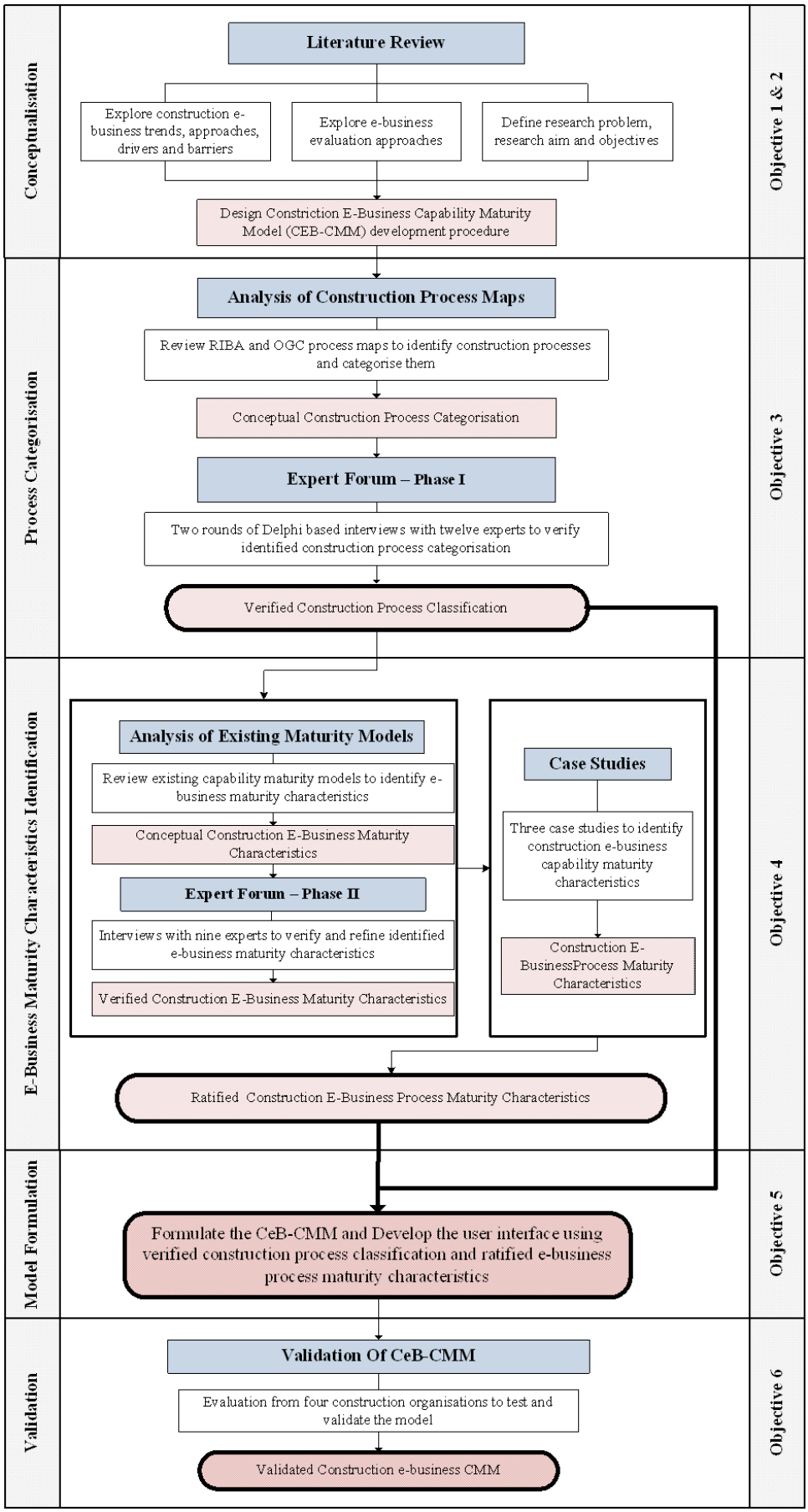

Figure 4.6: Overview of the Research Design of the Current Study

4.7.1 Literature Review Process

The first and second objective of this research was to explore the importance of e-business, drivers and barriers of e-business in construction organisations and to review e-business implementation and evaluation tools for construction organisations. In order to achieve these objectives, a comprehensive literature review was carried out covering the areas shown in the Figure 4.7 and Figure 4.8. Further, this comprehensive literature investigation provided a firm theoretical basis for the problem identification as well as for the research methodology.

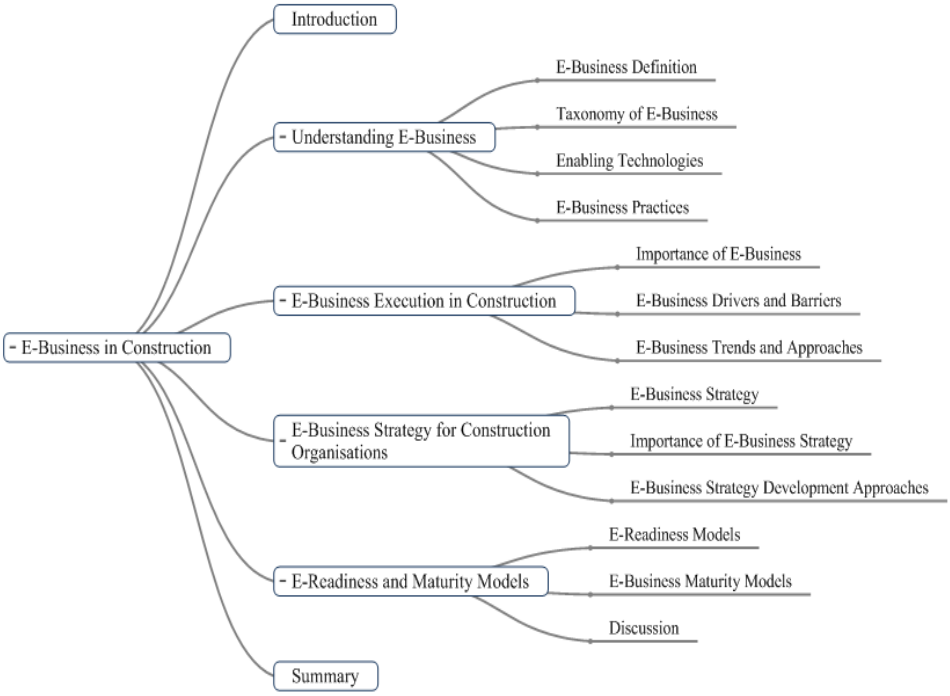

Figure 4.7: Main areas of the Literature Review – Chapter 2

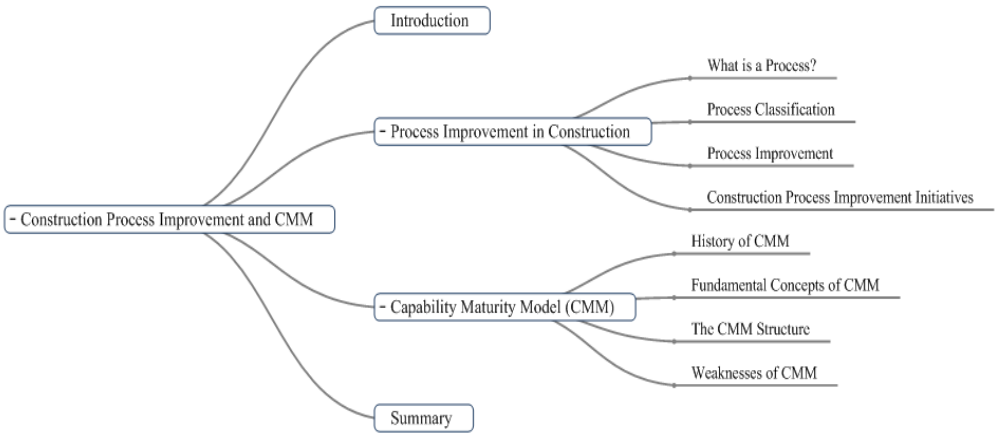

Figure 4.8: Main areas of the Literature Review – Chapter 3

Initially, literature materials regarding general e-business were reviewed to gain an understanding of e-business principles, characteristics, practices, drivers and barriers. Different approaches and tools available for successful e-business implementation and evaluation also reviewed. Subsequently, the search was narrowed down to construction specific e-business literature. Importance of e-business in construction, e-business strategies for construction and e-readiness and maturity models for construction e-business are investigated. This main literature review and synthesis laid the background and rationale to the current investigation and helped to establish the research gaps. These are presented in Chapter Two.

As the research progressed, the literature search was further expanded to process improvement initiatives in construction and capability maturity model. Researcher used this review and synthesis as the basis to develop the initial conceptual framework for construction e-business capability and maturity model. This review and synthesis and the conceptual framework development are presented in Chapter Three.

4.7.2 Analysis of Construction Process Maps

The third objective of the research was to identify and categorise current construction business processes. Analysis of construction process maps was introduced to address the need of a construction process categorisation to use in the construction e-business capability maturity model. RIBA 2013 plan of work and OGC gateway process reviews were selected for the reason that they are widely recognised as two solid construction process maps which define the construction project related processes and are widely used within the UK construction industry. The purpose of this analysis was to identify construction processes from RIBA plan of work and OGC gateway process reviews, headed for a conceptual construction process categorisation. This analysis and its findings are presented in the Chapter Five.

4.7.3 Analysis of Existing Maturity Models

Analysis of existing maturity models was introduced to identify potential capability maturity characteristics to use in the construction e-business capability maturity model. Three existing maturity models which were selected for the

analysis are the initial Capability Maturity Model (SW-CMM), Standardised Process Improvement for Construction Enterprises (SPICE) CMM and general E-Business Capability Maturity Model (EB-CMM). These three models were selected representing the contexts of initial maturity approach for software process improvement, applicability of capability maturity model for construction process improvement and applicability of capability maturity model for general e-business process improvements. The purpose was to identify potential maturity characteristics for construction e-business capability maturity model. This analysis and findings are presented in the Chapter Six.

4.7.4 Expert Forum

This research adopts two phases of expert forum to verify and validate the conceptual propositions established through secondary data analysis stages (analysis of construction process maps and analysis of existing maturity models). Interviews were used as the data collection technique for two phases of expert forum.

Interview is a widely employed data collection method in qualitative research (Bryman, 2012). Three generic types of interviews are highlighted in the literature as structured interviews, semi-structured interviews and unstructured interviews (Bryman, 2012; Saunders *et al*., 2012). Structured interviews are usually based on predetermined and standardised list of questions and often follow a standardised schedule. Conversely, unstructured interviews are informal and there is no predetermined set of questions to follow through. This type of interviews allows exploring in depth ideas as interviewee is given the opportunity to express ideas freely in relation to the topic area. Semi-structured interviews place in between structured and unstructured interviews and share characteristics of both. In semi-structured interviews, a formal prearranged question guideline is presented, but their use may vary and the order of questions may change depending on the flow of the questions. Further, semi-structured interviews offer the freedom to add, omit or modify the questions as the interview progressed. Within semi structured interviews, the interviewer has the freedom and flexibility to explore the interviewee's understanding related to the issues by introducing appropriate queries (Kendall and Kendall, 1992; Saunders *et al*., 2012).

In this research study, the purpose of expert forum was to extract the expert s' knowledge in great depth regarding the areas inquired. This purpose would be served from either semi-structured or unstructured interviews. However, considering the time constrains and other resource limitations associate with this study, use of semi-structured interviews was preferred over unstructured interviews. Therefore, semi-structured interviews were conducted with experts and they allowed to extract required knowledge and were sufficiently flexible to explore issues as they arose during the discussion.

4.7.4.1 Appointment of the Expert Forum

Expert forum comprised of 12 experts. Non-probability purposive sampling technique was followed to select the experts. The logic on the strategy for selecting cases for purposive sampling should be dependent on research objectives and cannot be considered as to be statistically representative of the total population. (Patton, 2002; Neuman, 2006; Saunders *et al*, 2012). With purposive sampling researcher has to use his or her judgement to select cases that are best enabling to answer research question (Saunders *et al*, 2012). Data saturation is indicated as sign to determine the number of interviews (Bryman, 2012; Saunders *et al*., 2012). For non-probability sampling techniques, the issue of sample size is vague and, unlike probability sampling, there are no rigid rules. Rather the logical relationship between the sample selection technique and the purpose and focus of the research is considered important as generalisations being made to theory rather than about a population (Saunders *et al*., 2012). Hence, specifying the selection criteria is vital.

In total 12 expert interviews were conducted in each round. Experts were selected based on satisfying a set of selection criteria. Accordingly, two expert groups were identified; 3 academic experts and 9 industry experts. Details of the expert profile are presented below in Table 4.3.

Table 4.3: Details of the experts interviewed

Expert	Expertise	Discipline	Role	Experience
EF/A/1	E-commerce, E-business and ICT	Academic	Senior Lecturer	18 years
EF/A/2	Construction, Information systems, Process management	Academic	Professor	Over 30 years
EF/A/3	Web based project management	Academic	Senior Lecturer	10 years
EF/C/1	Quantity Surveying, Contract management	Construction	Quantity Surveyor	7 years
EF/C/2	Quantity Surveying, Contract management and Dispute resolution	Construction	Quantity Surveying Manager	7 years
EF/C/3	Quantity Surveying, Contract administration and Cost management	Construction	Commercial Manager	7 years
EF/C/4	Procurement, Project management, Quantity Surveying	Construction	Project Manager	Over 30 years
EF/C/5	Quantity Surveying, Highway, road and rail projects	Construction	Senior Quantity Surveyor	10 years
EF/C/6	Civil engineering, Railways, water and airport projects	Construction	Senior Quantity Surveyor	15 years
EF/C/7	Highway maintenance, Drainage and winter maintenance	Construction	Highway Asset Manager	21 years
EF/C/8	Quantity Surveying and Commercial management	Construction	Senior Cost Manager	10 years
EF/C/9	Quantity Surveying,	Construction	Commercial	11 years

Expert	Expertise	Discipline	Role	Experience
	Commercial and Legal		Manager	

The academic expert group consisted of academics who have expertise in ICT or e-business. The purpose of selecting these academic experts was to extract their knowledge to verify the construction process categorisation. Further details of the academic expert profile are explained in the above Table 4.3.

The industry experts were selected based on their expertise and organisation type and size. They represented 6 large scale and 3 medium scale organisations. In addition they consisted of client, contractor and consultant practices and experienced with both civil and building projects. Attention was given to select experts from those organisations who are performing construction project related tasks within their working environment. The composition of industry expert profile is further explained in Table 4.4 below.

Table 4.4: Industry expert profile

Expert	Organisation Details		
	Size	**Type**	**Project Type**
EF/C/1	Large	Contractor	Civil and Building
EF/C/2	Medium	Consultant	Building
EF/C/3	Large	Client	Civil and Building
EF/C/4	Large	Client and Contractor	Building
EF/C/5	Medium	Consultant	Civil
EF/C/6	Large	Contractor	Civil and Building
EF/C/7	Large	Consultant	Civil
EF/C/8	Large	Consultant	Civil and Building
EF/C/9	Medium	Contractor	Building

4.7.4.2 Expert Forum – Phase I

The main aim of expert forum – phase I was to verify the conceptual construction process categorisation obtained from the analysis of construction process maps. In this first phase of expert forum, two rounds of Delphi based interviews were conducted. The original Delphi method was developed by Norman Dalkey of the RAND Corporation in the 1950's for a U.S. sponsored military project (Okili and Pawlowski, 2004; Hsu and Sandford, 2007; Skulmoski *et al*., 2007). Delphi is an interactive process, which has two or more rounds involving series of questionnaires or interviews, each building on the results of the previous one (Linstone and Turoff, 2002; Hsu and Sandford, 2007; Somerville, 2008).

Twelve experts were interviewed in round one of phase I to obtain their agreements and responses on the conceptual construction process categorisation. The process of data analysis of this is presented in Chapter 5 of the thesis. The questionnaire used for expert forum phase I is attached in Appendices II. After the first round of interviews, collected data was analysed and the conceptual construction process categorisation were modified. Then in second round, the modified conceptual construction process categorisation was presented to the expert forum to inquire about any further disagreements or comments.

4.7.4.3 Expert Forum - Phase II

Second phase of the expert forum was focused on verifying the conceptual construction e-business process maturity characteristics. In this phase, interviews with nine experts were conducted as remain three experts belonged to the case studies considered. The questionnaire used for expert forum phase II is attached in Appendices III and the data analysis process is described in Chapter 6 of the thesis.

4.7.5 Multiple Case Studies

As Yin (2009) indicates, case studies provide in-depth investigation about cases in an uncontrollable environment. As an in-depth understanding on construction e-business processes and working methods is needed for the identification of capability maturity characteristics, case studies are employed for this study. The

main focus of the case studies was to identify and ratify construction e-business capability maturity characteristics from construction organisations.

Main parameters in case study selection are number of cases investigated and the unit of analysis. There are five rationales to select single-case design over multiple cases design. The justifications for selecting a single case design is either it represents 'critical case', 'extreme or unique case', 'representative or typical case', 'revelatory case' or 'longitudinal case' (Yin, 2009). A single case can use when it represents the critical case in testing a well-formulated theory. A critical case which satisfies all of the conditions for testing the theory allows the researcher to challenge, confirm or extend the theory. A unique or extreme case is justified when a specific rare case is investigated. In opposition, a representative or typical case is justified when the objective is to capture the circumstances of an everyday situation. The findings of this type of case are assumed to be informative about the average situation. A revelatory case is justified when it represents a phenomenon which was not previously inaccessible for investigation. The fifth rationale of longitudinal case is justified when the objective is to study the same case at different points in time to investigate how several conditions change over time.

With reference to the current investigation, the objective of identifying construction e-business capability maturity characteristics does not reflect any of aforementioned cases. Therefore, multiple case study design was preferred for the current study. Accordingly, three case studies were conducted and presented in Chapter 6 of this thesis. Each case was carefully selected and they add the distinct advantage of possible replication of the findings. The criteria followed for case study selection is discussed in detail in Chapter Six.

The other parameter of case study design is based on the unit of analysis. Two types are to be considered as holistic verses embedded. Holistic case study design focuses on a single unit of analysis within single case or multiple cases. On the other hand, embedded case study design focuses on multiple unit of analysis. The objective of case studies in this research is to study and reflect the construction project related e-business processes and working methods to identify e-business capability maturity characteristics. Accordingly, this research employed an

embedded multiple-case study design, which considered organisation as the main unit of analysis and different stages of maturity characteristics of process categories as sub units within the main unit of analysis.

4.7.6 Validation of CeB-CMM

The final objective of this study was to test and validate the Construction e-Business Capability Maturity Model (CeB-CMM). To achieve this objective, a validation exercise was carried out using structured interviews with industry practitioners from four construction organisations. The main purpose of this validation process was to evaluate and determine the effectiveness of the CEB-CMM from the industry perspective. Altogether four evaluations were completed. Three evaluation interviews were conducted with professionals participated for multiple case studies, which aided in the development of CEB-CMM. One additional evaluation interview was conducted with an industry practitioner from an external organisation, who was new to the study, to evaluate and test the model from a different perspective increasing the applicability of the model in a wider scope. Validation process of CEB-CMM is further explained in Chapter 8.

4.7.7 Data Analysis Techniques Used

Qualitative content analysis was used in this research to analyse the data gathered during the data collection stages. The purpose of the qualitative content analysis was to analyse the interview data gathered from expert interviews and case study interviews. Qualitative content analysis is a common technique use in analysing the qualitative data to develop and organise a list of codes or categories representing the themes related to the phenomenon being invested (Miles and Huberman, 1994; Bryman, 2012; Saunders *et al*., 2012). The emphasis was given on identifying key themes and concepts emerging from interview data.

Initially the interview data captured through expert interviews and case studies were transcribed as a Microsoft Word (.docx) documents. Then those transcriptions were imported to 'Nvivo 10' data analysis software. 'Nvivo 10' software facilitated the content analysis process providing a structured way of storing, organising and analysing themes using nodes.

4.8 Reliability and Validity

Reliability and validity are important considerations in any research irrespective of quantitative or qualitative (Malhotra *et al*., 2002; Taylor, 2005; Yin, 2009; Saunders *et al*., 2012). It is vital to follow a rigorous process and take necessary actions to maintain the quality of research outcome in order to increase the reliability and validity of a research study. There are four key parameters to consider as construct validity, internal validity, external validity and reliability (Yin, 2009; Saunders *et al*., 2012).

Construct validity is assessment of whether the correct measures have been taken to investigate the research problem (Miles and Huberman, 1994; Saunders *et al*., 2012). It is considered with the extent to which the research methods actually measure what they intend to measure. Construct validity can achieve through triangulation of the findings of multiple research strategies and approaches (Guba, 1990). In this research, triangulation was introduced to meet the construct validity. In the first phase of the research, findings of the analysis of construction process maps and findings of the expert interview round one were triangulated. Similarly, in the second phase, findings of the analysis of existing maturity models, findings of the expert interview round two and case study findings were triangulated. In addition, findings from three case studies were also triangulated within the case study design.

In qualitative research, the concern over internal validity is problem of making inferences (Yin, 2009). This research study addressed internal validity by following a rigour research process by systematically considering the most appropriate research methods, approaches and strategies for the research. Every decision and assumption was taken considering the literature evidence and justifications and 'research process onion' was used as the basis to methodologically design the research. Further, the validation exercise carried out with case study organisations helped to increase the internal validity of the research findings.

External validity is considers with the extent to which the research findings can be generalised (Saunders *et al.,* 2012). In qualitative research designs, the main focus of the research is considered important as generalisations being made to

theory rather than about a population (Yin, 2009; Saunders *et al.,* 2012). In multiple case studies, cross case generalisation can be achieved if two or more cases support similar findings. Therefore in this research study, use of multiple case studies and finding similar findings has increased the generalisation of the findings to the context. Further, the validation exercise carried out with external organisation increased the external validity of the research findings.

Reliability demonstrates the extent to which data collection and analysis techniques can produce same consistent findings if they were repeated again population (Yin, 2009; Saunders *et al.,* 2012). A research need to be methodologically rigorous in the way it formulate and carry out to meet the reliability of research findings and conclusions. Accordingly, each part of the research process should fully explain and reported in a completely transparent way (Saunders *et al.,* 2012). Thus, the development of the methodological framework and research design of the current study was clearly explained and justified throughout this chapter to ensure the reliability.

4.9 Summary

This chapter discussed the research methodology of the current research study. It discussed several philosophical paradigms and established the methodological stance of the current research. The research process 'onion' (Saunders *et al.,* 2012) was applied to guide the review of research philosophies, research approaches, methodological choices, research strategies and techniques. Review of these methodological elements laid a solid theoretical foundation for methodological considerations of the current study. Further, the research design of the current study was explained in detail and reliability and validity measures were also discussed. The next chapter presents the framework of Construction e-Business Capability Maturity Model (CeB-CMM) and the development of construction process categorisation.

CHAPTER 5

FRAMEWORK DEVELOPMENT AND CONSTRUCTION PROCESS CATEGORISATION

5.1 Introduction

This chapter focuses on the Construction e-Business Capability Maturity Model (CeB-CMM) framework development and construction process classification. It introduces the background of CeB-CMM describing the framework and structure of the model. Then it presents the analysis of existing construction process maps and first phase of expert forum conducted in pursuant of the objective three of the study which is to identify and categorise construction project related processes in organisations.

The chapter is structured in three main sections. Firstly, the rationale for the CeB-CMM framework is described together with its fundamental components. Secondly, the analysis of RIBA (Royal Institute of British Architects) plan of work and OGC (Office of Government Commerce) gateway process archives are presented along with the findings. Finally, the analysis and findings of first round expert interviews are presented.

Results of process maps analysis and expert interviews are aided in developing the construction process categorisation, which formed a fundamental component of the CeB-CMM.

5.2 Framework Development

This section describes the development of CeB-CMM. It describes the aim of the CeB-CMM and distinguishes the model from SW-CMM. Structure and the fundamental components of CeB-CMM are illustrated and the significance of the CeB-CMM is explained.

5.2.1 Aim of CeB-CMM

The main aim of the CeB-CMM is to identify the current status of ICT implementation of project related processes in construction organisations. The intention is to decompose the e-business profile of the organisation according to process categories and provides maturity level indications for each process category. The CeB-CMM can be used not only as an assessment tool to evaluate organisation's e-business capabilities in different process categories but also as a roadmap which guides e-business strategy planning in the organisation.

5.2.2 Difference between Original CMM and CeB-CMM

The intended outcome of the CeB-CMM model is not a maturity ranking for the organisation based on the richness of its e-business process, but a maturity indication for e-business processes itself. It decomposes the e-business profile of a construction organisation and seeks to establish the maturity levels for each component (i.e. process category). The decomposition of the e-business process reduces the complexity of the model and it improves the applicability of the model to different types of construction organisations in different scales.

The original CMM was developed in the software development industry as a framework to evaluate capability maturity of software providers. As described in previous section 3.3, the basic principles of CMM focus on the capability and maturity of software process towards organisation's maturity (Paulk *et al..*, 1993). CMM provides an overall maturity level indication for the organisation based on the richness of its processes. This aspect demonstrates a difference between the fundamental thinking of two models.

Further, the original CMM is structured with maturity levels and key process areas. In practice, it evaluates the key process areas to assess the maturity level of an organisation. E-business itself is a process and it is similar to a key process area applicable to an advance maturity level of an organisation. Any organisation at a lower maturity level would not be thinking of e-business primarily. Within the original CMM philosophy, e-business itself can interpret as a process area rather than a unit of analysis.

Intention of CeB-CMM is to consider e-business as the key unit of analysis and seek how mature is that process within an organisation for construction processes. CeB-CMM measures the maturity of the process of application of ICT and innovation achieved through application of ICT to processes. It decomposes the e-business profile of an organisation and provides maturity rankings for each segment. The structure of the CMM was customised in order to facilitate these unique features of CeB-CMM by introducing a process categorisation and replacing KPAs with Maturity characteristics. The structure of the CeB-CMM and its fundamental components are presented in the next section.

5.2.3 Structure and Fundamental Components of CeB-CMM

As explained in the previous section, framework of CeB-CMM was not developed following the identical structure of the original SW-CMM. SW-CMM was used as the guide and its structure was customised according to specific CeB-CMM requirements. Figure 5.1 illustrates the structure and the fundamental components of the CeB-CMM framework.

Construction Process Categorisation		Maturity Levels				
		Level 1 - Initial	**Level 2 - Repeatable**	**Level 3 - Defined**	**Level 4 - Managed**	**Level 5 - Optimising**
Process Category I	Process I					
	Process II					
	Process III to n_2					
Process Category II	Process I					
	Process II					
	Process III to n_3					
Process Category III	Process I					
	Process II					
	Process III to n_4					
Process Category IV to n_1	Process I					
	Process II					
	Process III to n_5					

Construction e-business capability maturity characteristics

Figure 5.1: Fundamental components of the CeB-CMM framework

CeB-CMM comprises with process categorisation and e-business capability maturity characteristics. Number of process categories (n1) and processes in each

category (n2, n3, n4 and n5) is determined after the analysis of data collection stages. The process of determining this process categorisation is explained in Chapter 5. The process of determining construction e-business maturity characteristic is explained in Chapter 6.

Even though the framework structure is customised, CeB-CMM used SW-CMM as the reference model and borrowed basic principles from original CMM. Previous sections discussed the adoption of CMM principles in various disciplines and industries including construction. Within construction context, SPICE is a major research project which attempted to confirm the applicability of CMM concepts in construction. In SPICE, lower maturity levels were mapped in construction context (Sarshar *et al.*., 1999; 2000) and later the applicability of higher maturity levels were confirmed (Keraminiyage, 2009). These studies have investigated the basic concepts of SW-CMM and defined them in relate with construction.

Respectively those definitions of CMM basic concepts are interpreted within the context of construction e-business since it closely accepted a similarity to general construction process in an organisation. As Table 5.1 illustrates, the construction process maturity concepts are expressively converted into e-business context in the same manner which they were transformed from the original CMM maturity concepts.

Table 5.1: Interpretation of CMM basic concepts within construction e-business context

Software Process (Paulk *et al*.,1993)	**Construction Process (Keraminiyage, 2009)**	**Construction E-Business Process**
Software process: A set of activities, methods, practices and transformations that people use to develop and maintain software and the associated products.	Construction process: A set of activities, methods, practices and transformations that people use to construct and maintain buildings and other civil engineering structures and the associated products.	Construction e-business process: A set of electronically supported activities, methods, practices and transformations that people use to construct and maintain buildings and other civil engineering structures and the associated products.

Software Process (Paulk *et al*.,1993)	**Construction Process (Keraminiyage, 2009)**	**Construction E-Business Process**
Software process capability: Describes the range of expected results that can be achieved by following a software process.	Construction process capability: Describes the range of expected results that can be achieved by following a construction process.	Construction e-business process capability: Describes the range of expected results that can be achieved by following construction e-business processes.
Software process maturity: The extent to which a software process is explicitly defined, managed, measured, controlled and effective	Construction process maturity: Describes the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective.	Construction e-business process maturity: Describes the extent to which an e-business process is explicitly defined, managed, measured, controlled, and effective.

As shown in Figure 5.1, there are three main elements of the CeB-CMM; process categories, maturity levels and capability maturity characteristics.

5.2.3.1 Process Categories

CeB-CMM framework defines a process categorisation for construction processes. Archival analysis and experts interviews were carried out to establish a set of construction process categorisation. This categorisation stands as a standard classification for the industry, not only for construction e-business but also for any construction process aspect. This component itself contributes to the knowledge by providing a standard construction process classification.

5.2.3.2 Maturity Levels

CeB-CMM adopts the same maturity levels from original SW-CMM as follows.

- Maturity Level 1 - The Initial Level
- Maturity Level 2 - The Repeatable Level
- Maturity Level 3 - The Defined Level
- Maturity Level 4 - The Managed Level
- Maturity Level 5 - The Optimising Level

5.2.3.3 E-Business Maturity Characteristics

Third key component of CeB-CMM is e-business capability maturity characteristics. This element describes the maturity characteristics of process categories in each maturity level. Archival analysis of existing capability maturity models followed by a set of expert interviews and three case studies were used to establish these characteristics and are described in chapter 6.

5.3 Conceptual Construction Process Categorisation

Analysis of construction process maps was introduced to address the need of a construction process categorisation to use in the CeB-CMM. RIBA 2013 plan of work and OGC gateway process reviews are considered as the two main standard construction process maps which define the construction project related processes and are widely used within the UK construction industry. The purpose of this analysis was to identify construction processes from RIBA plan of work and OGC gateway process reviews for a conceptual construction process categorisation, which was then verified and refined through an expert forum.

5.3.1 Identification of Construction Processes from RIBA Plan of Work

The RIBA plan of work and its internal structure was introduced in the Section 3.2.3. The main aspect of this analysis was to identify construction project related processes from RIBA work stages. The archival information provided on RIBA 2013 work stages were sorted and analysed by creating parent nodes and child nodes in Nvivo 10. Under the ‘RIBA’ parent node, child nodes were created for eight work stages. Each work stage child node was further divided into two sub nodes named ‘objectives’ and ‘processes’. The node structure arrangement is presented in the Figure 5.2.

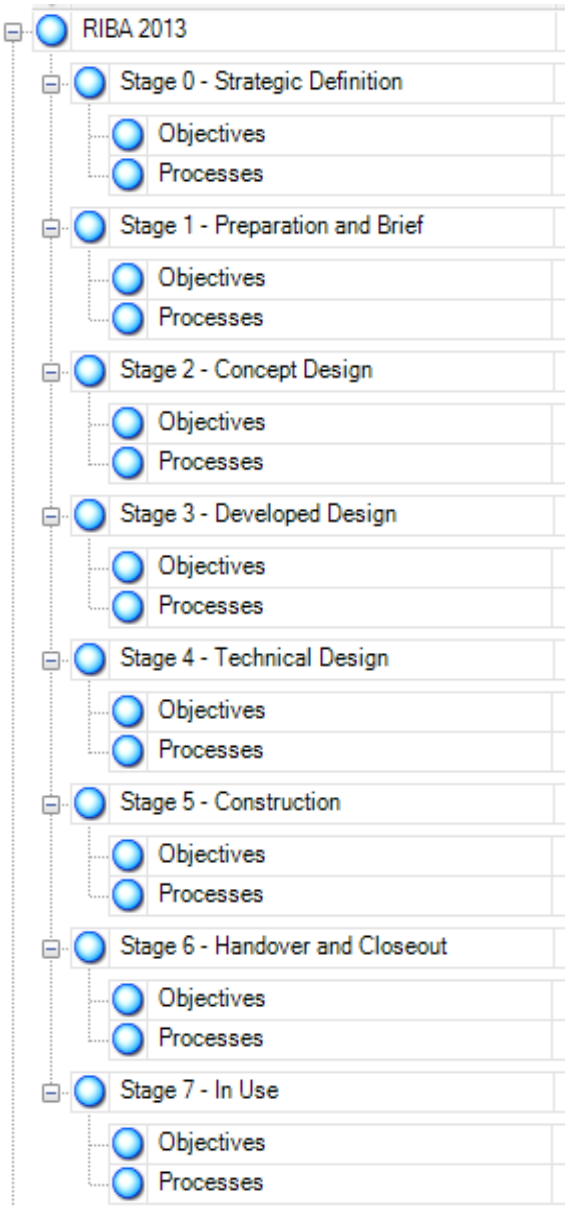

Figure 5.2: Node structure for identification of construction processes from RIBA work stages

The purpose of the 'objectives' nodes were to identify the scope of each work stage. The 'processes' nodes were used to identify the processes relate to each work stage. Table 5.2 presents the construction processes identified from RIBA work stage. Reference codes were introduced to the identified processes in order to maintain the transparency and ease of identification in subsequent analysis stages.

Table 5.2: Construction processes identified from RIBA 2013 plan of work

Identified Processes	Reference Code
Identify business case	RIBA1
Identify project requirements	RIBA2
Establish project programme	RIBA3
Identify project objectives	RIBA4
Develop initial project brief	RIBA5
Preparation of feasibility studies	RIBA6
Determine client's risk profile	RIBA7
Prepare initial project programme	RIBA8
Determine procurement strategy	RIBA9
Project risk assessment	RIBA10
Preparation of concept design	RIBA11
Preparation of developed design	RIBA12
Preparation of technical design	RIBA13
Construction accordance with the project programme	RIBA14
Resolution of design queries	RIBA15
Administration of contract	RIBA16
Update project information	RIBA17
Review of project performance in use	RIBA18
Facilities management	RIBA19

Aforementioned 19 processes were identified from the analysis of RIBA plan of work and they are categorised in to five categories as shown in Table 5.4.

5.3.2 Identification of Construction Processes from OGC

An introduction to OGC gateway reviews was provided in the Section 3.2.3. The information provided in OGC gateways reviews and guides were sorted and analysed by using parent nodes and child nodes in Nvivo 10. Under the 'OGC' parent node, child nodes were created each gateway. Each gateway child node was further divided into two sub nodes named 'objectives' and 'processes' as presented in Figure 5.3.

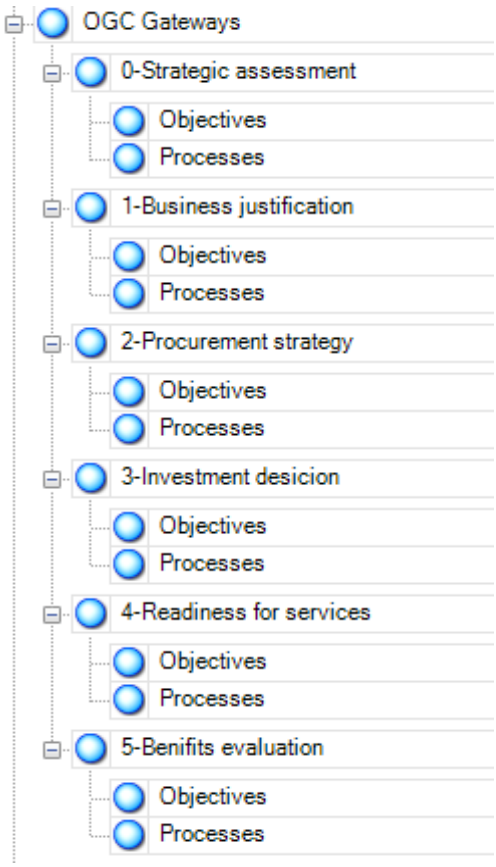

Figure 5.3: Node structure for identification of construction processes from OGC gateway reviews and guides

Table 5.3 presents the construction processes identified from OGC gateway reviews. Reference codes were introduced to maintain the transparency and ease of explanation in subsequent analysis stages.

Table 5.3: Construction processes identified from OGC gateway reviews and guides

Identified Processes	Reference Code
Establish business needs	OGC1
Prepare cost estimate	OGC2
Develop business case	OGC3
Conduct feasibility studies	OGC4
Develop project brief	OGC5
Develop procurement strategy	OGC6
Contract preparation	OGC7
Tender process	OGC8
Prepare outline design	OGC9
Prepare detailed design	OGC10
Cost management	OGC11
Quality Control	OGC12
Payments	OGC13
Claims management	OGC14
Dispute resolution	OGC15
Record keeping	OGC16
Project evaluation	OGC17

As shown in above Table, 17 processes were identified from the analysis of OGC and hey are categorised in to five categories as presented in Table 5.4.

5.3.3 Conceptual Construction Process Categorisation

All the identified processes from RIBA and OGC were assigned to five process categories according to construction project life cycle phases in order to establish the conceptual process categorisation. Table 5.4 presents the conceptual process categorisation attained from findings of the analysis of RIBA and OGC process maps.

Table 5.4: Conceptual construction process categorisation

Process Category	Processes	Reference Code	Reference
PC1 – Preparation and Brief	Identify business needs	PC1.P1	RIBA1, OGC1, OGC3
	Identify project requirements	PC1.P2	RIBA2, RIBA4
	Develop project brief	PC1.P3	RIBA5, OGC5
	Undertake feasibility studies	PC1.P4	RIBA6, OGC 4
	Risk assessment	PC1.P5	RIBA7, RIBA10
PC2- Planning and Design	Prepare initial project programme	PC2.P1	RIBA3
	Preliminary cost planning	PC2.P2	OGC2
	Preparation of concept design	PC2.P3	RIBA11, OGC9
	Preparation of developed design	PC2.P4	RIBA12, OGC10
	Preparation of technical design	PC2.P5	RIBA13
PC3 – Tendering and Procurement	Determine procurement strategy	PC3.P1	RIBA9, OGC6
	Determine contract strategy	PC3.P2	OGC7
	Preparation of contract documents	PC3.P3	OGC7
	Tender process	PC3.P4	OGC8

Process Category	Processes	Reference Code	Reference
PC4 – Construction	Project management	PC4.P1	RIBA14, RIBA16
	Project team coordination	PC4.P2	RIBA14
	Project planning, tracking and monitoring	PC4.P3	RIBA14
	Change management	PC4.P4	RIBA15, RIBA16
	Cost management	PC4.P5	OGC11
	Quality control	PC4.P6	OGC12
	Payments	PC4.P7	RIBA16, OGC13
	Record keeping	PC4.P8	OGC16
	Claims management	PC4.P9	RIBA16, OGC14
	Dispute resolution	PC4.P10	RIBA16, OGC15
PC5- Use and Aftercare	Project performance review	PC5.P1	RIBA18, OGC17
	Update project information	PC5.P2	RIBA17
	Facilities management	PC5.P3	RIBA19

The conceptual process categorisation consist of five main process categories named Preparation and Brief (PC1), Planning and Design (PC2), Tendering and Procurement (PC3), Construction (PC4) and Use and Aftercare (PC5). Each process category consists of construction processes identified from the analysis of RIBA OGC. Construction processes identified from the initial analysis were conceptually assigned to these five process categories and this conceptual categorisation is further verified and refined through an expert forum. The verification of this conceptual process categorisation is presented in the following sections.

5.4 Verification of Construction Process Categorisation

This section describes the first phase of expert forum conducted to verify and the construction processes categorisation established from the analysis of construction process maps. The expert forum profile, selection criteria and the process of conducting expert forum phase I were explained in section 4.7.4 in Chapter 4.

5.4.1 Verification of Construction Process Categorisation

In the interviews experts expressed their views regarding the conceptual process categorisation. Experts explained the reasons for their responses and any other additional comments and remarks on them. In addition they expressed their level of agreement in five point Likert scale. Nvivo10 software was used to analyse the qualitative responses given from the experts. Each process is referenced using a unique code and nodes were created for them. The node structure used to analyse expert responses for process categories and their processes are shown in following Figure 5.4 and Figure 5.5.

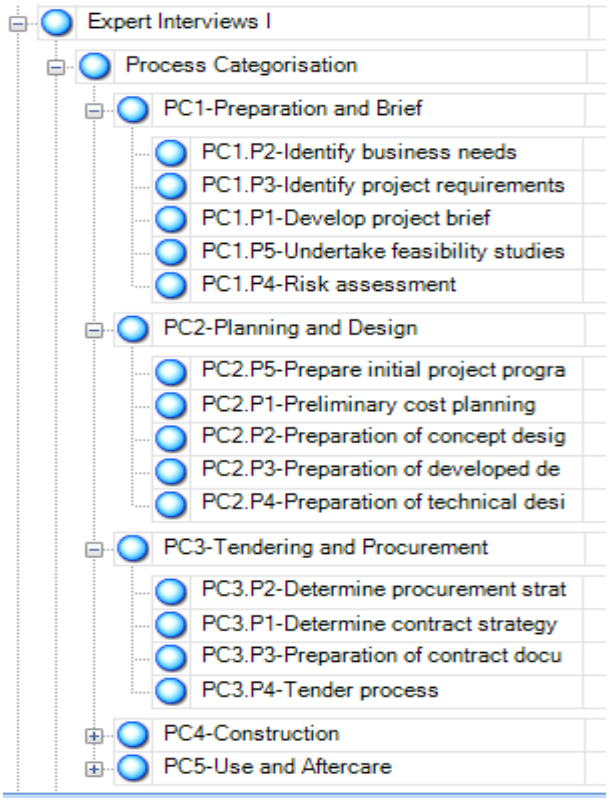

Figure 5.4: Node structure used for the verification of construction process categories - I

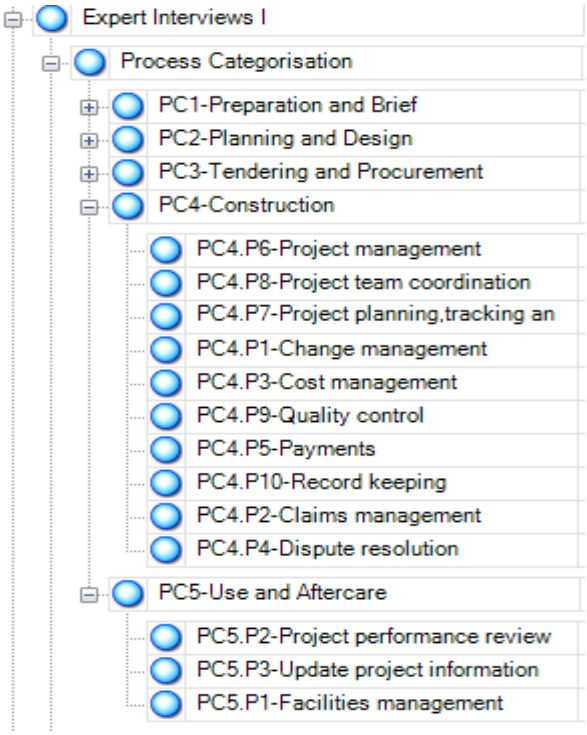

Figure 5.5: Node structure used for the verification of construction process categories - II

5.4.1.1 Preparation and Brief Process Category (PC1)

Five processes were categorised under the Preparation and Brief process category. Positive responses were received from the experts for the process categorization and constituent processes. Majority of the experts agreed to consider the processes as proposed but there were some instances where experts disagreed or had neutral views. The frequency of expert responses given for the processes under Preparation and Brief category are summarised in Table 5.5.

Table 5.5: Expert responses for the Preparation and Brief Process Category

Process	Expert Responses		
	Agree	Neither Agree nor Disagree	Disagree
PC1.P1 - Identify business needs	9	2	1
PC1.P2 - Identify project requirements	9	3	0
PC1.P3 - Develop project brief	7	3	2
PC1.P4 - Undertake feasibility studies	6	5	1
PC1.P5 - Risk assessment	8	2	2

As shown in the Table 5.5, majority of the experts were agreed for the Preparation and Brief process category and its processes. It proves the fact that as an overall assessment, the experts were agreed to consider those processes in the proposed category. Nine experts completely agreed to consider Identify business needs in the category. Two experts had neutral views on this and suggested that this process might be carried out at very early stage and might be applicable to a category before Preparation and Brief. At the same time they acknowledged the fact that it can belong to this category according to proposed categorisation as there are no other category which defines the processes prior to Preparation and Brief. Only expert EF/C/8 indicated disagreement for the process with neutral confidence. The reason for this disagreement was argued by the expert EF/C/8 as:

"I think identify business needs is spreading probably to tendering and procurement as well. Because you need to choose which type of project is going to tender for based on what client needs. In the business plan also you put business needs. I think they all are linked. So preparation and brief to tendering and procurement category for me".

The above argument pointed an important aspect to consider for the categorisation. That is some processes might applicable for more than one category. This can happen due to the complexity of the construction processes. As a general comment experts accept the fact that it is a very difficult task to establish a categorisation for construction processes as they are linked and hugely depend on each project particulars. However, according to the intention of this categorisation, processes do not share categories. Therefore this process was categorised under the most suitable category within which the identification of business needs usually happens. This decision was based on the agreement of majority of the experts.

There were no disagreements for Identify project requirements process. Nine experts agreed and other three experts neither agreed nor disagreed. The comments on this process were similar to the previous process as the experts who had neutral views thought this process might also belong to very early stage and can be categorised under a prior category. Expert EF/C/8 shared the same view for

this process as well and stated that this process also has a link to tendering and procurement route determination.

Developed project brief process received agreed responses from seven experts and neutral responses from 3 experts. Two experts disagreed to consider this process in the category. The reason for the disagreement was identifying that this can be applicable to both Preparation and Brief and Planning and Design categories. Expert EF/C/2 noted:

"It depends on the contract. If its design and build and contractor involves early to design, you know the buildability of the brief early. So it depends on the contract. At least I think it should stand for both preparation and brief and planning and design".

However the expert accepted the fact that he agreed to consider this process in the category as well because it is difficult to separate the processes of first two categories.

Similarly Undertake feasibility studies also received mixed responses. Only 6 experts agreed and five experts had neutral views. One expert disagreed. The experts who didn't agree for this process identified it as a process which might belong to Planning and design. This reason is partially explain by the comment given by expert EF/A/3 regarding the category as:

"There is a little bit of a blur between Preparation and Brief and Planning and Design I would say. So the processes could belong to both. They could come under both".

Another view pointed out regarding Undertake feasibility studies was that it has to be clearly explained that this is the initial feasibility assessment. Further this point was explained as feasibility is checked at different stages of the project along with the developed designs and cost estimates as well. Therefore this process is renamed as 'Undertake initial feasibility studies' when using it in the final model

Risk assessment also received mixed responses. Eight experts agreed to consider the process as proposed. Two experts neither agreed nor disagreed and other two experts were disagreed. The explanation given for the disagreement was similar to

previous process responses. Several experts argued that risk assessments are done at the beginning of each stage to identify the potential risks of each stage and to decide how to manage them. Therefore this process is considered as 'Initial risk assessment' to use for the final model.

5.4.1.2 Planning and Design Process Category (PC2)

Planning and Design category consisted of five processes. The responses given by the experts for the processes under this category are summarised and presented in Table 5.6.

Table 5.6: Expert responses for the Planning and Design Process Category

Process	Expert Responses		
	Agree	**Neither Agree nor Disagree**	**Disagree**
PC2.P1 - Prepare initial project programme	11	1	0
PC2.P2 - Preliminary cost planning	8	3	1
PC2.P3 - Preparation of concept design	10	1	1
PC2.P4 - Preparation of developed design	10	1	1
PC2.P5 - Preparation of technical design	8	3	1

Processes of the Planning and design process category received positive responses from the experts. There were no disagreements for Preparation of initial project programme process. Eleven experts agreed and only one expert had neutral views for the proposed process and categorisation. Other four processes also received positive responses from the experts and only one expert were disagreed for the categorisation. The reason behind the disagreement was the expert thought these processes can drag to other process categories as well. However since the majority of the experts proved the overall agreement, no amendments were done to the processes of this category to consider for the final model.

There were some suggestions to merge this process category with the Preparation and Brief category as some experts though that the processes are moving between

two categories. But as an overall remark, majority of the experts agreed to consider the category and its processes as proposed. Therefore two categories were not merged together for the final model.

5.4.1.3 Tendering and Procurement Process Category (PC3)

Expert views on Tendering and Procurement category were mixed with both positive and negative opinions towards the proposed processes. The expert responses received under this process category are shown in Table 5.7.

Table 5.7: Expert responses for the Tendering and Procurement Process Category

Process	Expert Responses		
	Agree	**Neither Agree nor Disagree**	**Disagree**
PC3.P1 - Determine procurement strategy	5	2	5
PC3.P2 - Determine contract strategy	6	2	4
PC3.P3 - Preparation of contract documents	9	1	2
PC3.P Tender process	10	2	0

Most of the experts thought that determination of procurement strategy and contract strategy are processes which should be classified under planning and design category. Those two processes are identified as very closely linked processes and majority of the experts noted that these have to be considered at an early stage category. Expert EF/C/5 explained the reason as:

"The level of designs, you have to do them considering design and built or traditional. So you have to do them different accordingly. There's no point of developing a design for traditional method and go for design and build. Isn't it? The initial thought would have given at the planning stage I would say."

Expert views on these two processes explained that the determination of both the procurement strategy and contract strategy has an impact upon every other process in the first two categories. Therefore experts proposed to move those processes to the earlier categories. The agreement levels for these were also quite

low as five experts disagreed and two experts had neutral views for determine procurement strategy process. Similarly four experts disagreed and two experts had neutral views for determine contract strategy process. Therefore determine procurement strategy and determine contract strategy processes were moved to Planning and Design process category to refine the process categorisation.

Nine experts agreed to consider the preparation of contract documents under Tendering and Procurement process category. One expert had neutral views and two experts were disagreed. The experts who didn't agree argued that the designs and drawings are also considered as contract documents. To avoid the misinterpretation the process was renamed as preparation of tender documents to consider for the final model.

None of the experts disagreed for the tendering process. Ten experts agreed and two experts had neutral views. However as additional comments, experts suggested decomposing the tender process into sub-processes. When comparing to other process categories and their processes, tendering process was identified as a process with much wider scope. At the same time it showed similarities to the category name and scope as well. Thus tender process was decomposed into three processes named 'invitation to tender', 'tender submission' and 'tender evaluation'. Accordingly the process category was named as Tendering process category.

5.4.1.4 Construction Process Category (PC4)

There were ten processes considered under the construction process category. The responses given for the processes under this Construction process category are shown in Table 5.8.

Table 5.8: Expert responses for the Construction Process Category

Process	Expert Responses		
	Agree	**Neither Agree nor Disagree**	**Disagree**
Project management	8	3	1
Project team coordination	7	2	3
Project planning, tracking and monitoring	9	1	2

Change management	9	1	2
Cost management	8	2	2
Quality control	7	2	3
Payments	9	2	1
Record keeping	7	2	3
Claims management	7	3	2
Dispute resolution	7	2	3

Majority of the experts had positive responses for the processes in the Construction process category. As shown in Table 5.8, there were only few disagreements and neutral responses regarding this category.

Even though the experts responded positively to the project management process, they strongly believed that the term has to be modified to use for the categorisation. Experts identified the term project management is very wide and broad. In addition they identified that some of the underneath processes can also be covered under the project management process scope. But they agreed that project management process is an important process which can categorise under this category. Experts suggested the terms of 'site management' or 'post contract project management' would be more appropriate to use in the categorisation. By considering the overall agreement and suggestions, the project management process was renamed as 'post-contract project management' process. Post-contract project management implies the process within the construction phase and not from the beginning of the project.

Project team coordination and project planning, tracking and monitoring processes had agreed responses from majority of the experts to be considered in the Construction category. However there were few disagreements for these two processes. The experts who had disagreements explained the reason for their response as they feel that these processes might be considered in Planning category as well. By supporting this agreement some of the other experts also suggested that the use of term 'post contract' to avoid the confusion. This view highlighted a weak point of the conceptual categorisation and it was acknowledged by using the terms of 'post contract project team coordination' and

'post contract project planning, tracking and monitoring' in the verification of the categorisation.

Similarly, the experts suggested using the term 'post-contract' for change management and cost management processes as well. Expert EF/C/5 noted that:

"Change management.. In the design as well you have to change. Isn't it? Unless you narrowly define the Change management as post-contract. If you define it as change management only for post-contract then I would agree. But if not change management is for the whole project, then it could really start from the planning and design".

Same suggestion was made regarding the cost management process as well by expert EF/A/3 saying:

"Earlier we came across preliminary cost planning. Now that is also a part of cost management. Isn't it? So then you have to define cost management as 'post contract' activity".

By considering these suggestions, these two processes were renamed by adding term 'post contract' to the. However these two processes received high agreement responses from the experts which indicated the overall agreement of experts for them to be categorised under Construction process category.

Quality control, payments and record keeping processes also received majority of positive responses towards agreement. However, experts pointed out some weak use of terms for processes of payments and record keeping. They noted that the process of payments would cover the payments for the designers as well which might not be considered in Construction phase. Similarly the record keeping process would include the elements from early stages and other categories. Therefore these were named as 'interim payments' and 'site record keeping' while refining the categorisation to be used for the final model.

Claims management and dispute resolution processes also received overall high responses as agreed by seven experts. Some experts questioned the relationship of these processes to e-business. They agreed to the categorisation, but not entirely satisfied that these processes might have strong relationships with e-business.

However the main purpose of this categorisation is to categorise the general construction project related processes and the relationship of these with e-business was explained to them.

In addition the possibility of dragging these processes to Use and aftercare category was highlighted. However majority of experts agreed that these processes can categorise under construction category as proposed. By considering overall agreement responses these processes were considered to be use as proposed in the conceptual process categorisation.

5.4.1.5 Use and Aftercare Process Category (PC5)

The Use and aftercare category consisted of three processes such as project performance review, update project information and facilities management. The frequencies of expert responses for the processes of Use and Aftercare category are summarised in Table 5.9.

Table 5.9: Expert responses for the Use and Aftercare Process Category

Process	Expert Responses		
	Agree	Neither Agree nor Disagree	Disagree
Project performance review	6	4	1
Update project information	6	5	1
Facilities management	7	5	0

Three processes were categorised under Use and Aftercare process category. This process category received mixed responses from experts. Only six experts agreed to consider project performance review process in the category. At the same time only one expert disagreed for the process to categorise under Use and Aftercare category. Other four experts neither agreed nor disagreed. The reason for the neutral views and disagreement was that experts thought project performance review would carry out in during construction as well as after handover and in use. That means experts thought this process would belong to both categories. And the experts who had neutral views also commented that this process might happen at the handover so it might move towards construction category as it is the end of the construction phase.

Similarly, update project information process received agreed responses from six experts. But only one expert disagreed and other five experts had neutral views. The reason was similar to the previous process as experts identified this as a process which might belong to both Construction and Use and Aftercare category. This fact was identified as a limitation of the process category as within this categorisation, processes do not share categories. However to refine the categorisation, this process category was renamed as Handover and Aftercare according to the reviews from the experts.

Facilities management process didn't receive any disagreed responses. Seven experts agreed and other five experts neither agreed nor disagreed. Since there were no disagreements from experts, no amendments were done for the facilities management process.

5.4.2 Verified Construction Process Categorisation

The conceptual process categorisation was verified considering the expert views and responses received through first round of interviews. The analysis and justifications were discussed in previous sections. Table 5.10 presents the verified construction process categorisations.

Table 5.10: Verified construction process categorisations

Process Category	Processes
Preparation and Brief	Identify business needs
	Identify project requirements
	Develop project brief
	Undertake initial feasibility studies
	Initial risk assessment
Planning and Design	Determine procurement strategy
	Determine contract strategy
	Prepare initial project programme
	Preliminary cost planning
	Preparation of concept design

Process Category	**Processes**
	Preparation of developed design
	Preparation of technical design
Tendering	Preparation of tender documents
	Invitation to tender
	Tender submission
	Tender evaluation
Construction	Post-contract project management
	Post-contract project team coordination
	Post-contract project planning, tracking and monitoring
	Post-contract change management
	Post-contract cost management
	Quality control
	Interim payments
	Site record keeping
	Claims management
	Dispute resolution
Handover and Aftercare	Project performance review
	Update project information
	Facilities management

This verified construction process categorisation was presented to experts at the second round of interviews of expert forum phase I to get their opinions and feedback regarding first round findings. All the experts agreed to revised categorisation and accepted it as a suitable process categorisation to use in developing the construction e-business capability maturity model. Therefore this verified construction process categorisation remained same for the final CeB-CMM model. This Verified construction process categorisation forms a fundamental component of the CeB-CMM. The development of CeB-CMM using this categorisation is explained in Chapter 7.

5.5 Summary

The development of CeB-CMM framework and the process of establishing construction process classification were discussed within this chapter. First section of the chapter described the framework development of CeB-CMM. It explained the aim of CeB-CMM and differentiates it from the original SW-CMM. The reasons for the amendments to the original model were explained and justified. Finally the structure and the main components were presented.

Second section of the chapter explained the analysis of RIBA plan of work and OGC gateway reviews to establish the conceptual construction process categorisation. 19 processes were identified from RIBA plan of work 2013 and 17 processes were identified from OGC reviews. These identified processes were then categorised into five process categories and the conceptual process categorisation was established (Table 5.4).

Third section of the chapter described the verification of the conceptual process categorisation using expert interviews. The experts' views about the processes and process categories were analysed and presented. The verified construction process categorisation was presented in Table 5.12. It forms a fundamental element of the CeB-CMM and the development of CeB-CMM using this categorisation is explained in Chapter 7. Next chapter presents the establishment of construction e-business process maturity characteristics which forms the other element of the CeB-CMM.

CHAPTER 6
E-BUSINESS PROCESS MATURITY CHARACTERISTICS

6.1 Introduction

This chapter focuses on developing construction e-business maturity characteristics. It describes the analysis of existing maturity models, second round expert interviews and case studies conducted in pursuant of the objective four of the study which is to identify e-business capability and maturity characteristics in construction organisations. This chapter is structured in four main sections.

Firstly, an analysis of initial Software Capability Maturity Model (SW-CMM), Standardised Process Improvement for Construction Enterprises (SPICE) CMM and general E-Business Capability Maturity Model (EB-CMM) were conducted to identify potential capability maturity characteristics for Construction e-Business Capability Maturity Model (CeB-CMM). The analysis process is described along with the findings.

Secondly, the analysis and findings of second round expert interviews are presented. Thirdly, the analysis and findings of three case studies are presented. Finally, the comparison of second round expert interviews findings and case study interviews are discusses to obtain the final set of construction e-business capability maturity characteristics. These final set of capability maturity characteristics forms a fundamental component of the CeB-CMM.

6.2 Conceptual Construction E-Business Capability Maturity Characteristics

Analysis of existing maturity models was introduced to identify potential maturity characteristics to use in the Construction e-Business Capability Maturity Model (CeB-CMM). Three existing maturity models which were selected for the analysis are described in the Table 6.1.

Table 6.1: Maturity models selection for the Archival Analysis Stage II

Maturity model	Focused Area	Reason for the Selection
SW-CMM	Software Process Improvements	To consider general process related capability maturity characteristics
SPICE	Construction Process Improvements	To consider general construction capability maturity characteristics
EB-CMM	E-Business Process Improvements	To consider general e-business capability maturity characteristics

These three maturity models and their maturity level characteristics are considered for the analysis to identify the potential characteristics for CeB-CMM. The motives for integration of aforementioned maturity models are shown in following Figure 6.1.

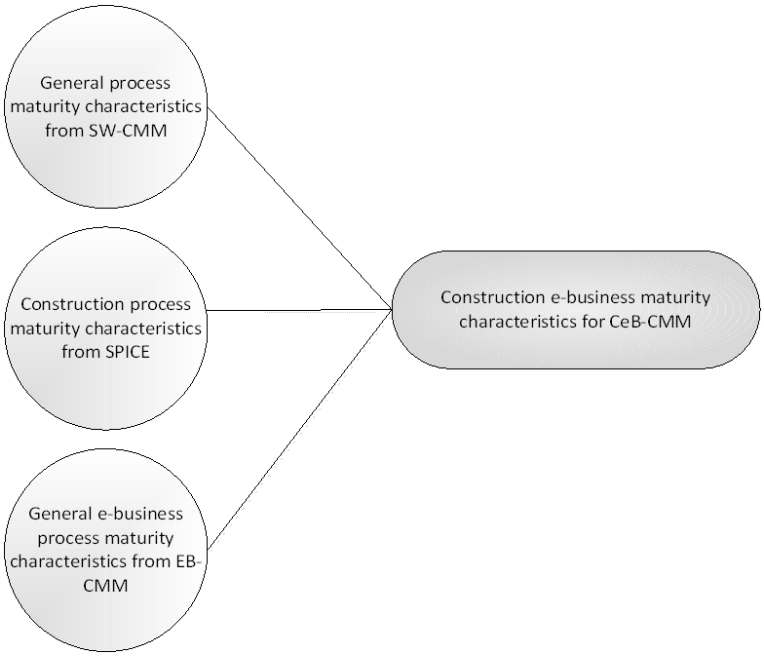

Figure 6:1: Integration of existing maturity models to establish construction e-business capability maturity model

There is no current capability maturity model which focuses on construction e-business process improvement. Therefore in order to determine the maturity characteristics for a construction e-business capability maturity model, general process maturity characteristics, construction process maturity characteristics and general e-business process maturity characteristics were analysed and integrated. Following sections illustrate the analysis process and the results. Content analysis with the use of Nvivo 10 software was used to facilitate the analysis process in a systematic way. The findings of this analysis are then verified and refined through a series of expert interviews.

6.2.1 Maturity Characteristics from SW-CMM

The main aspect of the analysis of Software Capability Maturity Model (SW-CMM) was to consider general process related capability maturity characteristics. SW-CMM is also considered as the first maturity model developed as a process improvement initiative. Sections 3.3 described SW-CMM in detail. SW-CMM defines five maturity levels. Under each maturity level, key process areas and goals are defined. In order to identify potential maturity characteristics for the CeB-CMM, the maturity levels definitions and process area descriptions were examined. Table 6.2 presents the maturity characteristics identified from the SW-CMM. Reference codes were introduced to the identified characteristics to maintain the transparency and clear explanations in subsequent analysis stages.

Table 6.2: Maturity Characteristics identified from SW-CMM

Maturity Level	Characteristics	Reference Code
1 - Initial	Process capability is unpredictable because the software process is constantly changed or modified as the work progresses (the process is ad hoc).	CMM-1-1
	Only few stable software processes in evidence.	CMM-1-2
2 - Repeatable	Policies for managing a software project and procedures to implement those policies are established.	CMM-2-1
	Organisations repeat successful practices	CMM-2-2

Maturity Level	Characteristics	Reference Code
	developed on earlier projects.	
3 - Defined	Standard process for developing and maintaining software across the organisation is documented.	CMM-3-1
	Both software engineering and management processes, and these processes are integrated.	CMM-3-2
	An organisation-wide training program is implemented to ensure that the staff and managers have the knowledge and skills required.	CMM-3-3
	Software process contains a coherent, integrated set of well-defined software engineering and management processes.	CMM-3-4
4 - Managed	Organisation sets quantitative quality goals for both software products and processes.	CMM-4-1
	Software processes are instrumented with well-defined and consistent measurements. These measurements establish the quantitative foundation for evaluating the projects' software processes and products.	CMM-4-2
	Projects achieve control over their products and processes by narrowing the variation in their process performance to fall within acceptable quantitative boundaries.	CMM-4-3
	When these limits are exceeded, action is taken to correct the situation.	CMM-4-4
5 - Optimising	Organisation is focused on continuous process improvement.	CMM-5-1
	Innovations that exploit the best software engineering practices are identified and transferred throughout the organisation.	CMM-5-2
	Organisations analyse defects to determine their causes.	CMM-5-3

6.2.2 Maturity Characteristics from SPICE

Standardised Process Improvement for Construction Enterprises (SPICE) model considers the applicability of CMM concepts within construction context. It is a construction process improvement model with capability and maturity focus as further described in Section 3.2.4. SPICE CMM was selected for this initial analysis to consider general construction capability maturity characteristics. There are five maturity levels defined in SPICE model and the maturity characteristics identified from the SPICE are shown in the Table 6.3.

Table 6.3: Maturity Characteristics identified from SPICE

Maturity Level	Characteristics	Reference Code
1 - Initial	Construction process capability of organisation is unpredictable because the process is not specified and is constantly changed or modified as the work progresses.	SPICE-1-1
2 - Repeatable	Policies and procedures for managing the major project based processes are established.	SPICE-2-2
	Focus on effective management processes within each construction project and repeat the successful practices of earlier projects.	SPICE-2-3
3 - Defined	The organisation has the capability to capture and share good practices across projects at an organisational scale.	SPICE-3-1
	Project teams share common understanding of what are good practices in their organisation.	SPICE-3-2
	The processes are well defined and management has good insight into progress.	SPICE-3-3
4 - Managed	Measure and monitor performance.	SPICE-4-1
	Control variations in performance.	SPICE-4-2
5 - Optimising	Consistently achieve set performance targets.	SPICE-5-1

Maturity Level	Characteristics	Reference Code
	Improve performance benchmarks.	SPICE-5-2

6.2.3 Maturity Characteristics from EB-CMM

As described in Section 2.5.2, the E-Business Capability Maturity Model (EB-CMM) is a general e-business capability maturity model which was developed focusing cosmetic and drug industry. It was developed based on original CMM principles and consists of six maturity levels. EB-CMM was selected for this analysis to consider general e-business capability maturity characteristics. Table 6.4 presents the maturity characteristics identified from the SW-CMM with their reference codes.

Table 6.4: Maturity Characteristics identified from EB-CMM

Maturity Level	Characteristics	Reference Code
1 - Initial	Operate business mostly using manual processes and tasks.	EBCMM-1-1
	May have few computerised systems brought or implemented but are for ad-hoc, individual business requests.	EBCMM-1-2
2 - Internal	Able to improve internal business performance, resolve internal problems, or build particular information systems requested internally or externally by supply-chain players.	EBCMM-2-1
	Yet these automated processes and computerized information systems are not integrated and connected.	EBCMM-2-1
3 - Integrated	Organisations indicate mature integration of different systems within the organization or between/among organisations.	EBCMM-3-1
4 - Defined	Organisation e-business processes are properly defined.	EBCMM-4-1

Maturity Level	Characteristics	Reference Code
	Establish and maintaining e-business process assets for managing existing e-business processes.	EBCMM-4-2
	Developing and maintaining constant e-business culture and environment across the organisation.	EBCMM-4-3
5 - Quantitatively Managed	Quantitatively measure and monitor the performance of electronic business processes.	EBCMM-5-1
6 - Optimising	Analyse the root cause of e-business problems and taking corrective actions to prevent recurrence.	EBCMM-6-1
	Continually learn and use new IT solutions and evolve better electronic environment for keeping their business status, services, and competition competence optimal.	EBCMM-6-2

6.2.4 Conceptual Construction E-Business Process Maturity Characteristics

With the use of aforementioned analysis of existing maturity models, identified maturity characteristics are summarised and assigned into five maturity levels. The integration of maturity characteristics of SW-CMM, SPICE and EB-CMM established the conceptual maturity characteristics for CeB-CMM as presented in Table 6.5 below. These characteristics are further reviewed and refined through a series of expert interviews to use in the final model.

Table 6.5: Conceptual Construction E-Business Process Maturity Characteristics

Maturity Level	Code	Characteristics	References
1 - Initial	L1MC1	Most processes operate manually	CMM-1-2, EBCMM-1-1
	L1MC2	E-business initiatives within the organisation are unplanned.	CMM-1-1, SPICE-1-1
	L1MC3	Organisation does not provide stable environment to support e-business processes.	EBCMM-1-2
2 - Repeatable	L2MC1	Basic e-business processes are established.	CMM-2-1, SPICE-2-1
	L2MC2	Established successful e-business processes are recognisably repeated within organisation practice.	CMM-2-2, SPICE-2-2
	L2MC3	Established e-business processes are isolated and are not integrated within the organisation.	EBCMM-2-1, EBCMM-2-2
3 - Defined	L3MC1	E-business processes are well established and understood.	CMM-3-1, CMM-3-4, EBCMM-4-1, EBCMM-4-2, SPICE-3-2, SPICE-3-3
	L3MC2	Standardised e-business processes are used constantly across the organisation for all projects.	EBCMM-4-3, SPICE-4-1
	L3MC3	Different e-business processes are integrated within the organisation.	CMM-4-2, EBCMM-3-1

	L3MC4	Provide necessary training for staff regarding e-business processes.	CMM-3-3
Maturity Level		Characteristics	Reference
4 - Managed	L4MC1	Establish quantitative indicators for measure e-business process performance.	CMM-4-1
	L4MC2	Organisation quantitatively measures and monitors e-business process performance.	CMM-4-2, EBCMM-5-1, SPICE-4-1
	L4MC3	E-business processes are quantitatively understood and controlled.	CMM-4-3, CMM-4-4, EBCMM-5-1, SPICE-4-2
	L4MC4	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems.	EBCMM-3-1
5 - Optimising	L5MC1	Focused on continuous improvement of e-business capabilities.	CMM-5-1, EBCMM-6-2, SPICE-5-2
	L5MC2	Problem diagnosis and resolution.	CMM-5-3, EBCMM-6-1, SPICE-5-1
	L5MC3	Identify new innovative technology improvements and deploy suitable approaches.	CMM-5-3, EBCMM-6-2

The maturity characteristics in above table forms the conceptual characteristics for construction e-business process maturity which will be subjected to an expert forum to develop the verified Construction e-business process maturity characteristics.

6.3 Expert Forum - Phase II

This section describes the second round expert interviews conducted to verify and refine the construction e-business characteristics established from the analysis of aforementioned capability maturity models.

6.3.1 Verification of E-Business Maturity Characteristics

In the expert forum phase II, experts were asked to express their views regarding the conceptual e-business maturity characteristics. Experts gave their agreement level response in five point Likert scale and explained the reasons for their responses and any other additional comments and remarks on them. Content analysis with the use of Nvivo 10 software was used to analyse the qualitative responses given from the experts.

6.3.1.1 Maturity Level 1 - Initial

Three conceptual e-business process maturity characteristics were identified for the maturity level 1 of CeB-CMM. These were reviewed through expert interviews. The frequency of expert responses given for the e-business maturity characteristics under Maturity level 1 are summarised in Table 6.6.

Table 6.6: Expert responses for maturity characteristics in Maturity Level 1

Maturity Characteristics		Expert Responses		
		Agree	Neither Agree nor Disagree	Disagree
L1MC1	Most processes are operated manually.	8	1	0
L1MC2	E-business initiatives within the organisation are unplanned.	8	1	0
L1MC3	Organisation does not provide stable environment to support e-	8	1	0

	business processes.

The e-business maturity characteristics of level 1 of the conceptual model are related to Initial e-business maturity level of an organisation. The conceptual characteristics of this maturity level indicate that most of the organisation business processes are operated manually and e-business initiatives within the organisation are unplanned. Further at Initial maturity level, organisation does not provide stable environment to support e-business processes. As shown in Table 6.6, experts showed very positive attitudes towards the conceptual characteristics of Level 1.

Experts agreed that these proposed characteristics belong to the early stage of maturity in e-business implementation and progression. With reference to Table 6.7, eight out of nine experts agreed for L1MC1; that at Initial e-business maturity level, most business processes are operated manually. They acknowledge this as the starting point and some experts stated that they have experienced this as the initial stage of e-business implementation. Only expert EF/A/1was neither agreed nor disagreed. The reason for his neutral response was expressed as;

‘‘*Because I think now we've moved from this. So this might not be completely relevant. You might have to name as ad-hoc rather simply manually. Because what you would find may be some parts are manual and some parts are automated. But there might be no integration between the two*’’.

According to above statement, expert believed that the industry has completely moved forward from having most manual processes. However in the maturity model, this level represents the initial and first maturity stage. Therefore the early stage characteristics also have to be included and described. Further the agreement of other experts confirmed the suitability of this L1MC1 characteristic for CeB-CMM.

The second characteristic of maturity level 1 also received similar responses as the first characteristics. Eight out of nine experts agreed for L1MC2; that e-business initiatives within the organisation are unplanned at Initial maturity stage. Experts agreed with this characteristic to consider in first maturity level and identified this

as a characteristic of initial maturity progression. However, expert EF/C/8 carried a neutral view regarding this characteristic. The reason was that the expert felt that the term 'unplanned' was not properly explained. Further, he proposed to be specific about what aspect of e-business initiatives are unplanned. In the model the scope of 'unplanned e-business initiatives' considers the planning of e-business process implementation in terms of process, technology, people and governance. Considering the agreement level of the majority this characteristic was accepted for the model.

The third conceptual e-business maturity characteristic is that at maturity level 1, organisation does not provide stable environment to support e-business processes (L1MC3). Only expert EF/C/8 neither agreed nor disagreed for this characteristic. He argued that an organisation might know or have e-business capabilities, but not using them for financial or client reasons. However unstable environment are not enlightening the characteristics of a matured e-business process. Other eight experts agreed and acknowledged this characteristic as belongs to maturity level 1. Considering agreed responses of experts, no amendments are done to the proposed three e-business characteristics (L1MC1, L1MC2 and L1MC3) of the Initial maturity level.

6.3.1.2 Maturity Level 2 - Repeatable

Maturity level 2 consisted of three conceptual e-business maturity characteristics. The responses given by the experts for maturity characteristics under this maturity level are summarised and presented in Table 6.7.

Table 6.7: Expert responses for maturity characteristics in Maturity Level 2

Maturity Characteristics		**Expert Responses**		
		Agree	**Neither Agree nor Disagree**	**Disagree**
L2MC1	Basic e-business processes are established.	8	0	1
L2MC2	Established successful e-business processes are recognisably repeated within organisation practice.	8	0	1

L2MC3	Established e-business processes are isolated and are not integrated within the organisation.	8	1	0

According to the Table 6.7, majority of the experts were agreed for the proposed e-business maturity characteristics in Repeatable maturity level. It proves the fact that as an overall assessment, the experts were agreed to consider those characteristics in the proposed maturity level 2. The conceptual characteristics of this level explained an organisation at Repeatable e-business maturity level as its' basic e-business processes are established, established successful e-business processes are repeated within organisational practice and they are integrated within the organisation.

Eight experts completely agreed to consider the first and second maturity characteristics (L2MC1 and L2MC2) under maturity level 2. They agreed that the second level of e-business maturity is that establishing basic e-business processes and repeat them within organisation practice if they are successful. They related these characteristics to construction context and stated that;

''that's the normal way in construction industry. You use one project as pilot one and if its success you use it for others''

Experts directly agreed and they expressed high confidence on their responses regarding L2MC1 and L2MC2. Only expert EF/A/2 disagreed to consider these characteristics in Level 2. The reasons for the disagreement was explained as the expert felt that there should be another level in-between this level and Initial level. According to his opinion, it will take more time for an organisation to establish basic e-business processes. However, different organisations may have different approaches to achieve e-business capability maturity and it will take different time scales to achieve certain maturity levels. Forward looking organisations might use effective approaches differ to laggards and the important fact is that there are certain capabilities to be achieved to increase the maturity irrespective of the associated time scale. This argument is further confirmed by the majority of experts' agreement toward these maturity characteristics under Level 2.

The third conceptual e-business maturity characteristic of Level 2 is that the established e-business processes are isolated and are not integrated within the organisation at Repeatable maturity level. None of the experts were disagreed to consider this characteristic as proposed. Expert EF/C/8 had a neutral view on this and stated that he is not certain to consider integration of e-business processes under maturity Level 2 or Level 3. Other eight experts agreed with high confidence levels to consider this under Level 2 maturity. They explained that integration is an important aspect of successful e-business execution and therefore if an organisation is having isolated e-business processes, it cannot consider as having a higher maturity level. Experts agreed that maturity level 2 is the most suitable level for this characteristic. By considering the approval of expert views; aforementioned conceptual e-business maturity characteristics (L2MC1, L2MC2 and L1MC3) confirmed to consider under Repeatable maturity level.

6.3.1.3 Maturity Level 3 - Defined

Expert views on maturity characteristics of level 3 were mixed with both positive and negative opinions. The expert responses received under this process category are shown in Table 6.8.

Table 6.8: Expert responses for maturity characteristics in Maturity Level 3

Maturity Characteristics		Expert Responses		
		Agree	**Neither Agree nor Disagree**	**Disagree**
L3MC1	E-business processes are well established and understood.	7	0	2
L3MC2	Standardised e-business processes are used constantly across the organisation for all projects.	6	1	2
L3MC3	Different e-business processes are integrated within the organisation.	5	2	2
L3MC4	Provide necessary training for staff regarding e-business processes.	5	2	2

Maturity level 3 consisted with four maturity characteristics. This maturity level is ‘Defined maturity’ level where the organisation define and establish stable e-

business processes within the business environment. According to expert opinions on conceptual characteristics in this level, few of them did not agree with the proposed characteristics. Expert EF/A/2 disagreed for all the characteristics to be considered in Level 3. He expressed his views as;

"*I think these should be further down to at next stage or so. As I mentioned earlier level, think it will take more time and you can't change straightaway like that. I don't see them yet*".

According to his views, there should be an additional maturity level in between Level 2 and Level 3 to facilitate an easy transition from Repeatable maturity level to Defined maturity level. However, these maturity levels are not linked with any time frame and the maturity model does not expect the organisations to move up straight away. Organisations can take their time to establish and integrate e-business processes within their working environment and achieve a smooth transition between levels. Expert EF/C/8 also did not totally approve L3MC1 as he thought that at this level e-business processes might be well established but might not be understood by everyone in the organisation. Further he explained his view by giving an example as at this stage operational people might well understand the e-business processes but the top management might not fully understand the e-business processes of their organisation. Considering the fact that gaining understanding on e-business process performance through measurements in level 4, the argument of expert EF/C/8 is valid. Because at level 3 organisation e-business processes might be well established but may not be fully understood as their performances are not measured. Also at next maturity level, L4MC3 explains gaining understanding and controlling e-business processes. Expert EF/A/1 also commented on this characteristic and stated that a proper understanding of e-business processes would gain after providing necessary training for employees. Therefore L3MC1 was amended as organisation e-business process are well established at this stage and are well understand at next maturity level.

Second maturity characteristic of level 3 explains the constant application of standardised e-business processes across the organisation for all projects. Six experts agreed to this characteristics and expert EF/C/4 neither agreed nor

disagreed. However, majority of the expert questioned the fact that it is not possible to apply standardised e-business processes to each and every project of the organisation. The same argument was presented by expert EF/C/4 who had neutral views and expert EF/C/8 who was disagreed for this characteristic. Expert EF/C/8 stated that;

"*It will depend on size of the project and for some projects you can't use standardised ones. Because all these software comes with a cost, cost of license fee and all. So it depends on the number of people whom going to use and the location*".

Experts who agreed for L3MC2 also mentioned that even though they agree for this characteristics, they are not sure about applying standardised e-business processes for all projects. They further explained that each project has its own requirements with stake holders and project parameters of cost, time and quality. Even though a company have well established e-business processes within the organisation, they might not use them for all projects due to project requirements. Therefore as maturity increases, organisations should standardised and encourage constant usage of e-business processes across their projects. But in some circumstances they might not be applicable for all projects and the appropriate e-business processes have to be selected and deployed.

L3MC3 explains that at this stage, e-business processes are integrated within the organisation. As Table 6.9 presents, five experts agreed that this characteristic is applicable in maturity level 3. Experts EF/A/2 and EF/C/4 disagreed for this characteristic to be considered as proposed. Expert EF/A/2 had the same view as explained in previous discussions and Expert EF/C/4 did not believe that at any stage an organisation would actually integrate their systems. However as other experts agreed and explained this actually happens in organisations as they mature with e-business processes. Some of them have experienced e-business process integration within their organisations. Experts EF/C/5 and EF/C/8 had neutral views regarding this as they thought this should be a characteristic of next maturity level. At the same time they accepted that e-business processes and systems have to be integrated while achieving e-business maturity. In view of the

agreement and confirmation of this characteristic by majority of the experts, L3MC3 was accepted to consider in the verified and refined maturity model.

Final conceptual maturity characteristic of level 3 was providing training on e-business processes for staff. Expert EF/A/1 did not accept L3MC4 to be considered at this level and stated that;

"*I think people should have recognised and considered even more at earlier stages when the processes are not established. I think this has to be considered at level 2. Because people understood the processes because training is provided for them. So I think this has to be considered earlier at level 2. Here at level 3 you could say like continuous training or further training of the previous level*". Conversely, expert EF/C/5 stated that;

"*For the training I strongly agree. It should at this level. Because level 1 and 2 will be too early to do that because at those levels processes are not well established*".

Similarly, other experts also agreed and accepted that providing staff training on e-business processes is a characteristic of this stage. The two experts who had neutral views (expert EF/C/5 and EF/C/8) also acknowledged that L3MC4 is what should be happened in organisations, but they were not certain whether actually organisations can provide training for staff in real practical situations. Considering aforementioned expert views, L3MC4 was accepted to consider at maturity level 3 as proposed to develop the construction e-business CMM.

6.3.1.4 Maturity Level 4 - Managed

There were four maturity characteristics considered under Maturity level 4. The responses given for maturity characteristics under this maturity level are shown in Table 6.9.

Table 6.9: Expert responses for maturity characteristics in Maturity Level 4

Maturity Characteristics	Expert Responses		
	Agree	Neither Agree nor Disagree	Disagree

L4MC1	Establish quantitative indicators for measuring e-business process performance.	5	1	3
L4MC2	Organisation quantitatively measures and monitors e-business process performance.	5	1	3
L4MC3	E-business processes are quantitatively understood and controlled.	5	2	2
L4MC4	Organisation e-business processes are compatible with and capable of incorporating into other partnering organisations' e-business processes.	6	1	2

Proposed conceptual e-business characteristics of maturity level 4 were related quantitative management of e-business process performances. Four maturity characteristics were proposed under this level and experts had mixed views regarding this maturity level. The first characteristic (L4MC1) was establishing quantitative indicators for e-business process performance. The second characteristic (L4MC2) was organisation quantitatively measures and monitors e-business process performance.

Experts had similar views and opinions on these two characteristics to be considered for the e-business maturity model level 4. Only five experts agreed to consider these maturity characteristic for the e-business model and three experts were disagreed. Expert EF/C/1 and expert EF/C/2 stated that they have experienced this situation at their work place as their organisation have already established performance indicators for their e-business processes. All the five experts who agreed to L4MC1 expressed that this should be the next level of maturity for an organisation after establishing and integrating e-business processes in their work environment. They accepted that quantitative indicators are the appropriate measurements to manage their e-business performances to achieve maturity. However, four experts had different views regarding establishing quantitative measurements at this level. They disagreed and had neutral views because they believed that not only quantitative measurements but also qualitative measurements should be introduced to measure e-business performances. They agreed that this maturity level should focus on measuring and

controlling, but they questioned why only the quantitative measures are concerned.

Expert EF/A/1 expressed his views as;

"*I agree with this level as this means they are monitoring and controlling their performances. But my issue is why only quantitative measures? Why not qualitative measures? If you look at the technology implementation cycle, usually the implementation failures occurs from result of multiple set of factors. Not simply something that can measure quantitatively, that might be due to attitude or behavioural which is more qualitative*"

Further he explained his view as;

"*And if we don't have measures in place for qualitatively recognising where those issues are, no matter how much of measurement that... quantitative measure is only going to tell you that we are not performing well. But it won't give you any explanation as to why. So you might see a rise or fall in your analysis because it is measured by numbers. But you don't understand why they exists*".

Expert EF/A/2 had a similar opinion on these characteristics and stated that, it is important to have both quantitative and qualitative measures in place to gain a true understanding of what is happening. These experts explained that qualitative measures will help to understand the reasons behind the quantitative findings so that the performances can accurately managed by addressing the real issues. Considering these arguments, both quantitative and qualitative performances are reflected in level 4 maturity characteristics for the e-business model as presented in Section 6.3.3.

Third characteristic of level 4 (L4MC3) was that e-business processes are quantitatively understood and controlled according to the findings of performance measurements. The experts had similar views as in previous two characteristics and pointed out the importance of having qualitative measures to gain a clear and true understanding of actual situation. Further they explained introducing having both qualitative and quantitative measurements are important and possible and as they progressed through these maturity levels, organisations can look back at some point and see how they have progressed in every aspects. It is a good

reflection for an organisation to quantitatively monitor and control performances together with qualitative understanding. Therefore L4MC3 characteristic was refined introducing both quantitative and qualitative aspects.

The last characteristic of level 4 (L4MC4) was compatibility and capability of incorporating organisational e-business processes and systems with partnering organisations' e-business processes and systems. Most of the experts agreed to this and only two experts were disagreed to consider this characteristic in level 4. Expert EF/C/4 disagreed as he thought that organisations are not willing to incorporate with others' e-business systems in practical situation. He was concerned about security issues of organisational systems. However, with current technological advancements it is possible to connect and integrate with other external systems with system restrictions to protect sensible data and information of the company. In other terms it is important for a construction organisation to be compatible with other systems as in construction projects they have to incorporate with other project parties and stakeholders in a collaborative environment. Expert L disagreed to L4MC4 because he thought that this characteristic should be considered at an early maturity level. Expert EF/C/8 neither agreed nor disagreed because he was not sure about the possibility of having compatible e-business systems considering in-house software. Still, both experts acknowledge the importance of having compatible systems and integration in collaborative construction environment. Considering the acceptance of majority of experts, L4MC4 was confirmed to be used for the e-business CMM.

6.3.1.5 Maturity Level 5 - Optimising

The Maturity level 5 consisted of three conceptual e-business maturity characteristics. The frequencies of expert responses for maturity characteristics of Maturity level 5 are summarised in Table 6.10.

Table 6.10: Expert responses for maturity characteristics in Maturity Level 5

Maturity Characteristics	Expert Responses		
	Agree	Neither Agree nor Disagree	Disagree

L5MC1	Focused on continuous improvement of e-business capabilities.	8	1	0
L5MC2	Problem diagnosis and resolution.	7	2	0
L5MC3	Identify innovative technology improvements and deploy suitable approaches.	9	0	0

E-business characteristics of Maturity Level 5 describes an organisation at Optimising maturity level as focused on continuous e-business capability improvements, carry out problem diagnosis and resolution for e-business process complications and identifies innovative technology improvements to deploy suitable approaches. Experts' opinions on these maturity characteristics were positive and there were no disagreements for the characteristics explained. Eight experts agreed that at this stage an organisation would focus on continuous improvements of their e-business process capabilities. Expert EF/C/8 neither agreed nor disagreed for L5MC1. He believed that maintenance of existing e-business processes is also equally important as continuously improving their capabilities. He proposed rewording for L5MC1 and stated that;

"*It should not just continuous improvement, you have to maintain what has achieved. So you might have to say 'focus on maintain and continuous improvements'*".

This argument is acceptable as an organisation have to maintain and update their existing capabilities in order to achieve continuous improvement. This characteristic was accepted by all other experts and they acknowledged that this is what should be happened when an organisation reached to its highest maturity stage.

Expert EF/C/8 neither agreed nor disagreed for L5MC2 and stated that problem diagnosis should consider in an early maturity level. He argued that it is not appropriate to wait until this level to diagnose problems of e-business processes. Expert EF/C/1 also had a neutral view regarding this characteristics. He accepted that this characteristic should be applicable at this stage, but was questioning whether an organisation would do this in real practice. As all other experts agreed

to this characteristic this was considered to be included to the revised and refined e-business CMM. It is important that an organisation do identify the problems of their e-business processes and resolve them in order to maintain and achieve continuous improvement of their e-business capabilities.

Final characteristic of maturity level 5 was identification of innovative technology improvements in the market and deploy appropriate ones for the organisation. There were no disagreements for this and all the experts agreed that this is what organisations are doing and have to be done after they achieve the highest maturity level. They identified the importance of looking for improvements and keeping up to date with new technology advances in order to optimise organisations' e-business capability and maturity.

6.3.2 Developed Construction E-Business Process Maturity Characteristics

The conceptual e-business maturity characteristics for CeB-CMM were verified considering the expert views and responses received through interviews. The analysis and justifications were discussed in previous sections. Table 6.11 presents the developed construction e-business maturity characteristics.

Table 6.11: Developed construction e-business maturity characteristics

Maturity Level	Characteristics	Reference Code
1 - Initial	Most processes operate manually	CEB-MC1.1
	E-business initiatives within the organisation are unplanned.	CEB-MC1.2
	Organisation does not provide stable environment to support e-business processes.	CEB-MC1.3
2 - Repeatable	Basic e-business processes are established.	CEB-MC2.1
	Established successful e-business processes are recognisably repeated within organisation practice.	CEB-MC2.2

Maturity Level	**Characteristics**	**Reference Code**
	Established e-business processes are isolated and are not integrated within the organisation.	CEB-MC2.3
3 - Defined	E-business processes are well established.	CEB-MC3.1
	Standardised e-business processes are used constantly across the organisation.	CEB-MC3.2
	E-business processes are integrated within the organisation.	CEB-MC3.3
	Provide necessary training for staff regarding e-business processes.	CEB-MC3.4
4 - Managed	Establish quantitative and qualitative indicators for measure e-business process performance.	CEB-MC4.1
	Organisation quantitatively and qualitatively measures and monitors e-business process performance.	CEB-MC4.2
	E-business processes are quantitatively and qualitatively understood and controlled.	CEB-MC4.3
	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems.	CEB-MC4.4
5 - Optimising	Focused on maintenance and continuous improvement of e-business capabilities.	CEB-MC5.1
	Problem diagnosis and resolution.	CEB-MC5.2
	Identify new innovative technology improvements and deploy suitable approaches.	CEB-MC5.3

Applicability of these conceptual construction e-business maturity characteristics are further refined using three case studies. The case study data analysis and discussion is presented in the forthcoming sections.

6.4 Ratification of construction e-business process maturity characteristics through case studies

The main purpose of the case studies was to investigate the actual practices of e-business implementation from selected construction organisations in order to ratify construction e-business process maturity characteristics. As described in the section 4.7.5, multiple case studies were carried out investigating project level and organisational level e-business maturity characteristics. The investigation was focused on exploring current e-business profile of the organisation and different stages of e-business implementation of the organisations. The rationale for selecting the target organisations included the size and type of the business and experience in implementing e-business to their business practices.

6.4.1 Background of Case Study Organisations

Three case study organisations were selected for in-depth investigation to participate the multiple case studies. This section provides background information and details of interviewees of each case study organisation.

6.4.1.1 Case Study 1 - Company X

Company X is a sub division of a public sector multidisciplinary organisation operating in areas of transportation, civil engineering and mechanical engineering. As a sub division, Company X operates within the business area of urban planning and construction. It delivers services in planning, building and maintenance of surface transport infrastructure, rail and underground transportation. The organisation employs over 25000 employees in the UK. The company was founded in 2000 and has a vision of being the top service provider in the UK. The company defines its corporate strategy to meet the national needs and identifies innovation as the key for the company's success both now and in future. They are committed to invest on new innovative technologies and to lead construction e-approaches and practices. Three key employees, responsible for e-business process management and experienced in using e-business processes of Company X were interviewed during the data collection stage for case study one. Table 6.12 summarises the details of interviewees of Company X.

Table 6.12: Case Study 1 – Details of Interviewees of Company X

Interviewee	Job Function
Interviewee X-1	BIM Consultant – Organisational Change Management
Interviewee X-2	BIM Consultant - Process Change Management
Interviewee X-3	Commercial Manager

6.4.1.2 Case Study 2 - Company Y

Company Y is a global integrated design, engineering and management consultancy organisation providing multi-disciplinary consultancy services for property and infrastructure. The company was established in 1960 and has over 50000 employees across the world. Company Y is a leading provider of property, engineering and regulatory services to local councils, transport authorities, schools and local community groups. They are typically involved throughout the whole project life cycle, from early planning to final occupation. The company vision is to continue building a sustainable business that meets clients' needs, creating value and delivering innovative and cost effective solutions. They are at the forefront of innovative design and construction management and invest heavily in new information and communication technologies. Three employees, experienced in using and managing e-business processes of Company Y were interviewed for case study two. Table 6.13 presents the details of interviewees of Company Y.

Table 6.13: Case Study 2 – Details of Interviewees of Company Y

Interviewee	Job Function
Interviewee Y-1	Asset Manager
Interviewee Y-2	Senior Quantity Surveyor
Interviewee Y-3	Senior Project Manager

6.4.1.3 Case Study 3 - Company Z

Company Z is a medium scale construction company in the UK which offers their clients complete property and construction solutions in construction, development and management services. The company employed around 240 employees and delivers its services from five offices located throughout England, ensuring a local consistent client experience across the country. The overall company business strategy is built around four key principals of providing excellent customer service, employing best people, delivering excellent product and services and underpinning by solid and sustainable performance. Through working with leading companies in the construction industry, company Z has been committed to strengthen their e-business capabilities and invested in different e-business initiatives to deliver better projects and more value to clients. Five professionals who are using and involving and experiencing e-business processes were interviewed from company Z as shown in Table 6.14.

Table 6.14: Case Study 3 – Details of Interviewees of Company Z

Interviewee	Job Function
Interviewee Z-1	Client Liaison Coordinator
Interviewee Z-2	Senior Quantity Surveyor
Interviewee Z-3	Building Surveyor
Interviewee Z-4	IT Manager
Interviewee Z-5	Commercial Manager

6.4.2 Case Studies Analysis and Findings

This section discusses the analysis and findings of three case studies on establishing and verifying construction e-business maturity characteristics. Analysis is discussed under two main sections explaining the current e-business profiles of Company X, Y and Z and examining different stages of their e-business capability and maturity.

Current e-business profiles of case study organisations were investigated to gain an understanding of their level of current e-business implementation and different approaches and usages of e-business processes. Different stages of e-business implementation and capability maturity of organisations were examined to identify and verify conceptual construction e-business maturity characteristics while investigating how e-business processes were introduced and developed within three case study organisations, and their future plans for improvements in e-business. Finally, summary and comparison of case studies findings are presented.

6.4.2.1 Case Study 1 – Company X

Current E-Business Profile

Company X identifies e-business as a key to their success in achieving competitive advantages. They aim to increase their e-business capabilities and achieve government benchmarks on BIM. Organisation shows a vast interest on spreading their e-business profile across all business process areas. Currently they have implemented e-business in most of their process areas and Figure 6.2 presents their current e-business profile.

As presented in Figure 6.1, Company X has implemented e-business for most of their construction business processes. Interviewees acknowledged that they have a very good e-business systems in place and they optimise efficiency and effectiveness of information flows with them.

Company X uses some common software such as Microsoft Word, Excel and Project and Emails for their day to day work. In addition they have some bespoke software and systems which are based in their company intranet. For planning and design they have mainly use AutoCAD and recently started using BIM systems for large projects. Tender portals and online e-procurement software are mainly used for tendering processes. ‘RIB’ tendering software is also used for some projects of Company X. ‘ASITE’ is a collaborative software platform which they use for some of their main projects and it enables automation workflows through procurement, project management, contract management and document management of projects.

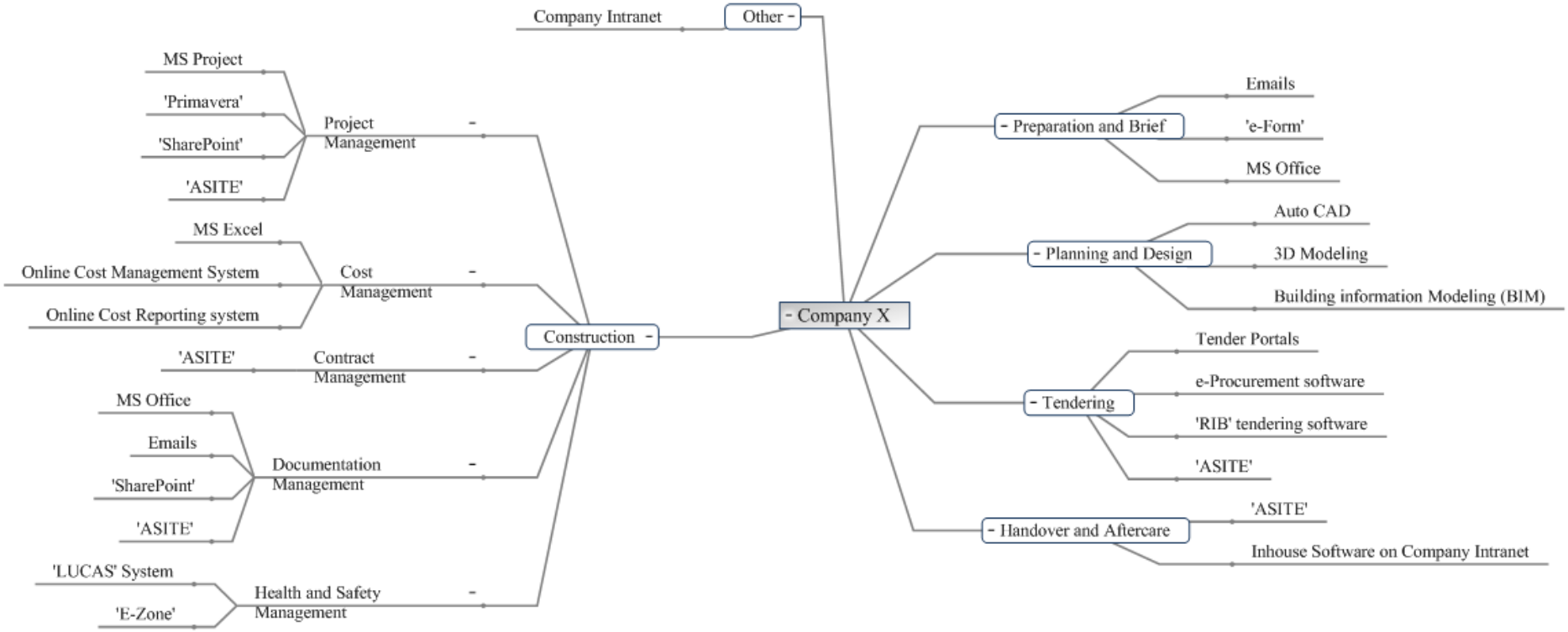

Figure 6.2: Current E-Business Profile of Company X

Company X has bespoke cost management and cost reporting systems built in their intranet. In addition they have MS Excel templates for preparation of cash flows and other cost management activities. 'SharePoint' is used for documentation management and project management processes. They collaborate with project stakeholders and share their documents using "SharePoint'. Company X uses 'LUCAS' system and 'E-Zone' for health and safety management of their projects. They record relevant information using these systems and use them for health and safety management.

Current e-business profile of company X and previous discussion about it explains a characteristic of their organisational e-business maturity as they initially had basic e-business processes established and subsequently increasing their e-business capabilities by implementing e-business in to all of their business processes (CS1-MC1).

Interviewees stated that they have a very sophisticated intranet for their company which includes several built in applications and software. Company X allows 24/7 access to their intranet and employees can log into their personal virtual desktops using Citrix service. They have a central IT department for the organisation and all the branches are connected to it. Interviewee X-3 stated that their IT department maintain their e-business systems up to date and very responsive to their requests. Maintaining current e-business processes vigorous and up to date is another characteristic of e-business capability maturity of an organisation (CS1-MC2). Further interviewees expressed that their organisation is keen on innovation and they try to deploy new e-business tools and systems to strengthen their e-business profile.

How the e-business processes were implemented and developed and their future plans

Company X has initiated e-business in very early years. They have good resources of hardware and in-house information systems. According to Interviewee X-3, company have adopted many e-business processes during last couple of years. He stated that as a government organisation, company X has got lot of initiatives in terms of e-business. For example, they have started using 'ASITE' collaborative software which enables integrated automation of workflows through procurement,

project management, contract management and document management of projects. 'E-form' is another new electronic system which they introduced in the company to create a paper-less working environment. Company provides all the necessary resources to implement these processes and their IT department is always educating them providing help guides and assistance in using these e-business tools. Interviewee X-1 stated;

"*Whenever you have a problem you can chat to the IT guys and let them know what your problems are and then they will attempt your question and they will sort it out and they will reply for the chat and email. And the process is nicely set up".*

This means that company provides assistance in e-business tools and creates a stable environment for e-business processes (CS1-MC3).

Building Information Modelling (BIM) is another new e-business approach which company X recently implemented in their projects. As Interviewee X-2 stated, they initiated BIM for one of their large project at first. There were some difficulties and challenges at first with using this new initiative such as incorporating sub-contractors, training employees, providing sufficient infrastructure etc. However, management realised the potential benefits and success of BIM from that project and started implementing it to their other new projects. This can identify as one of the e-business characteristic of early maturity stage of establishing new e-business processes in the company (CS1-MC4). Company X set a target of achieving government mandate benchmark on BIM by 2016 and established a separate BIM department to manage the change and enable a smooth transition of traditional processes and people to BIM. Interviewee X-1 and X-2 explained that they are studying on how the new change will have an impact on organisational people processes. Further, top management have a great support and interest in these new e-business approaches and it really helped their organisation to consider these new initiatives (CS1-MC5).

Providing necessary training is another characteristic which identified from company X (CS1-MC6). They provide training programmes on new e-business initiatives as BIM for their employees. Additionally they facilitate online training materials on their existing e-business processes and tools. Employees can log into

their systems and download various training materials or follow online training courses provided.

Interviewees described that their organisational e-business processes are integrated (CS1-MC7) and they use them for all of their construction projects. Interviewee X-3 explains this as;

"*Almost all of our electronic systems are integrated and connected. Usually output of one software easily feed information to the other. For example, we have our online cost management system and cost reporting system. These two are interrelated and if we enter data into one system, it automatically feed them into the other system output"*

"And all our branches are linked into one company intranet. So all the information and systems of different branches and different projects are connected with each other and stored in a central location".

Being a client organisation, company X initiate and motivate their stakeholders to implement and collaborate with their e-business processes and are capable of incorporating with them as needed (CS1-MC8). Another characteristic of company X's e-business maturity is that they use performance indicators to measure and monitor their e-business processes (CS1-MC9). Interviewees stated that their IT department carrying out surveys and collect feedback forms regarding performance of their e-business processes. And also they frequently circulate performance reports and information on successful execution of e-business processes. They think that their organisation is trying to increase their e-business capabilities to be competitive among other lead organisation. Company X is trying to keeping up to date with new technological improvements (CS1-MC10) and motivate their employees to effectively use e-business processes by informing them about their potential benefits (CS1-MC11).

Since Company X recently established their BIM department, still there is a gap in integration of them with central IT department. Interviewee X-1 and X-2 stated that they are planning to integrate with IT department and develop central strategic plans for e-business and BIM implementation. And also at the moment

Company X does not use all BIM for all of their projects. They are planning to implement it to more of their projects in future (CS1-MC12).

Interviewee X-1 identified that there are some people issues to be considered in order to increase the effective usage of e-business their company. Interviewee stated that;

"*People issue is always there. There are so many behaviours that you can't change. It's also the culture. No matter whether you train them or not, they are not going to incorporate or effectively use the systems. They do not have positive attitudes towards IT, because they have used manual systems all of their lifetime*".

Interviewees identified that creating positive attitudes towards e-business is vital to achieve desired benefits from e-business processes. Training programmes can be introduced as a part of this. At the same time, also equally important (CS1-MC13).

The construction e-business process characteristics identified in above discussion are summarised below in Table 6.15.

Table 6.15: E-Business Process Maturity Characteristics identified from Case Study X

Reference Code	Maturity Characteristics
CS1-MC1	Initially basic e-business processes are established and subsequently increased organisation e-business capabilities by implementing e-business in to all of their business processes
CS1-MC2	Maintaining current e-business processes up to date.
CS1-MC3	Organisation provides assistance in e-business tools and creates a stable environment for e-business processes.
CS1-MC4	Success e-business process are repeated in other projects.
CS1-MC5	Top management interest and support towards e-business.
CS1-MC6	Providing necessary trainings.

Reference Code	Maturity Characteristics
CS1-MC7	Integration of e-business processes.
CS1-MC8	Compatibility with outside e-business systems.
CS1-MC9	Measure and monitor e-business process performances.
CS1-MC10	Keeping up to date with new technological improvements.
CS1-MC11	Motivate their employees to effectively use e-business processes by informing them about their potential benefits.
CS1-MC12	Use e-business process for all projects.
CS1-MC13	Provide stable and optimistic culture and environment for e-business within the organisation.

6.4.2.2 Case Study 2 - Company Y

Current E-Business Profile

Company Y's current e-business profile is shown in Figure 6.3. Company has a strong e-business profile with some main bespoke and robust e-business systems. As shown in the Figure 6.2, Company Y does not use any special tools or software for preparation and brief. They use only emails and MS Office software for preparation and brief. Building Information Modeling (BIM) is used for planning and design of their projects and Auto CAD is used for create project drawings for some projects.

"Pipeline' is an in-house e-business system built in company intranet which facilitates several e-business processes as estimating, cost management, contract management and documentation management. Interviewees explained that they use past cost data stored in 'Pipeline' system to create estimates and bids for new projects. MS Office is used to prepare tender documentation and tender evaluation. Almost all of their tendering process is carried out through online tender portals.

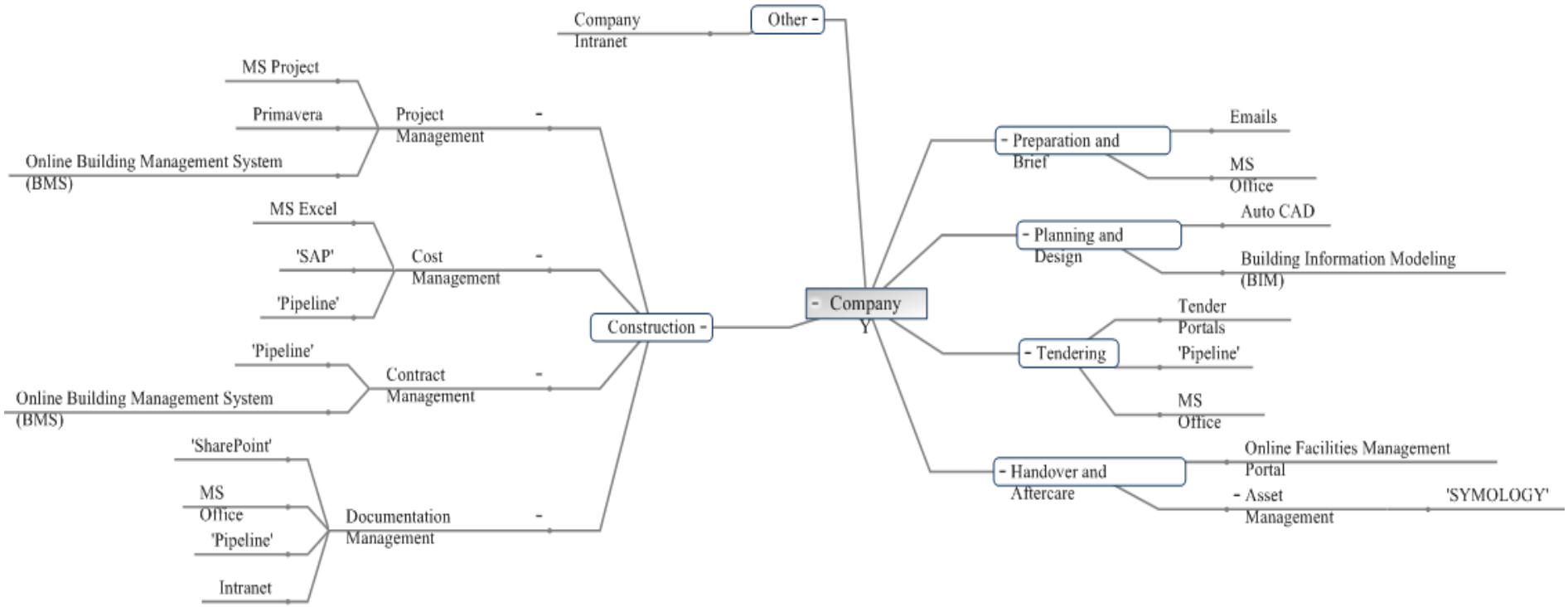

Figure 6.3: Current E-Business Profile of Company Y

MS Project and Primavera software are used for creating project programme and project planning and monitoring. Company Y has an online Building Management System (BMS) which they use for their project management and contract management activities. As explained above, 'Pipeline' is used for cost management of their projects. In addition 'SAP' cost management software and MS Excel are also used for cost management of projects. Apart from 'Pipeline' and MS office, Company Y uses 'SharePoint' for documentation management of their construction projects. It allows a collaborative shared platform to store and share documents and drawings. In addition company intranet is used to store project documents in a central place.

Company Y uses online facilities management portal for facilities management of their completed projects. For asset management, they use a specific software called 'SYMOLOGY'. These e-business tools provide a constant platform for e-business processes in the organisation. Following section describes the development and current status of e-business processes of company Y and establishes construction e-business maturity characteristics.

How the e-business processes were implemented and developed and their future plans

As described in Section 6.4.1, Company Y is a large scale, global, leading construction company. The company currently has very good e-business systems in place. Interviewees stated that the company provides necessary hardware and resources for their e-business tools (CS2-MC1) and frequently update their systems (CS2-MC2). Interviewee Y-3 said that, few years back their company did not have many e-business processes and solid e-business systems were built later. Earlier, most of the business processes were conducted manually (CS2-MC3). But with the advancements in the technology and with increased competitiveness, they started implementing e-business processes within the organisation (CS2-MC34). He expressed his views as;

"*In the last ten years, probably there has been a lot of progress in terms of e-business in our company. Before, there were handful of IT systems, but now there are plenty. We have adopted lot more during this period. Lot more companies are coming in with new systems and we are rapidly catching up*".

Building Information Modeling (BIM) is a new system which company Y recently started using for their projects. Interviewees said that they have had a series of training programmes on BIM (CS2-MC5). Further they stated that initial training sessions were available for all the employees in the construction department and company is planning to provide more sophisticated training to employees who are actually working with BIM. According to Interviewee Y-1, currently they do not use BIM for all of their projects and use it only for large scale projects. However, top management is planning to use BIM for all of their new projects in future after establishing it within organisational practice (CS2-MC6).

Interviewee Y-3 identified the importance integration of e-business processes within the company and flexibility of integration with other companies. He stated that;

"*Our systems have to be flexible around the other external system and have to be able to work with what is provided. So we integrate our company system and be flexible with others*".

This explains features of e-business maturity of an organisation. In order to optimise and increase e-business capabilities, organisation have to integrate their e-business processes (CS2-MC7). At the same time they have to be flexible and compatible to integrate with external e-business systems (CS2-MC8). These characteristics are already established in company Y as they have one central e-business systems which integrates all of its e-business processes. Interviewee Y-2 raised some challenges they face with this one integrated system as;

"*Like it's not always one size and fits all. Company Y is a big company and they are trying to make their system fits to everyone rather than tear apart. For example at desktop we are using the same system which Finance team also using. So it sometimes it doesn't fit to all our needs*".

However having an integrated system will help the organisation to utilise and optimise its' e-business tools. This will bring large cost savings and time savings for the organisation and will increase their capability of e-business processes.

Company Y has outsourced a separate company for IT services of their organisation. The IT Company is responsible for monitor and maintenance e-business processes of company (CS2-MC9). However Interviewee Y-2 identified some drawbacks of having a separate large IT department as;

"I think since our company is very big, it is hard to get IT provisions specifically to our section. Sometimes, if we request something and probably the job might be finished when we actually get what we requested. But I think if it's a smaller company who has their own IT department, you can straight away go and ask for a 3G stick or whatever you want. Here you have to follow so many procedures to get what you need in terms of IT. There are so many layers of authorisations and procedures".

As Interviewees explained, Company Y has established performances indicators to monitor their e-business performances (CS2-MC10). Employees are invited to provide data and information to IT department as they requested. Usually managers are requested to provide their opinion and suggestions prior to implementing a new e-business tool or prior to a changing an existing e-business process.

The construction e-business process characteristics identified in above discussion are summarised below in Table 6.16.

Table 6.16: E-Business Process Maturity Characteristics identified from Case Study II

Reference Code	Maturity Characteristics
CS2-MC1	Organisation provides necessary hardware and resources for their e-business tools.
CS2-MC2	Frequently update their e-business systems.
CS2-MC3	At very early stage, most of the processes were conducted manually.
CS2-MC4	Later, most of the e-business processes are established within the organisation.
CS2-MC5	Provide training programmes.

Reference Code	Maturity Characteristics
CS2-MC6	Organisation planning to use established e-business processes to every project.
CS2-MC7	Integration of e-business processes.
CS2-MC8	Flexibility and ability to incorporate with external systems.
CS2-MC9	Monitor and maintain e-business processes.
CS2-MC10	Establish performance indicators to measure e-business process performances.

6.4.2.3 Case Study 3 - Company Z

Current E-Business Profile

Company Z is medium scale contracting company which identifies the value of e-business processes. Currently most of its business processes are conducted electronically and they are benefited from those established e-business processes. While being a medium scale organisation, it has the challenge of strict budgets for electronic infrastructure. However, Company Z has a strong e-business profile compared to other large scale companies. It has had converted many traditional business processes into e-business processes while establishing a stable environment for e-business. Following Figure 6.4 presents the current e-business processes of Company Z.

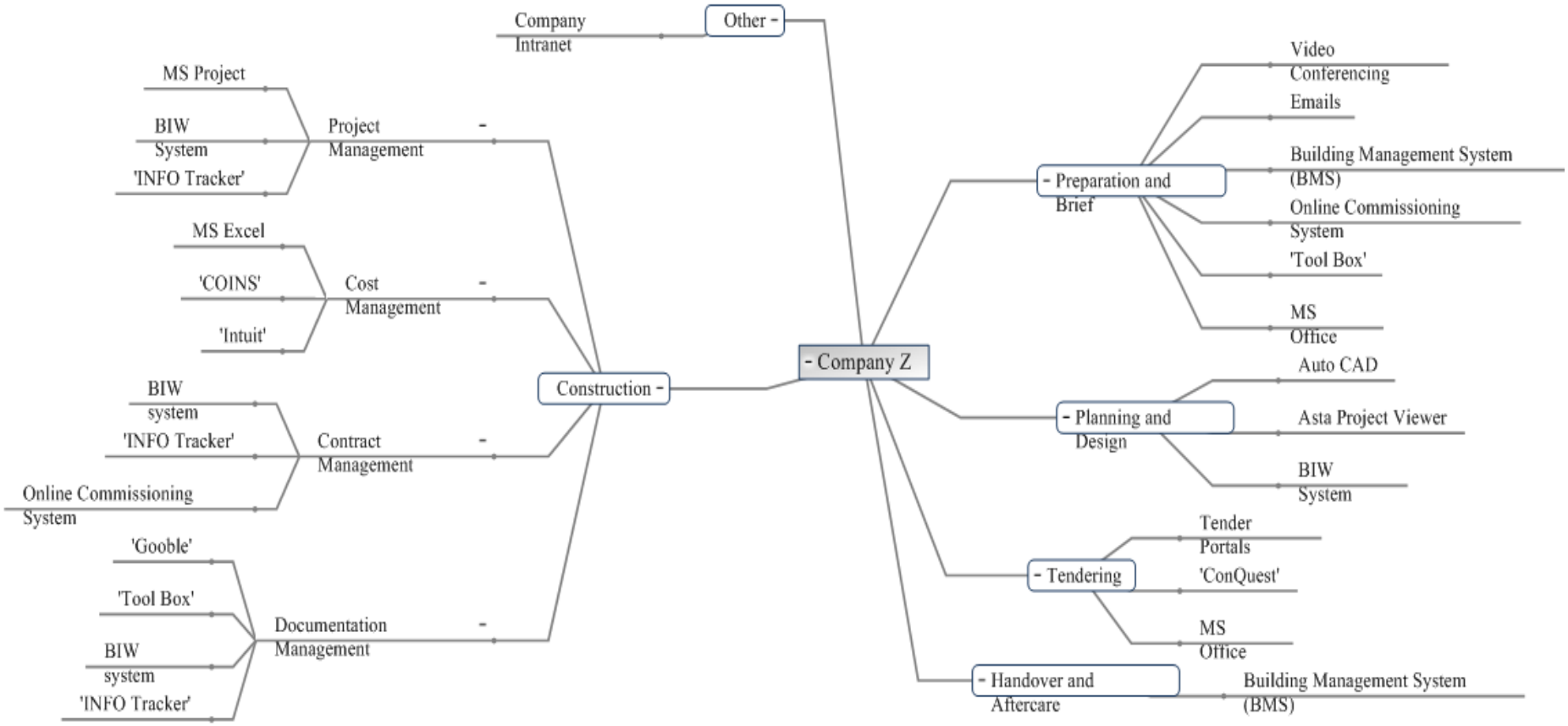

Figure 6.4: Current E-Business Profile of Company Z

Company Z is using different e-business tools for preparation and brief. They conduct meetings with client and consultant through video conferencing. Emails and MS office are used as the main mode of general communication through preparation and brief process. Specifically it uses Building Management System (BMS) and Online Commissioning System to receive client requirements and to communicate with them. 'Tool Box' is another software which Company Z use at this pace and it consists with all the documentation and templates to prepare brief and other relevant reports. AutoCAD and Asta Project viewer are used for create drawings in planning and design of projects. BIW systems used to share those drawing with other project parties. BIW provides improved access to drawings and documents unrestricted by location or technology.

Tender portals are mainly used for e-tendering process. Tender documents are prepared using MS Office and 'ConQuest' estimating software is used to prepare estimates for bids. For project management, Company Z mainly uses BIW system. Project planning and programming is done with the use of MS Project. 'Info Tracker' is an in-house system for project management and site management. It keeps all site records and project details on daily basis and at any time project reports can be easily printed out from the system. 'COINS' and 'Intuit' financial management systems are used for the cost management of construction projects of Company Z. In addition MS Excel also used to prepare cash flows for some projects.

Contract management is done with the use of BIW system and Online Commissioning System. 'Info Tracker' is used to obtain project data for managing contracts where necessary. For documentation management, Company Z has their own bespoke electronic system called 'Gooble'. It is a web based documentation management system which use to store and share documents across employees of Company Z. In addition 'Tool Box' is also used for documentation management purposes. BIW system is used to manage project documents with project parties. It is a collaborative platform which provides a common space to share project documents. 'Info Tracker' is mainly used to documentation management in project sites. Company Z has a Building Management System (BMS) which they use for aftercare of their completed projects. Additionally, Company Z is

furnished with a company intranet and in house IT department which stabilise and strengthen their current e-business profile.

How the e-business processes were implemented and developed and their future plans

Interviewees of the Company Z explained their experience in adopting and using e-business processes in their work practices. Company Z has recently defined their e-business processes and rapidly moving away from traditional manual processes to achieve competitive advantages. Interviewees mentioned that they had most manual processes at the beginning (CS3-MC1) and acknowledged the benefits of their current e-business processes. Some of the benefits which they identified were cost savings, time savings, ease of use, ease of alterations, storage space savings and collaboration. Interviewee Z-5 stated that "

"In e-business point of view; we've actually just been through a process of converting our business documents to electronic documents. We had big containers, hundreds of them full of project documents and correspondences. All the details of old projects. But now we just keep few important correspondents only and everything is online and paperless. That's advantage for us a very big".

Company Z have well established e-business processes for their business areas. They use some bespoke e-business software and many other construction software for their businesses. Interviewees stated that their top management is very interested in expanding their e-business capabilities. Therefore the company tries to provide a supportive and steady environment with necessary facilities for e-business. They provide necessary infrastructure and hardware to support e-business systems (CS3-MC2). Company provide computers and internet facilities not only in the main office, but also in all of their construction sites. However Interviewee Z-4 suggested that it will be more beneficial if they update their systems with the latest versions of software (CS3-MC3). It will increase the compatibility of their work with other project parties.

Company Z is at its primary stages of adopting some new e-business processes and the employees acknowledge the benefits and reward of the new e-business systems. Presently they are planning to use BIM for their projects and they have initiated it with one of their recent major project (CS3-MC4). In addition they

have started providing trainings on BIM and related software. Interviewees identified the need of providing proper training for the staff regarding new processes and tools (CS3-MC5). Interviewee Z-3 expressed his opinion as;

"There is a lot of learning and development need for our staff. And its money and we need to train and coach people. For example take BIM. To use it to full extent, you need to train people. So I think learning and training is the first and foremost".

Training programs provides education and necessary skills for the employees to optimise e-business processes in their work. Therefore it is a key characteristic to increase the capability of organisations e-business processes. However interviewees identified that people issue should also be considered. They stated that no matter how much training they provide, peoples' attitudes towards e-business have to be changed to positive to gain maximums rewards from them. This indicates that qualitative aspects are important to be considered to determine the efficiency of e-business processes (CS3-MC6).

Company Z has a separate IT department which provides services for maintaining their e-business systems (CS3-MC7). Mainly IT department look after technical aspects such as infrastructure fixing and maintaining. Further they provide help and guidance on their existing e-business systems. If they want specific changes in their systems, company hires separate professional companies.

Proper administration of existing e-business processes is another characteristic identified from Company Z (CS3-MC8). Interviewees identified the need of proper administration and management of their current e-business systems. For example they explained the issues occurred in their document management system called 'Gooble' due to improper administration and usage. Company did not provide adequate training for people when they initialise 'Gooble' system and after some time it became unusable due to improper usage. It decreased capabilities of the system and company had to restore the system and reorganise all the documents of it. This process consumed considerable amount of time and cost of the company and later they assigned a separate manage to administrate the system. Therefore proper administration and management of current e-business systems is needed in order to achieve continuous improvements.

According to interviewees the e-business systems of Company Z are not integrated with each other. They explained some difficulties they are experiencing and identified the need of having more centralised systems (CS3-MC9). Currently company Z does not have established procedures for measuring their e-business process performances using performance indicators. IT department conduct frequent surveys and gather feedback from employees, but does not measure the performances of e-business processes against performance indicators. Feedback regarding e-business processes are analysed to identify problems in their systems and IT department take necessary actions to resolve them (CS3-MC10). Interviewee Z-5 accepted that establishing performance indicators as a good stepping stone for them to consider in future to increase their e-business capabilities.

Company Z is devoted to increase their e-business capabilities to achieve competitive advantages. They are keen on innovative e-business advancements in construction (CS3-MC11) and try to adopt suitable initiatives to deliver more value to their clients (CS3-MC12). As a result, they initiated using BIM for their projects and they are planning to use web-based 'Livelink' collaborative construction management system for their future projects.

The construction e-business process characteristics identified in above discussion are summarised below in Table 6.17.

Table 6.17: E-Business Process Maturity Characteristics identified from Case Study Z

Reference Code	Maturity Characteristics
CS3-MC1	Had most manual processes at the beginning.
CS3-MC2	Provide necessary infrastructure and hardware to support e-business systems.
CS3-MC3	Keep current e-business systems up to date.
CS3-MC4	Initiate new e-business approaches with one project and then use it for other projects.
CS3-MC5	Provide proper training to people.

Reference Code	Maturity Characteristics
CS3-MC6	Consideration of qualitative aspects to determine the efficiency of e-business processes.
CS3-MC7	Maintaining current e-business systems.
CS3-MC8	Proper administration and management of e-business processes.
CS3-MC9	Centralising existing e-business systems.
CS3-MC10	Problem identification and resolve.
CS3-MC11	Keen on innovative e-business advancements in construction.
CS3-MC12	Adopt suitable initiatives to deliver more value to their clients.

6.4.3.4 Comparison of Case Studies Findings

Above sections summarised and presented construction e-business process maturity characteristics established from aforementioned discussion sections. Based on the findings of the case studies, construction e-business maturity characteristics were identified. Table 6.15, 6.16 and 6.17 recaps the e-business maturity characteristics identified from three case study organisations; Company X, Y and Z. Those construction e-business process maturity characteristics are compared with the maturity characteristics developed from the second phase of expert forum to determine the ratified construction e-business process maturity characteristics to formulate the CeB-CMM. The comparison of maturity characteristics established from expert interviews and case studies are presented in following Table 6.18.

Table 6.18: Comparison of maturity characteristics established from expert interviews and case studies

Maturity characteristics established from expert interviews	Comparison to case studies maturity characteristics

Maturity characteristics established from expert interviews		**Comparison to case studies maturity characteristics**
CEB-MC1.1	Most processes operate manually	CS2-MC3, CS3-MC1
CEB-MC1.2	E-business initiatives within the organisation are unplanned.	
CEB-MC1.3	Organisation does not provide stable environment to support e-business processes.	CS1-MC2, CS1-MC3, CS1-MC13, CS2-MC1, CS3-MC2
CEB-MC2.1	Basic e-business processes are established.	CS1-MC1, CS2-MC4
CEB-MC2.2	Established successful e-business processes are recognisably repeated within organisation practice.	CS1-MC4, CS3-MC4
CEB-MC2.3	Established e-business processes are isolated and are not integrated within the organisation.	CS1-MC7, CS2-MC7, CS3-MC9
CEB-MC3.1	E-business processes are well established.	CS1-MC1, CS2-MC4
CEB-MC3.2	Standardised e-business processes are used constantly across the organisation.	CS1-MC12, CS2-MC6
CEB-MC3.3	E-business processes are integrated within the organisation.	CS1-MC7, CS2-MC7, CS3-MC9
CEB-MC3.4	Provide necessary training for staff regarding e-business processes.	CS1-MC5, CS1-MC6, CS1-MC11, CS2-MC5, CS3-MC5
CEB-MC4.1	Establish quantitative and qualitative indicators for measure e-business process performance.	CS1-MC9, CS2-MC10, CS3-MC6
CEB-MC4.2	Organisation quantitatively and qualitatively measures and monitors e-business process performance.	CS1-MC9, CS2-MC9
CEB-MC4.3	E-business processes are quantitatively and qualitatively understood and controlled.	CS1-MC9, CS2-MC9, CS3-MC8

Maturity characteristics established from expert interviews		Comparison to case studies maturity characteristics
CEB-MC4.4	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems.	CS1-MC8, CS2-MC8
CEB-MC5.1	Focused on maintenance and continuous improvement of e-business capabilities.	CS1-MC2, CS1-MC10, CS2-MC2, CS3-MC3, CS3-MC7, CS3-MC11
CEB-MC5.1	Problem diagnosis and resolution.	CS3-MC10
CEB-MC5.1	Identify new innovative technology improvements and deploy suitable approaches.	CS1-MC5, CS1-MC10, CS3-MC12

6.4.3 Ratified Construction E-Business Capability Maturity Characteristics for CeB-CMM

Comparison of e-business maturity characteristics established from expert interviews and case studies are discussed and analysed in previous section. Accordingly, e-business maturity characteristics for the CeB-CMM were verified and refined to develop the final model. Table 6.19 presents the final construction e-business capability maturity characteristics attained from two data analysis stages.

Table 6.19: Construction e-business capability maturity characteristics established from the comparison of expert interviews and case studies analysis

Maturity Level	Characteristics
1 - Initial	Most processes operate manually
	E-business initiatives within the organisation are unplanned.
	Organisation does not provide stable environment to support e-business processes.

Maturity Level	**Characteristics**
2 - Repeatable	Basic e-business processes are established.
	Established successful e-business processes are recognisably repeated within organisation practice.
	Established e-business processes are isolated and are not integrated within the organisation.
	Provide a stable environment to support e-business processes.
3 - Defined	E-business processes are well established.
	Standardised e-business processes are used constantly across the organisation.
	E-business processes are integrated within the organisation.
	Provide necessary training and education for staff regarding e-business processes.
	Updating their existing e-business systems with new advancements.
4 - Managed	Administrate and maintain current e-business processes.
	Establish quantitative and qualitative indicators for measure e-business process performance.
	Organisation quantitatively and qualitatively measures and monitors e-business process performance.
	E-business processes are quantitatively and qualitatively understood and controlled.
	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems.
5 - Optimising	Focused on maintenance and continuous improvement of e-business capabilities.
	Problem diagnosis and resolution.
	Identify new innovative technology improvements and deploy suitable approaches.

Above Table 6.19 presents the final construction e-business capability maturity characteristics established from the comparison of expert interviews and case studies analysis. These maturity characteristics are used to develop the CeB-

CMM. The development procedure of CeB-CMM using these maturity characteristics is described in Chapter 7.

6.5 Summary

Identification and verification of construction e-business capability maturity characteristics are explained in this chapter. First section of the chapter described the identification conceptual construction e-business capability maturity characteristics by analysing three existing capability maturity models; SW-CMM, SPICE and EB-CMM. Second section of the chapter explained the verification of conceptual construction e-business capability maturity characteristics using second round of expert interviews. Experts' views and opinions on identified maturity characteristics were presented and analysed. The verified e-business maturity characteristics were presented in Table 6.12.

Third section of the chapter described the analysis of three case studies. Backgrounds of each case studies and their interviewees were explained at first. Then, the analysis of case study findings are discussed. Finally the findings of case studies are compared with expert interview findings to determined construction e-business capability maturity characteristics for CeB-CMM. Verified and refined maturity characteristics were presented in Table 6.18. Use of these characteristics for the development of CeB-CMM is explained in Chapter 7.

CHAPTER 7
CONSTRUCTION E-BUSINESS CAPABILITY MATURITY MODEL (CEB-CMM)

7.1 Introduction

This chapter describes the formulation and validation of Construction e-Business Capability Maturity Model (CeB-CMM) to assess capability and maturity levels of e-business processes in construction organisations. This chapter is structured in six main sections. First section provides an introduction to the chapter and explains how the contents are organised. Second section describes the formulating procedure of CeB-CMM with the use of process categorisation and maturity characteristics. Third section presents the user interface of CeB-CMM and the output of CeB-CMM; the e-Business Capability Maturity Map. Fourth section of the chapter describes the validation process of CeB-CMM. Fifth section discusses the analysis and findings of the validation process of CeB-CMM. Finally the chapter concludes with a summary of chapter contents.

7.2 Formulating the complete model of the CeB-CMM

The framework development of the CeB-CMM was described in Chapter 5 Section 5.2. CeB-CMM decompose e-business profile of an organisation according to process categories and provides maturity level indications for each process category. The main aim of the CeB-CMM is to identify the current status of ICT implementation of project related processes in construction organisations. The skeletal structure of the CeB-CMM was illustrated in Figure 5.1 in Chapter 5. Two main model components are process categorisation and e-business maturity characteristics. Process categorisation was established in Chapter 5 and construction e-business maturity characteristics were established in Chapter 6. Accordingly number of process categories (n1) and number of processes of each process category (n2, n3, n4 and n5) also determined. Forthcoming sections describe the use of those two components to formulate the CeB-CMM.

7.2.1 Interpretation of Maturity Characteristics for Process Categories

Analysis of first round interviews of the expert forum determined the verified and refined construction process classification to use for the CeB-CMM. This is presented in the Table 5.12 in Chapter 5. Final process categorisation comprised of five process categories named as Preparation and Brief, Planning and Design, Tendering, Construction and Handover and Aftercare. Preparation and Brief process category consists with five processes and Planning and Design category consists with six processes. Four processes are categorised under Tendering process category. There are ten processes for Construction process category and three processes for Handover and Aftercare process category. This process categorisation forms the first main component of the CeB-CMM.

Second key component of the CeB-CMM is construction e-business capability maturity characteristics. These characteristics were established through second round of expert interviews and three case studies. The analysis and establishment of construction e-business maturity characteristics were described in Chapter 6. The final set of construction e-business maturity characteristics for CeB-CMM were presented in Table 6.19 in Chapter 6.

In the process of development of CeB-CMM, these construction e-business maturity characteristics are interpreted into each process category. Following Table 7.1 illustrate the interpretation of construction e-business maturity characteristics for the Preparation and Brief process category of CeB-CMM.

Table 7.1: Interpretation of construction e-business maturity characteristics for the Preparation and Brief process category

Maturity Level	Characteristics of Preparation and Brief Process Category
1 - Initial	Most processes of Preparation and Brief category operate manually
	E-business initiatives of Preparation and Brief category within the organisation are unplanned.

Maturity Level	**Characteristics of Preparation and Brief Process Category**
	Organisation does not provide stable environment to support e-business processes of Preparation and Brief category.
2 - Repeatable	Basic e-business processes of Preparation and Brief category are established.
	Established successful e-business processes of Preparation and Brief category are recognisably repeated within organisation practice.
	Established e-business processes of Preparation and Brief category are isolated and are not integrated within the organisation.
	Provide a stable environment to support e-business processes of Preparation and Brief category.
3 - Defined	E-business processes of Preparation and Brief category are well established.
	Standardised e-business processes of Preparation and Brief category are used constantly across the organisation.
	E-business processes of Preparation and Brief category are integrated within other categories' e-business processes.
	Provide necessary training and education for staff regarding Preparation and Brief category e-business processes (if needed).
	Updating their existing e-business systems of Preparation and Brief category with new advancements (if available).
4 - Managed	Administrate and maintain current e-business processes of Preparation and Brief category.
	Establish quantitative and qualitative indicators for measure e-business process performance of Preparation and Brief category.
	Organisation quantitatively and qualitatively measures and

Maturity Level	Characteristics of Preparation and Brief Process Category
	monitors e-business process performance of Preparation and Brief category.
	E-business processes are quantitatively and qualitatively understood and controlled of Preparation and Brief category.
	Organisation e-business processes of Preparation and Brief category are compatible and capable to incorporate with other partnering organisations' ICT systems.
5 - Optimising	Focused on maintenance and continuous improvement of e-business capabilities of Preparation and Brief category.
	Problem diagnosis and resolution.
	Identify new innovative technology improvements and deploy suitable approaches for the processes of Preparation and Brief category.

Accordingly, identified construction e-business maturity characteristics are interpreted to other four process categories to develop the CeB-CMM.

7.2.2 Construction e-Business Capability Maturity Model (CeB-CMM)

Interpretation of established construction e-business maturity characteristics for all five process categories formed the Construction e-Business Capability Maturity Model (CeB-CMM). The final complete CeB-CMM is presented in Table 7.2.

Table 7.2: Construction e-Business Capability Maturity Model (CeB-CMM)

Construction E-Business Capability Maturity Model (CEB-CMM)						
Process Categories		**Maturity Levels**				
		Level 1 - Initial	**Level 2 - Repeatable**	**Level 3 - Defined**	**Level 4 - Managed**	**Level 5 - Optimising**
Preparation and Brief	Identify business needs Identify project requirements Develop project brief Undertake initial feasibility studies Initial risk assessment	Most processes of Preparation and Brief category operate manually	Basic e-business processes of Preparation and Brief category are established	E-business processes of Preparation and Brief category are well established and understood	Administrate and maintain current e-business processes of Preparation and Brief category	Focused on continuous improvement of e-business capabilities of Preparation and Brief category
		E-business initiatives for the processes of Preparation and Brief category within the organisation are unplanned	Established successful e-business processes of Preparation and Brief category are recognisably repeated within organisation practice	Standardised e-business processes of Preparation and Brief category are used constantly across the organisation	Establish quantitative and qualitative measures for e-business process performance of Preparation and Brief Category	Problem diagnosis and resolution
		Organisation does not provide stable environment to support e-business processes of Preparation and Brief category	Established e-business processes of Preparation and Brief category are isolated and are not integrated with other categories' e-business processes	Different e-business processes of Preparation and Brief category are integrated with other categories' e-business processes	Organisation measures and monitors e-business process performance of Preparation and Brief category	Identify new innovative technology improvements and deploy suitable approaches for the proceses of Preparation and Brief category
			Organisation provides stable environment to support e-business processes of Preparation and Brief category	Provide necessary training and education for staff regarding e-business processes of Preparation and Brief category (if needed)	E-business processes of Preparation and Brief category are understood and controlled	
				Update existing e-business systems with new advancements/versions (if available)	Organisation e-business processes of Preparation and Brief category are compatible and capable to incorporate with other partnering organisations' ICT systems	
Planning and Design	Determine procurement strategy Determine contract strategy Prepare initial project programme Preliminary cost planning Preparation of concept design Preparation of developed design Preparation of technical design	Most processes of Planning and Design category operate manually	Basic e-business processes of Planning and Design category are established	E-business processes of Planning and Design category are well established and understood	Administrate and maintain current e-business processes of Planning and Design category	Focused on continuous improvement of e-business capabilities of Planning and Design category
		E-business initiatives for the processes of Planning and Design category within the organisation are unplanned	Established successful e-business processes of Planning and Design category are recognisably repeated within organisation practice	Standardised e-business processes of Planning and Design category are used constantly across the organisation	Establish quantitative and qualitative measures for e-business process performance of Planning and Design Category	Problem diagnosis and resolution
		Organisation does not provide stable environment to support e-business processes of Planning and Design category	Established e-business processes of Planning and Design category are isolated and are not integrated with other categories' e-business processes	Different e-business processes of Planning and Design category are integrated with other categories' e-business processes	Organisation measures and monitors e-business process performance of	Identify new innovative technology improvements and deploy suitable approaches for the proceses of Planning and Design category
			Organisation provides stable environment to support e-business processes of Planning and Design category	Provide necessary training for staff regarding e-business processes of Planning and Design category (if needed)	E-business processes of Planning and Design category are understood and controlled	
				Update existing e-business systems with new advancements/versions (if available)	Organisation e-business processes of Planning and Design category are compatible and capable to incorporate with other partnering organisations' ICT systems	

Process Categories		Maturity Levels				
		Level 1 - Initial	**Level 2 - Repeatable**	**Level 3 - Defined**	**Level 4 - Managed**	**Level 5 - Optimising**
Tendering		Most processes of Tendering category operate manually	Basic e-business processes of Tendering category are established	E-business processes of Tendering category are well established and understood	Administrate and maintain current e-business processes of Tendering category	Focused on continuous improvement of e-business capabilities of Tendering category
	Preparation of tender documents Invitation to tender	E-business initiatives for the processes of Tendering category within the organisation are unplanned	Established successful e-business processes of Tendering category are recognisably repeated within organisation practice	Standardised e-business processes of Tendering category are used constantly across the organisation	Establish quantitative and qualitative measures for e-business process performance of Tendering Category	Problem diagnosis and resolution
	Tender submission	Organisation does not provide stable environment to support e-business processes of Tendering category	Established e-business processes of Tendering category are isolated and are not integrated with other categories' e-business processes	Different e-business processes of Tendering category are integrated with other categories' e-business processes	Organisation measures and monitors e-business process performance of Tendering category	Identify new innovative technology improvements and deploy suitable approaches for the proceses of Tendering category
	Tender evaluation		Organisation provides stable environment to support e-business processes of Tendering category	Provide necessary training and education for staff regarding e-business processes of Tendering category (if needed)	E-business processes of Tendering category are understood and controlled	
				Update existing e-business systems with new advancements/versions (if available)	Organisation e-business processes of Tendering category are compatible and capable to incorporate with other partnering organisations' ICT systems	
Construction		Most processes of Construction category operate manually	Basic e-business processes of Construction category are established	E-business processes of Construction category are well established and understood	Administrate and maintain current e-business processes of Construction category	Focused on continuous improvement of e-business capabilities of Construction category
	Post-contract project management Post-contract project team coordination Post-contract project planning, tracking and monitoring Post-contract change management	E-business initiatives for the processes of Construction category within the organisation are unplanned	Established successful e-business processes of Construction category are recognisably repeated within organisation practice	Standardised e-business processes of Construction category are used constantly across the organisation	Establish quantitative and qualitative measures for e-business process performance of Construction Category	Problem diagnosis and resolution
	Post-contract cost management Quality control	Organisation does not provide stable environment to support e-business processes of Construction category	Established e-business processes of Construction category are isolated and are not integrated with other categories' e-business processes	Different e-business processes of Construction category are integrated with other categories' e-business processes	Organisation measures and monitors e-business process performance of Construction category	Identify new innovative technology improvements and deploy suitable approaches for the proceses of Construction category
	Interim payments Site record keeping Claims management Dispute resolution		Organisation provides stable environment to support e-business processes of Construction category	Provide necessary training and education for staff regarding e-business processes ofConstruction category (if needed)	E-business processes of Construction category are understood and controlled	
				Update existing e-business systems with new advancements/versions (if available)	Organisation e-business processes of Construction category are compatible and capable to incorporate with other partnering organisations' ICT systems	

Process Categories		Maturity Levels				
		Level 1 - Initial	**Level 2 - Repeatable**	**Level 3 - Defined**	**Level 4 - Managed**	**Level 5 - Optimising**
Handover and Aftercare	Project performance review Update project information Facilities management	Most processes of Handover and Aftercare category operate manually	Basic e-business processes of Handover and Aftercare category are established	E-business processes of Handover and Aftercare category are well established and understood	Administrate and maintain current e-business processes of Handover and Aftercare category	Focused on continuous improvement of e-business capabilities of Handover and Aftercare category
		E-business initiatives for the processes of Handover and Aftercare category within the organisation are unplanned	Established successful e-business processes of Handover and Aftercare category are recognisably repeated within organisation practice	Standardised e-business processes of Handover and Aftercare category are used constantly across the organisation	Establish quantitative and qualitative measures for e-business process performance of Handover and Aftercare Category	Problem diagnosis and resolution
		Organisation does not provide stable environment to support e-business processes of Handover and Aftercare category	Established e-business processes of Handover and Aftercare category are isolated and are not integrated with other categories' e-business processes	Different e-business processes of Handover and Aftercare category are integrated with other categories' e-business processes	Organisation measures and monitors e-business process performance of Handover and Aftercare category	Identify new innovative technology improvements and deploy suitable approaches for the proceses of Handover and Aftercare category
			Organisation provides stable environment to support e-business processes of Handoverand Aftercare category	Provide necessary training and education for staff regarding e-business processes of Handover and Aftercare category (if needed)	E-business processes of Handover and Aftercare category are understood and controlled	
				Update existing e-business systems with new advancements/versions (if available)	Organisation e-business processes of Handover and Aftercare category are compatible and capable to incorporate with other partnering organisations' ICT systems	

The CeB-CMM is comprised of five maturity levels and five process categories. The five maturity levels are sequential levels named as Initial, Repeatable, Defined, Managed and Optimising. The five process categories are Preparation and Brief, Planning and Design, Tendering, Construction and Handover and Aftercare.

Planning and Design process category is comprised of five processes as identify business needs, identify project requirements, develop project brief, undertake initial feasibility studies and initial risk assessment. The processes of the Planning and Design category are determine procurement strategy, determine contract strategy, prepare initial project programme, preliminary cost planning, preparation of concept design, developed design and technical design. Tendering process category comprised of four processes such as preparation of tender documents, invitation to tender, tender submission and tender evaluation. Ten processes are considered under Construction category as post-contract project management, post-contract project team coordination, post-contract project planning, tracking and monitoring, post-contract change management, post-contract cost management, quality control, interim payments, site record keeping, claims management and dispute resolution. Final process category of handover and Aftercare is comprised of three processes as project performance review, update project information and facilities management.

CeB-CMM gives maturity levels for aforementioned process categories in terms of their e-business process capability and maturity. Level 1 maturity level is named as Initial level. In this level, most of the organisational processes are operated manually. Organisation does not provide suitable environment to support e-business processes and e-business initiative s are unplanned. When an organisation is at Repeatable level (Level 2); basic e-business processes are established. Further, established e-business processes are repeated in other projects and organisation provides a stable environment and infrastructure to support e-business processes. However, at this level, e-business processes of a particular process category are isolated and are not integrated with other categories' e-business processes.

Third level of maturity is called as Defined maturity level. At this level of maturity, organisation's e-business processes are well established and understood. These established e-business processes are used consistently across organisational practices and e-business processes of different process categories are integrated with each other. Organisation provides necessary training and education on e-business processes. Besides they update existing e-business systems with new versions is available.

When an organisation moves to level 4 Managed maturity level, they introduce quantitative and qualitative measures for evaluate e-business process performance. At this level, e-business process performances are measured and monitored. According to the results of the measurements, e-business processes are understood and controlled. Organisation administrates and maintains current status of e-business processes and e-business processes are compatible and capable of incorporate with other partnering organisations' systems.

The final and highest maturity level is Optimising level. At this level organisation focuses on continuous improvement of e-business capabilities. They conduct problem diagnosis and find resolutions for e-business problems. Organisation is keen on the market and identify new innovative technology improvements to deploy suitable approaches.

7.3 User Interface of CeB-CMM

A user interface for CeB-CMM was developed in order to facilitate an ease of use for the model. The user interface was developed using MS Excel. It will provide use friendly forms to the user to gather information about their organisation and create an e-business capability maturity map as the output. E-business capability maturity map will indicates the maturity level of each e-business process category. The user interface also contains examples of maturity characteristics explaining the applicability of each characteristic in practical situations. This will increase the usability and understanding of the CeB-CMM user interface.

Flow chart of CeB-CMM, use of CeB-CMM interface and output of CeB-CMM user interface are explained in the forthcoming sections.

7.3.1 Flow Chart of CeB-CMM User Interface

Flow chart of the use interface of CeB-CMM is presented in the following Figure 7.2. As the Figure 7.2 illustrates, CeB-CMM user interface forms allow users to select the process categories which are applicable to their organisations. Then it explains different maturity characteristics and enquire users to select characteristics which explain current state of their organisation. According to the selections final output indicates maturity levels for each process category applicable for the particular organisation. MS Excel formulas are written and used to analyse the inputs of users to generate the e-business capability maturity map output.

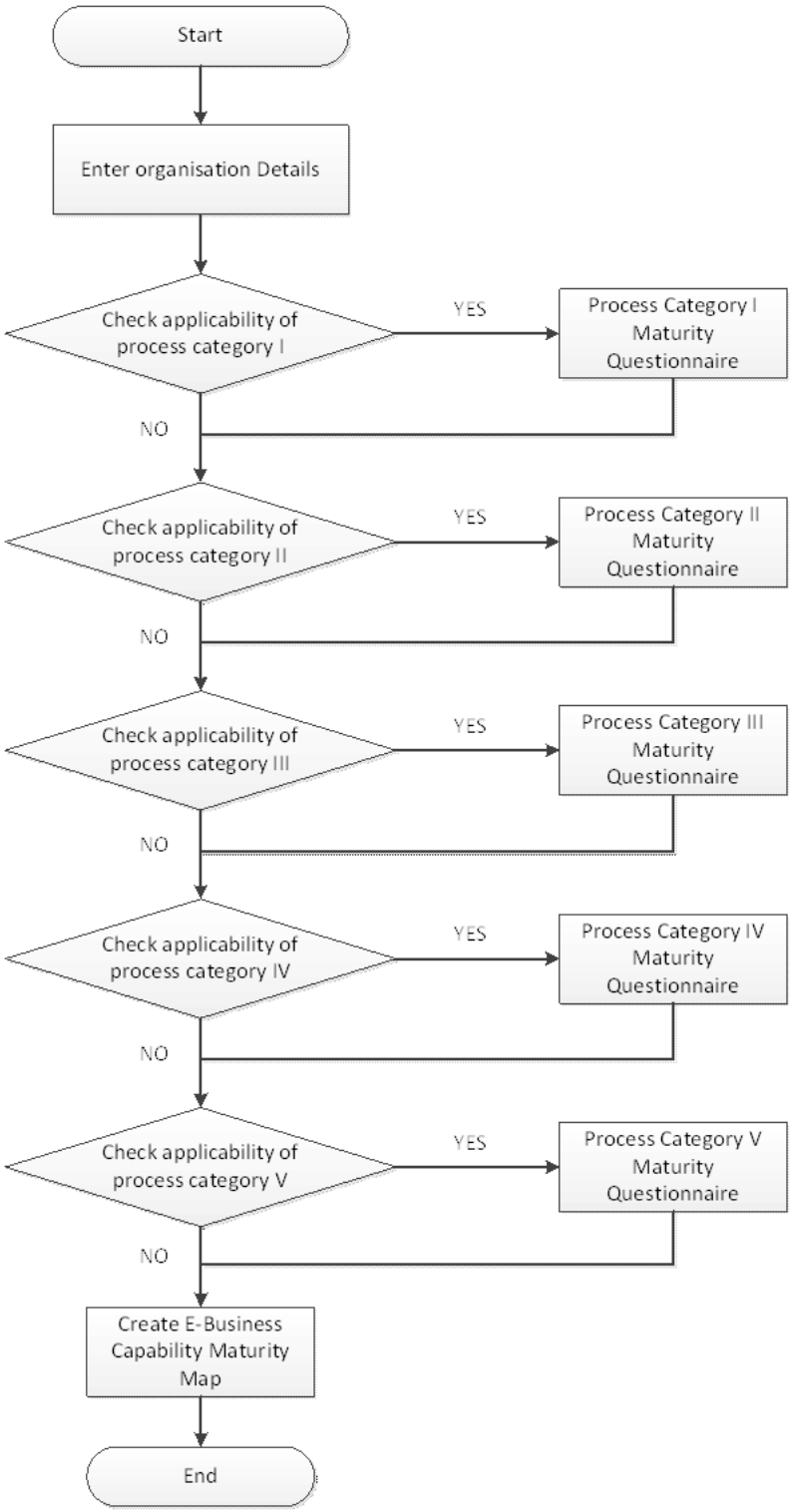

Figure 7.1: Flowchart of CeB-CMM User Interface

7.3.2 Use of CeB-CMM User Interface

The CeB-CMM user interface initiates with a welcome window follows by a form to enter organisation details of the user. These first two forms are presented below in Figures 7.3 and 7.4.

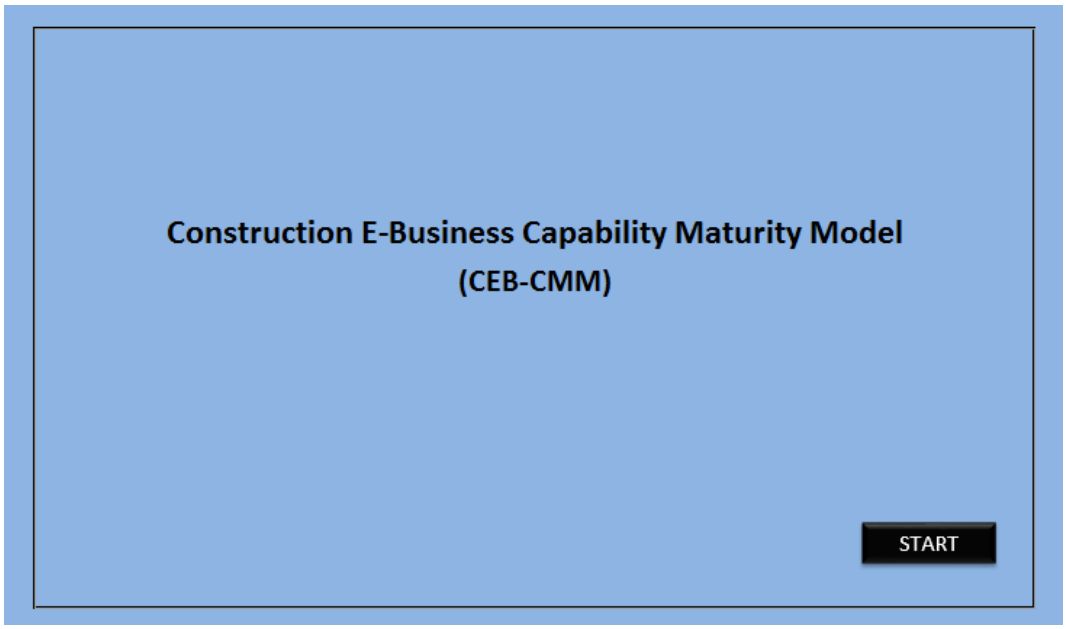

Figure 7.2: Welcome page of CeB-CMM interface

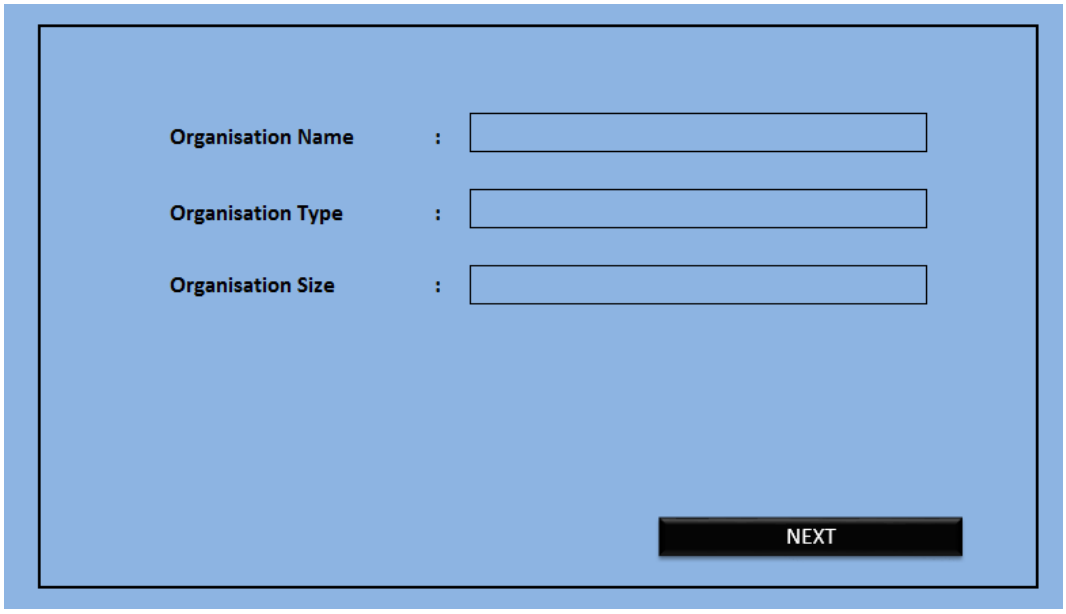

Figure 7.3: Form for enter organisational details

After entering the organisational details, the interface allows users to choose the process categories which are applicable for their organisational practices. Initially it explains the processes which define each process category and let users select whether the particular process category is applicable or not.

If that process category is applicable, then it brings up the form to select characteristics which explain current state of their e-business processes of particular process category. If that process category is not applicable, then it

directs user to the next process category details page which explains the processes and inquire about the applicability of next process category. Following Figures 7.5 and 7.6 presents an example of aforementioned two windows of CeB-CMM interface.

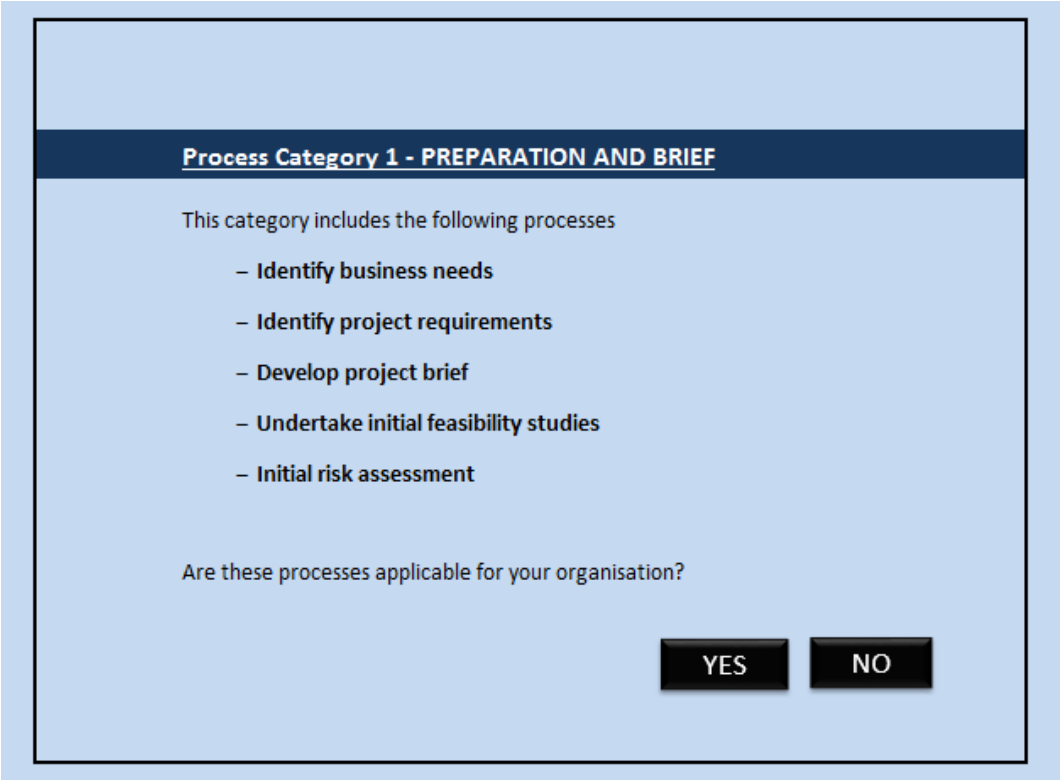

Figure 7.4: Form to inquire the applicability of Preparation and Brief Category

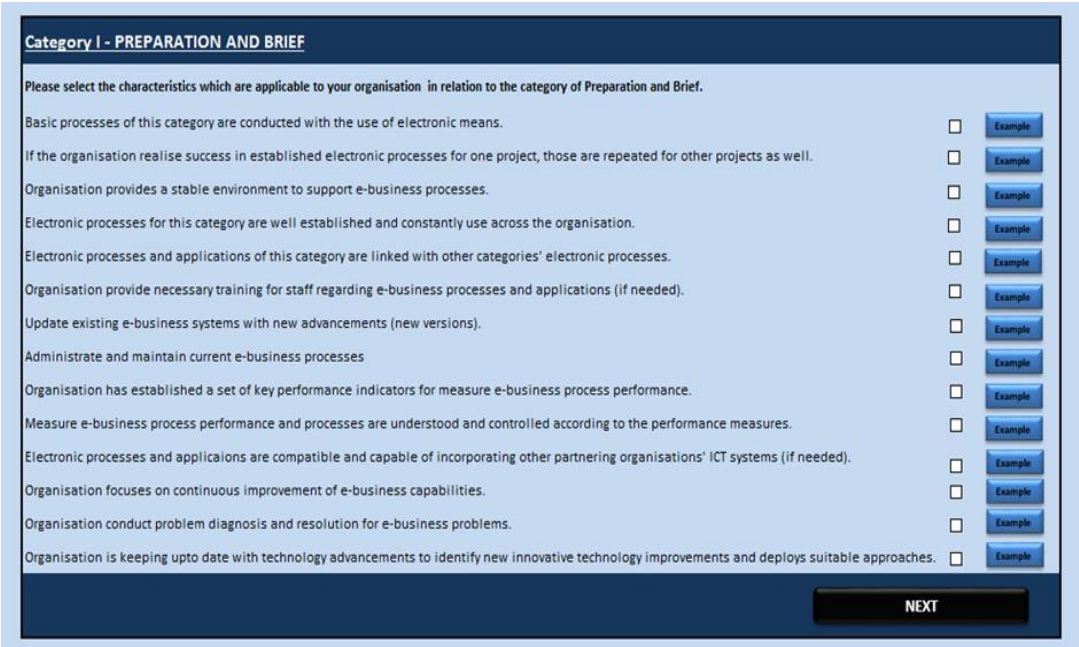

Figure 7.5: Questionnaire form of Preparation and Brief Category

In the same way, the applicability of other process categories are inquired using similar forms and questionnaire forms are presented for applicable process categories. The entire CeB-CMM interface including all the forms is attached in Appendix X. After gathering responses on all five process categories and their characteristics in the organisation, e-business capability maturity map is generated according to provided MS Excel formulas. An example of e-business capability maturity map is presented in Figure 7.7 below.

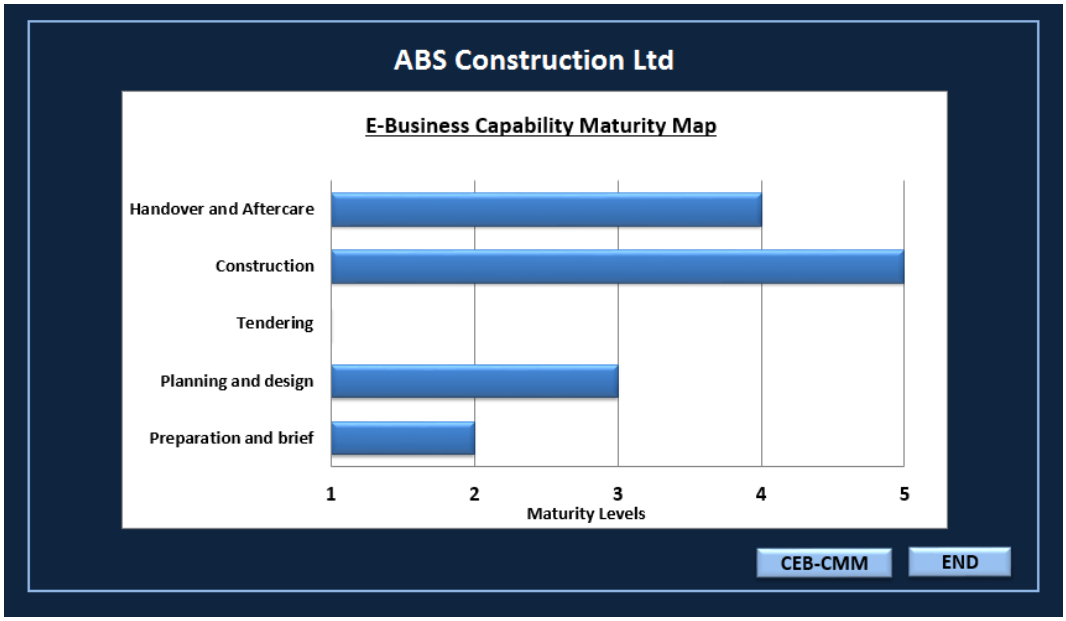

Figure 7.6: Example of e-business capability maturity map

E-Business capability maturity map indicates the e-business maturity levels of each process category applicable to a particular organisation. It provides a graphical representation of e-business maturity levels of different process categories of an organisation. This facilitates an ease of understanding and analysis of organisations' current maturity levels of their e-business profile.

The CeB-CMM was evaluated by four construction organisations with the use of this user interface. The validation process of CeB-CMM is presented and the analysis and findings of validation process are discussed in the forthcoming sections.

7.4 Validation of CeB-CMM

The main purpose of the validation was to measure and evaluate the appropriateness and effectiveness of CeB-CMM from the industry perspective. It helped to demonstrate that the CeB-CMM achieved the aim of the research, to identify weaknesses and strengths of the model and to obtain suggestions and recommendations for further improvements. Following sections explains the validation process and findings of the validation.

7.4.1 Purpose of the Validation

CeB-CMM was developed as a tool to assess capability maturity of construction e-business processes. The validation of CeB-CMM focused on investigating the appropriateness and effectiveness of proposed model in using it to determine the capability maturity levels of e-business processes of different types of construction organisations.

Appropriateness is defined as "the quality of having the properties that are especially suitable or compatible for a specific purpose" (Merriam-Webster Online, 2015). Effectiveness is defined as "the degree to which something is successful in producing a desired result or success" (Business Dictionary Online, 2015). Accordingly, the validation focused to determine the value of the model is being suitable for the requirements of assessing e-business process capability maturity and the extent to which the model is being successful in providing maturity level indications for e-business processes.

7.4.2 Process of the Validation

The CeB-CMM was validated by applying the developed model into four construction organisations and obtaining feedback from the users. An evaluation was conducted based on structured interviews with industry practitioners from different types of construction organisations. Industry practitioners were asked to apply the CeB-CMM model into their organisational practices using user interface to check the status of their e-business process maturity. Then they were asked to evaluate the model and its output.

Four evaluations were completed and they were focused on investigating the appropriateness and effectiveness of proposed model in using it to determine the capability maturity levels of e-business processes of different types of construction organisations. Three evaluations were undertaken with the same organisations which considered in multiple case studies (explained in Chapter 6), which aided in the development of the model. The involvement of the same organisations used to inspect the internal validity and consistency of the current research. An organisation which was new to the study was used to conduct another evaluation, which offered an external perspective and external validate the applicability of the model in a wider scope.

The first section of the validation interviews was focused on applying the CeB-CMM to organisations and evaluating the results. Second section of the questionnaire was focused on the ease of use and clarity of the CeB-CMM model. Final section of the questionnaire was composed with questions evaluating the appropriateness, applicability and review of model components. Each section contained open-ended statement questions with a Likert-scale of 1 to 5 on key criteria factors; where 1 = Very Unsatisfied, 2 = Unsatisfied, 3 = Neutral, 4 = Satisfied and 5 = Very Satisfied. In addition open-ended questions were included to gather further remarks, comments, suggestions and recommendations from the evaluators. The questionnaire used for the validation interviews is attached as Appendix V in the thesis.

7.4.3 Validation Organisation Profile

The involvement of the same organisations for the validation of CeB-CMM was used to inspect the internal validity and consistency of the current research (Creswell, 2014). An organisation which was new to the study was used to conduct another evaluation, which offered an external perspective and validate the applicability of the model in a wider scope (Wellington, 2000). Table 8.1 presents the details of the organisations participated in the model validation process.

Table 8.1: CeB-CMM Validation Organisation Profile

	Type of Organisation	Size of Organisation
Evaluation I	Client/Consultant	Large
Evaluation II	Consultant	Large
Evaluation III	Contractor	Medium
Evaluation IV	Consultant	Micro

The validation organisation profile comprised of different type of construction organisations such as client organisation, consultant organisations and contractor organisation. Furthermore they represent different sizes of organisation scales varied from micro to large. Therefore the evaluation facilitated validation of CeB-CMM for a wider scope of construction organisations.

7.5 Analysis and Findings of the Validation

The analysis and findings of the validation process is presented in this section. The findings are discussed in three sections. First the use of CeB-CMM in validation organisations were discussed and the maturity level scores of each organisation are presented. Next, the ease of use and clarity of the model are evaluated. Finally CeB-CMM was evaluated for its appropriateness and applicability and model components are reviewed.

7.5.1 Results of E-Business Capability Maturity Map

In the validation process, organisations were asked used CeB-CMM for analyse their current e-business profiles. They used the user interface of CeB-CMM (described in Chapter 7) and answered the questionnaires as appropriate to obtain maturity level scores for their organisation e-business processes. Forthcoming section presents the e-business capability maturity maps of validation organisations.

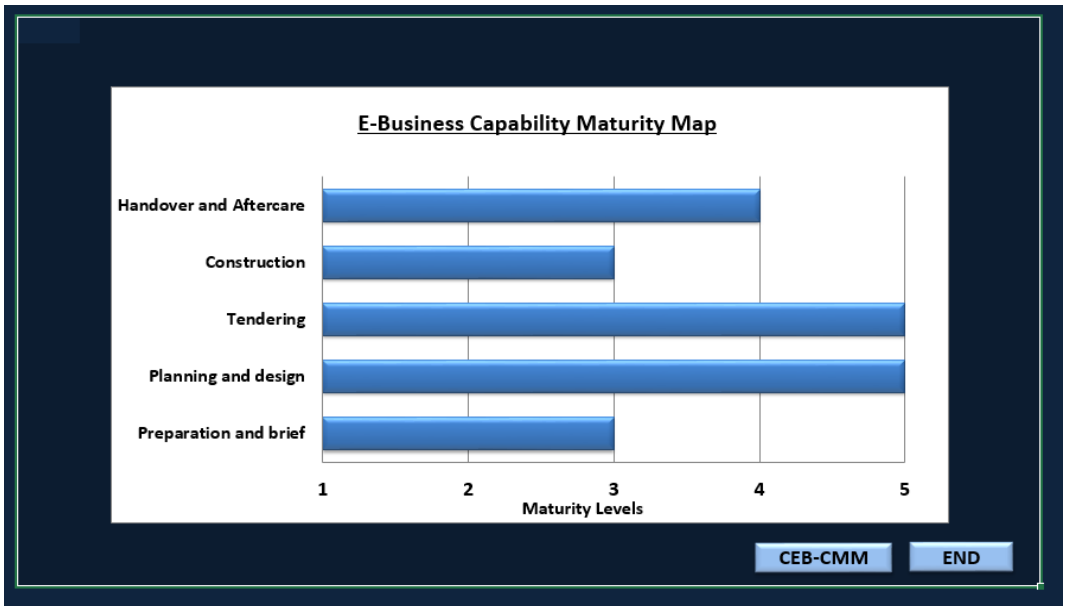

Figure 8.1: E-Business Capability Maturity Map of Validation Organisation I

Organisation I was a large scale client and consultant organisation. As presented in the above figure, the e-business maturity level of Preparation and Brief process category of organisation I was at level 3. Both Planning and Design and Tendering process categories were at the highest maturity level 5. Construction process category was at level 3. Handover and Aftercare process category was at level 4.

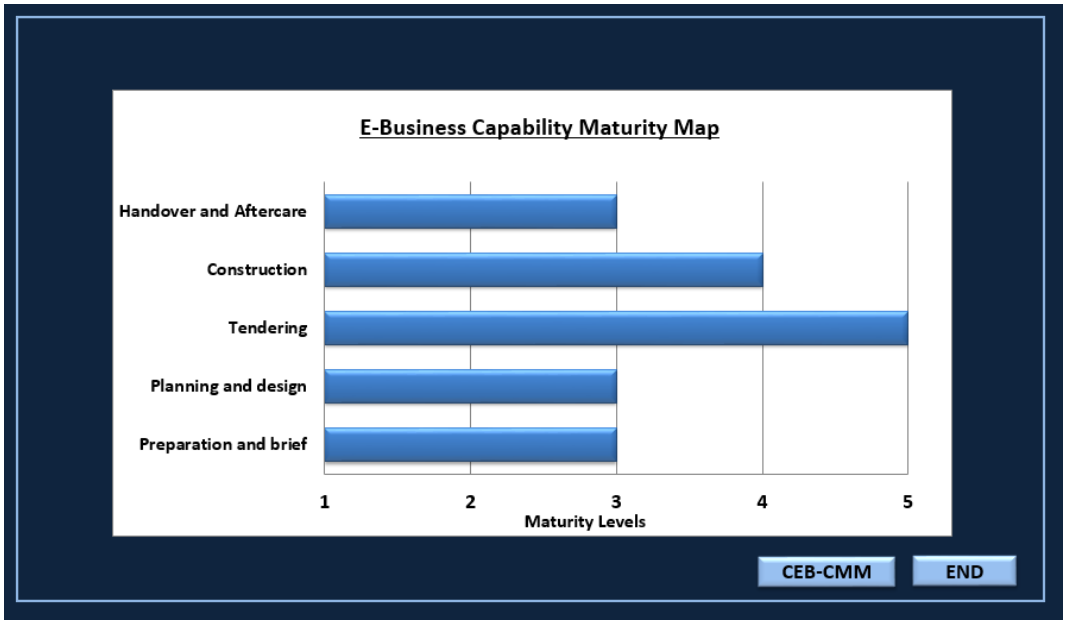

Figure 8.2: E-Business Capability Maturity Map of Validation Organisation II

Organisation II was a large scale consultant organisation. E-business processes of Preparation and Brief category of Company II was at maturity level 3. Similarly e-business processes of Planning and Design process category was at maturity level 3. Tendering Proces category was at the highest level of maturit; level 5. Construction process category was at maturity level 4 and Handover and Aftercare process category was at level 3.

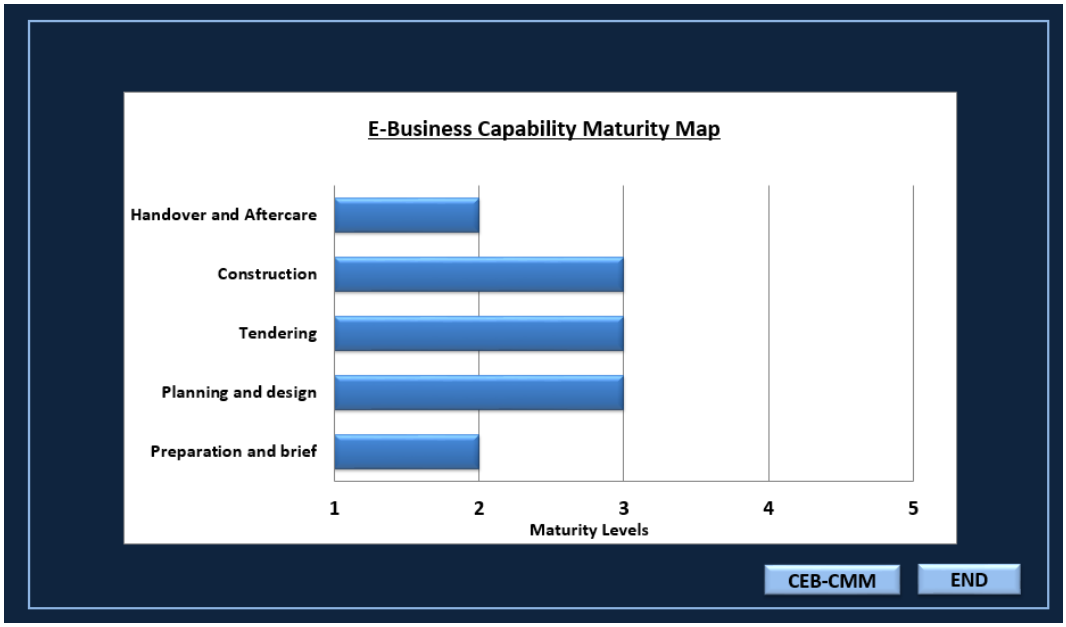

Figure 8.3: E-Business Capability Maturity Map of Validation Organisation III

Organisation III was a medium scale contractor organisation. Their e-business maturity levels were low compared to other three organisations. E-business processes of the Preparation and Brief category of Company III were at maturity level 2. E-business processes of Planning and Design, Tendering and Construction category were at maturity level 3. Handover and Aftercare process category was at maturitylevel 2.

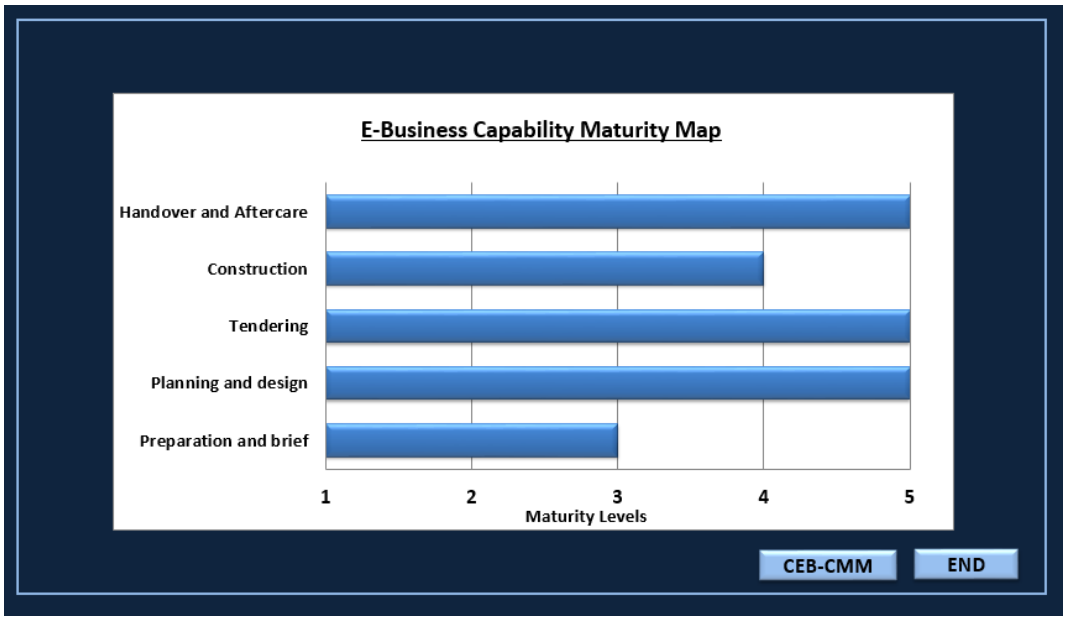

Figure 8.4: E-Business Capability Maturity Map of Validation Organisation IV

Organisation IV was a micro scale consultant organisation. It received high maturity levels for its' e-business processes compared to other validation organisations. E-business processes of Preparation and Brief category of Company IV was at maturity level 3. E-business processes of Planning and Design and Tendering process categories were at maturity level 5. Construction process category was at maturity level 4 and Handover and Aftercare category was at maturity level 5.

After using CeB-CMM interface tool for obtaining the e-business maturity maps of validation organisations, interviewees are asked for rate their level of satisfaction with the maturity scores obtained. Table 8.2 presents the average rating score given by the evaluators.

Table 8.2: Level of Satisfaction with maturity scores of obtained

	Average Ratings given by evaluators **(1=Very Unsatisfied, 2=Unsatisfied, 3=Neutral, 4=Satisfied, 5=Very Satisfied)**
Level of satisfaction with the maturity scores obtained	4.8

The findings indicated that the evaluators rated their level of satisfaction with the maturity levels obtained as very satisfied in general. A high average rating of 4.8 was given by the evaluators. Evaluators commented that the maturity map with maturity level scores is a clear way of understanding their current profile of e-business. They acknowledged their scores and identified the reasons behind the scores. Evaluators accepted the use of CeB-CMM by giving high ratings for level of satisfaction on its outcome. This indicated that CeB-CMM is confirmed and recognised as a suitable tool to assess the e-business maturity levels of e-business processes of construction organisations.

7.5.2 Ease of Use and Clarity of the CeB-CMM Tool

This section addresses the evaluation of ease of use and clarity of the CeB-CMM. The evaluation is based on the average ratings of satisfaction levels given by the evaluators from four organisations. Following Table 8.3 presents the results of the ease of use and clarity of CeB-CMM evaluation.

Table 8.3: Ease of use and clarity of CeB-CMM

	Average Ratings given by evaluators **(1=Very Unsatisfied, 2=Unsatisfied, 3=Neutral, 4=Satisfied, 5=Very Satisfied)**
Ease of use of CeB-CMM	4.8
Clarity of CeB-CMM	4.3

The findings indicated that evaluators rated the CeB-CMM high in terms of ease of use and clarity. An average satisfactory level of 4.8 was given to the ease of use of CeB-CMM. The user interface of CeB-CMM was used to apply the CeB-CMM for validation organisations. Evaluators were very satisfied with the ease of use of the interface tool. The user interface tool of CeB-CMM comprised with a separate section of examples which describes the e-business characteristics of each maturity level (refer Appendix X). This increased the ease of use of the model as

it provided the users a very explained and detailed background information to help with their response to maturity characteristics.

The word 'Clarity' means the quality of being clear and easily understood (Merriam-Webster Online, 2015). The evaluators are asked for rate the clarity of the CeB-CMM tool. The average rating given for the satisfaction level on clarity of the CeB-CMM tool was 4.3. This indicated that the evaluators are satisfied with the level of clearness of the CeB-CMM tool and they accepted that CeB-CMM tool is easily understandable.

7.5.3 Review of the CeB-CMM

This section considers the review of CeB-CMM. The validation focused on inquiring the satisfaction levels of evaluators on the appropriateness, applicability, benefits and model components of CeB-CMM. Overall, the evaluators reported that they were very satisfied or satisfied on CeB-CMM. Following Table 8.4 presents the average ratings given by the evaluators on review of CeB-CMM.

Table 8.4: Review of CeB-CMM

	Average Ratings given by evaluators **(1=Very Unsatisfied, 2=Unsatisfied, 3=Neutral, 4=Satisfied, 5=Very Satisfied)**
Appropriateness of CeB-CMM as a tool to measure construction e-business capability maturity	4.5
Applicability of CeB-CMM for organisation e-business processes	4.5
Process categories of CeB-CMM	4.0
Maturity level characteristics of CeB-CMM	4.3
Benefits of CeB-CMM	4.5
CeB-CMM and its appropriateness to the Construction industry	4.8

As indicated in the above table, the overall satisfaction on CeB-CMM was high with evaluators. They were satisfied with the appropriateness of CeB-CMM as a tool to measure construction e-business capability maturity and with the applicability of CeB-CMM for organisation e-business processes. Both of those reviews got an average rating of 4.5. Evaluators commented that the CeB-CMM is easily adoptable for their organisation processes and they accepted it as a suitable model to assess their e-business capability maturity levels.

The average rating for process categories of CeB-CMM from evaluators was 4.0. This indicates that the evaluators are satisfied and agreed for the process categories of the model. There are some suggestions proposed by the evaluators regarding the process categorisation and their maturity indications. These suggestions are presented in the next section 7.5.4. However, they were contented with the existing process categories and their processes and rated the process categorisation with a higher overall rating of 4.0.

The average satisfactory level for construction e-business maturity characteristics of CeB-CMM is 4.3. Evaluators were contented with the e-business maturity characteristics of five maturity levels. They stated that they can see how an organisation can increase their e-business capabilities by considering the maturity characteristics proposed in the model. They were experienced some of those proposed characteristics in their organisation practices and they confirmed the proposed e-business maturity characteristics to be considered in the model.

The benefits of CeB-CMM were explained to evaluators while adopting it to their organisation processes. This model can be used as a tool to investigate e-business capability maturity levels of their current e-business processes. CeB-CMM model decomposes organisation's current e-business profile into five process categories and assess maturity levels of each process category separately. It helps the organisation to identify the process areas which need more consideration in order to increase their e-business capabilities. Further the e-business capability maturity map can assist developing a robust e-business strategy for the organisation. In addition CeB-CMM can use as a process improvement tool to plan and aim high capability maturities of e-business processes. The satisfactory ratings for the benefits of CeB-CMM were high from the evaluators. The average rating was 4.5.

This indicated that the evaluators identified and realised the benefits of using CeB-CMM model as a systematic tool to assess capability maturity of their e-business processes.

Finally the evaluators are asked to rate their satisfactory level on the CeB-CMM and its appropriateness to the construction industry. As mentioned in previous section 7.4.1, appropriateness can describe as the suitability and compatibility. Therefore in this section evaluators were asked to rate the suitability and compatibility of CeB-CMM for the construction organisations. The average response rate was 4.8 which indicated that the evaluators are highly satisfied with the CeB-CMM and its appropriateness to the construction industry.

7.5.4 Final Discussion

The evaluators provided positive feedback on the appropriateness and effectiveness of the model. According to the responses of evaluators discussed above, it is evident that the CeB-CMM is accepted by all of the evaluators from different type of construction organisations. The evaluators used the CeB-CMM to assess their organisational e-business process capability maturity levels and they were satisfied with the user interface, ease of use, clarity and appropriateness of the model. This confirms the applicability of CeB-CMM in different types and sizes of construction organisations. Further this validate the CeB-CMM and its usage and appropriateness in the construction industry. All case studies concluded that the model has been satisfactory. Therefore the final model presented at Table 7.2 remains as the final model.

7.6 Summary

The development and validation of CeB-CMM is explained in this chapter. The first section of the chapter presents the final outputs of main model components; construction process classification and construction e-business capability maturity characteristics. Then the use of those components for the development of CeB-CMM was described. The final CeB-CMM is presented in the Figure 7.1.

Second section of the chapter presented the user interface of CeB-CMM which was developed using MS Excel. Some forms of the interface are presented as examples to describe the usability of the CeB-CMM interface. The complete CeB-

CMM interface is presented in Appendix X. Third section of the chapter describe the validation process of the CeB-CMM. The evaluators' organisation profiles were explained and the analysis and findings of the validation are discussed. The next chapter concludes the thesis by reviewing the research aims and objectives with research outcomes. Contribution to knowledge and future directions of the research are also identified and presented in the next chapter 8.

CHAPTER 8

CONCLUSIONS

8.1 Introduction

This chapter presents conclusions of this research reviewing the aim and objectives. It reviews the objectives set for the study and discusses how each of them were achieved. Further it describes the original contribution of this research to the knowledge and to the research domain. Then the limitations of the research and Construction e-Business Model (CeB-CMM) were also discussed and finally it identifies potential work for future research.

8.2 Achievement of Research Aim and Objectives

The main aim of the research was to develop a capability maturity model to systematically identify current status of e-business processes as a method of enhancing process efficiency in construction organisations. In achieving this aim, this study looked at how the CMM concept and principles could be applied with in construction e-business context. Six objectives were established and they were presented in chapter 1 section 1.3.

This section discusses the six objectives of this research study and provides conclusions to them on how the objectives were achieved by using several research methods.

8.2.1 Achievement of Objective 1

The first objective was to explore the importance of e-business for construction organisations. This was achieved through a review of literature which was presented in chapter two. A comprehensive literature review was conducted on the subject of e-business (section 2.2) and e-business execution within the construction industry (section 2.3). The literature review was further extended to examine the importance of e-business strategy for construction organisations (section 2.4).

The review examined different explanations of e-business and established a definition for e-business to use in this study (section 2.2.1). It defined e-business as: *"E-Business is the use of ICT and internet related technologies to create new ways of conducting business activities which enables transformation of business processes with added value "*. Further, different classifications of e-business are discussed (section 2.2.2) and e-business enabling technologies are identified (section 2.2.3) in the literature review. E-business enabling technologies are defined as the technologies which enable e-business adoption and expansion. Electronic data interchange, email, World Wide Web, intranet, extranet, internet and cloud computing were identified and described as enabling technologies for e-business.

The literature review included an investigation on the execution of e-business in the construction industry (section 2.3). Construction e-business process is defined as "*a set of electronically supported activities, methods, practices and transformations that people use to construct and maintain buildings and other civil engineering structures and the associated products*." It considered the benefits and limitations of e-business to construction industry and current construction trends and approaches. The importance of having e-business processes for construction businesses is identified through the review. As section 2.3 explains, the importance of e-business to the construction is associated with this unique nature of the industry. E-business strategies in construction organisations also reviewed through the literature to explore the significance of e-business in construction (section 2.4). Different e-business strategy development approaches are discussed (section2.4.3). Having a robust e-business strategy facilitates the alignment of business processes and technology to optimise its usage and benefits.

First part of the literature review established the need and importance of e-business for construction organisation to enhance construction processes and achieve process improvements. In this regard, the need of effective implementation and evaluation of construction e-business processes are identified (section 2.5.3).

8.2.2 Achievement of Objective 2

The second objective was to review e-business evaluation tools and process improvement tools for construction organisations. This objective was also achieved using a comprehensive literature review which has been presented in final section of chapter two and chapter three.

A comprehensive review of existing e-readiness models and e-business maturity models are conducted to examine current e-business evaluation tools (section 2.5). It was identified that, e-readiness models indicates how ready an organisation is to adopt e-business, but they does not provide guidance for further improvements. Maturity models are process improvement tools which provide as assessment of current status of existing maturity level and provide systematic guidance capability improvements. Thus, maturity models are identified as a prior step for e-business strategy development. However it was recognised that existing e-business capability maturity models are either specific to an industry other than construction or focus mainly on only one e-business approach such as e-procurement or BIM. The review indicated that there is a clear knowledge gap in defining e-business process capability as applied to construction organisations. As a result, it determined the need for development of a construction specific e-business CMM which focuses on different types of construction e-business processes.

Other achievement of objective two was the review of process improvement tools in construction. It helped to gain a broad understanding of construction processes and capability maturity concepts to explore construction process improvement concepts and existing approaches to gain an in-depth understanding of the context. This was presented in chapter three. Related literature was reviewed to explore the concepts of process definition, process thinking and process improvement in construction (section 3.2) and to comprehensively discuss the fundamental concepts and structure of original capability maturity model (section 3.3).

In achieving objective two, a summary of current state of e-business evaluation tools, construction process improvement tools and e-business and construction process capability maturity initiatives were derived through comprehensive literature review provided within chapter two and three. This generated the

background to the investigation by further strengthening the need for this research and provided the essential theoretical underpinning to the research.

8.2.3 Achievement of Objective 3

The third objective of the research was to identify and categorise current construction business processes. The investigation of this objective was accomplished through an analysis of existing construction process maps and Delphi based expert forum.

There is a knowledge gap identified in objective two for a construction process categorisation in order to use as a construction e-business categorisation for the maturity model. To fulfil that gap by providing a process categorisation, initially an analysis of construction process maps was conducted (section 5.3). Two well-known construction process maps which define the construction project related processes and are widely used within the UK construction industry; RIBA 2013 plan of work and OGC gateway process reviews were analysed to establish a conceptual construction process categorisation. The results of this analysis established a conceptual process categorisation with five main process categories (Preparation and Brief, Planning and Design, Tendering and Procurement, Construction and Use and Aftercare) and 27 processes (section 5.3.5).

In order to verify and confirm the conceptual process categorisation, a Delphi based expert forum was conducted (section 5.4). Expert forum consisted of 12 experts representing the industry and academia. Two rounds of Delphi based interviews were conducted to query and verify the conceptual process categorisation. According to the expert opinions and inputs, the conceptual construction process categorisation was amended and modified (section 5.4.2). The refined construction also consisted of five process categories named Preparation and Brief, Planning and Design, Tendering, Construction and Handover and Aftercare. It consisted of 29 processes as presented in Table 5.10 in section 5.4.3.

8.2.4 Achievement of Objective 4

The fourth objective was to analyse e-business process capability and maturity characteristics in construction organisations to develop the construction e-business

capability maturity model. This objective was achieved through three different stages of data collection and analysis. The achievement of objective four is described in chapter 6.

Chapter two identified a knowledge gap in the literature for a construction specific capability maturity model for construction e-business processes. In order to fil that gap the research undertaken for this objective was to develop a construction e-business process maturity model. Before the maturity model was developed, an initial analysis of existing capability maturity models was conducted to identify conceptual construction e-business process maturity characteristics (section 6.2). Three capability maturity models were considered for the analysis representing software process maturity (SW-CMM), construction process maturity (SPICE) and general e-business process maturity (EB-CMM). Since there is no current capability maturity model which focuses on construction e-business process improvement; general process maturity characteristics from SW-CMM, construction process maturity characteristics from SPICE and general e-business process maturity characteristics from EB-CMM were analysed to establish conceptual construction e-business process maturity characteristics. The results of this analysis established 17 conceptual construction e-business process characteristics for five maturity levels of Initial, Repeatable, Defined, Managed and Optimising (see section 6.2.4).

Phase two of expert forum was conducted to verify the conceptual construction e-business process maturity characteristics (section 6.3). Same experts of previous expert forum were interviewed. Majority of the experts agreed and confirmed proposed conceptual construction e-business process maturity characteristics and some modifications were done according to the expert opinions to some maturity level characteristics. The process of verification and modification is discussed in section 6.3.1 and the developed construction e-business process maturity characteristics are presented in section 6.3.2.

The final achievement of this objective used three case studies to ratify the developed construction e-business process maturity characteristics (section 6.4). Case studies were used to investigate and gain an in-depth understanding of e-business profiles and maturity characteristics of different types of construction

organisations. They provided evidence of practical and current construction e-business process maturity characteristics and extended the applicability of identified construction process maturity characteristics among different types of construction organisation. Furthermore, case study findings were used to verify the disagreements of experts on some maturity characteristics. The analysis of case study data is presented in section 6.4.2. The results of the case study findings established 20 ratified construction e-business process maturity characteristics to use for the model development (section 6.4.3).

8.2.5 Achievement of Objective 5

The fifth objective of the research was to develop a model to capture the status of maturity of e-business processes in construction organisations. This objective was achieved by formulating the final Construction e-Business Capability Model (CeB-CMM). CeB-CMM is a tool to systematically assess the capability and maturity of construction e-business processes.

The CeB-CMM was developed using the construction process classification and construction e-business maturity characteristics (section 7.2). The final CeB-CMM was presented in Table 7.2. It comprise of five process categories named Preparation and Brief, Planning and Design, Tendering, Construction, Handover and Aftercare. There are five maturity levels considered in the model named Initial, Repeatable, Defined, Managed and Optimising. Construction e-business maturity characteristics were interpreted to process categories to formulate the model. According to CeB-CMM; an organisation at Initial maturity level (level 1), most of the organisational processes are operated manually. Organisation does not provide suitable environment to support e-business processes and e-business initiative s are unplanned. When an organisation moves to Repeatable level (Level 2), basic e-business processes are established and are repeated in other projects. Organisation provides a stable environment and infrastructure to support e-business processes. However, at this level, e-business processes of a particular process category are isolated and are not integrated with other categories' e-business processes. At Defined maturity level (level 3), organisation's e-business processes are well established and understood. These established e-business processes are used consistently across organisational practices and e-business

processes of different process categories are integrated with each other. Organisation provides necessary training and education on e-business processes. Besides, they update existing e-business systems with new versions is available.

When an organisation moves to Managed maturity level (level 4), quantitative and qualitative measures are introduced to evaluate e-business process performance. E-business process performances are measured and monitored. According to the results of the measurements, e-business processes are understood and controlled. Organisation administrates and maintains current status of e-business processes and e-business processes are compatible and capable of incorporate with other partnering organisations' systems. The Optimising maturity level (level 5), organisation focuses on continuous improvement of e-business capabilities. They carry out problem diagnosis and find resolutions for e-business problems. When an organisation reach this level, it is keen on the market and identify new innovative technology improvements to deploy suitable approaches.

User interface for CeB-CMM is also development as an achievement of objective five. An easy and user friendly user interface was developed using MS Excel to facilitate the easy use of CeB-CMM for construction practitioners. The user interface development procedure and flow chart was presented in section 7.3. The output of the interface tool is an e-business process maturity map for construction organisation (Figure 7.7 in section 7.3.2). It indicates e-business maturity levels and provides a with a graphical representation maturity levels of each process category applicable to a particular organisation. This delivers an ease of understanding and analysis of organisations' current maturity levels of their e-business profile.

8.2.6 Achievement of Objective 6

The sixth objective was to validate the Construction e-Business Capability Maturity Model (CeB-CMM). This objective was achieved by conducting an industry evaluation of CeB-CMM based on structured interviews with industry practitioners from different types of construction organisations. Four evaluations were completed and they were focused on investigating the appropriateness and effectiveness of proposed model in using it to determine the capability maturity levels of e-business processes of different types of construction organisations.

Three evaluations were undertaken with the organisations which considered in multiple case studies (explained in Chapter 6), which aided in the development of the model. The involvement of the same organisations used to inspect the internal validity and consistency of the current research. An organisation which was new to the study was used to conduct another evaluation, which offered an external perspective and external validate the applicability of the model in a wider scope.

The evaluators provided positive feedback on the appropriateness and effectiveness of the model. The results of validation case studies are discussed in section 7.5. All case studies concluded that the model has been satisfactory. Therefore the final model presented at Table 7.2 remained as the final model.

8.3 Contribution to Knowledge

The primary contributions to knowledge of this research were the development of Construction specific e-Business Capability Maturity Model (CeB-CMM) and the development of a user interface for the maturity model. The specific contributions to knowledge are elaborated below.

- The developed CeB-CMM and user interface tool is used to systematically assess and evaluate the current status of construction e-business process maturity of construction organisations. It will help construction organisations to identify their present maturity levels and potential to improve their e-business process capability.

- CEB-CMM can also be used as a tool monitor the capability maturity levels of organisation business processes over a time period. The model can be applied to the same processes in different time periods and can compare the difference of maturity levels to evaluate them.

- In addition, this model enables organisations to predict the outcome of an e-business process before it commence by knowing its capability maturity level in advance.

- Furthermore, knowing the capability and maturity of their e-business processes allows them a pathway to further enhance those processes and have productivity and efficiency improvements.

- Further, this research established a construction process classification which can be used not only to formulate construction e-business maturity model, but it can also be applied to any other construction research as a general construction process categorisation.

- Moreover, this research has established the construction e-business process maturity characteristics. There was a niche in existing research to identify e-business maturity features applicable to construction processes. This research contributed to the existing knowledge by establishing construction e-business process maturity characteristics applicable to construction organisations.

The resulting sub contributions to the knowledge from this research are presented below in chronological order.

- This research explored general e-business applications and determined the importance of adoption those applications to construction processes in order to improve their efficiency and productivity. This research realigned those general e-business processes to suitable for the unique nature of construction industry and established the need of effective e-business execution in construction organisations to gain optimum benefits of e-business processes.

- It developed a methodology for formulating an e-business maturity model for construction processes. Further, it identified potential areas of future research to execute further research work built upon the current study.

8.4 Benefits of CeB-CMM

CeB-CMM is a construction e-business process capability maturity model which is used as a tool to systematically identify the current status of e-business process implementation of construction organisations. CeB-CMM user interface facilitates easy application of CeB-CMM for organisations. The CeB-CMM user interface application will generate a construction e-business process maturity map for construction organisations. Construction e-business process maturity map of an organisation can be used to identify and make decisions of areas which need further improvements and further ICT implementation. It helps organisations to prioritise investments on urgent areas which need ICT improvements. The

outcome of the CeB-CMM application can be feed to the organisation e-business strategy.

It is also anticipated that the developed tool can be used by construction organisations as a tool to systematically evaluate their current e-business process maturity and provide them a pathway to further improve those processes. Knowing the current status of their e-business process maturity indicates the potential to improve organisation's e-business process capability which enables organisation to predict the outcome of a process before it commence. Furthermore, knowing the capability and maturity of these processes it allows them a pathway to further enhance those processes and have productivity and efficiency improvements.

CeB-CMM can also be used by e-business consultants of construction industry to provide necessary assistant on construction organisations' e-business profiles and their capability maturity levels. ICT consultants can apply CeB-CMM tool for their client organisations and assess their e-business process maturity to provide guidance on how they can achieve further capability and maturity advancements and developments based on the model.

8.5 Limitations of Research

As with any research, this study has some limitations, which are identified in this section. The CeB-CMM provides maturity level indications for five main process categories of an organisation. Yet, it does not provide maturity level indications for each process of process categories. This is identified as a limitation of the model as some of the processes of process category may not be applicable to a particular organisation. Similarly, some of additional processes may applied for process categories. However, considering the time limitations of a doctoral research study and maintaining the simplicity of CeB-CMM, researcher developed the CeB-CMM model with an e-business maturity map for five main process categories. Having identified this limitation, the researcher proposed future work to be executed on this research to increase the flexibility of selecting applicable processes in use of CeB-CMM and to provide individual maturity scores for each applicable process.

Ensuring the generalisability and reliability of this research were difficult due to the philosophical stance of this research. Philosophical stance of this research leans towards interpretivism by its nature and the findings are sensitive to the context of experts of expert forum and case studies. Replication and generalisation of CeB-CMM was difficult. However, researcher evaluated the model using same three case studies which aided to the development of the model for internal validation and through a new external case study organisation to complement external validity.

The construction e-business maturity characteristics were investigated and ratified based on an expert forum and three construction organisations which demonstrate characteristics of different levels of e-business process maturity. Although the expert views and cases examined provided satisfactorily rich information, none of the experts or organisations were not at the highest level of maturity or following CMM concepts completely. Having identified this limitation, researcher introduced analysis of existing theoretical evidence to identify conceptual characteristics and used flexible research techniques such as semi structured interviews with open ended questions to collect data.

The evaluation of the CeB-CMM was carried out using four organisations. Although findings have not shown any significance differences between the opinions, it might have been more useful to include a broader representation including a greater variety of construction disciplines and also more participants from organisations that were not included in the case studies.

8.6 Further Research

Considering the limitations of this research and the research findings, the following areas are proposed as future research work.

The current CeB-CMM provides maturity level indications only for five main process categories of an organisation. The model can be further enhanced by providing maturity level indications for each process of process categories. Future work can be executed on this research to increase the flexibility of selecting applicable processes according to the type of the construction discipline in use of

CeB-CMM and to provide individual maturity scores for each applicable process. Further,

The user for CeB-CMM was developed using basic tools of MS Excel. This interface can be further enhanced using advance software development programmes to facilitate a more user friendly and detailed tool for the application of CeB-CMM.

The validity and generalisation of CeB-CMM can be further increased by extensive testing of the model in different test environments. This study used three internal case studies and one external study to evaluate the model. This can be extended by using more external organisations to test and evaluate the model. Different sizes and types of construction organisations can be used to evaluate the model in future research.

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APPENDICES

Appendix I –Publications and Presentations relate to Research

Conference Papers

Rodrigo, A., Perera, S., Zhou, L. and Udeaja, C., (2014) *Construction process categorisation towards developing an e--business maturity model*. International Conference on Construction in a Changing World Heritance, 4-7 May 2014, Kandalama, Sri Lanka.

Perera, S., Park, R., Udeaja, C., Zhou, L. and Rodrigo, A., (2012) *Mapping the e-business profile and trends in cost management in the UK construction industry.* In: 7th International Conference on Innovation in Architecture, Engineering and Construction (AEC 2012), 15-17 August 2012, The Brazilian British Centre, São Paulo, Brazil.

Rodrigo, A., Perera, S., Udeaja, C. and Zhou, L., (2011) *Towards a stepwise improvement tool for construction e-business: Conceptual approach*. 10th International Postgraduate Research Conference (IPGRC), 14-15 Sept 2011, University of Salford, UK.

Rodrigo, A., Perera, S., Udeaja, C. and Zhou, L., (2011) *Development of a model for the analysis of construction e-business capability and maturity*. ARCOM and LCI UK Doctoral Research Workshop. University of Northumbria, Newcastle, UK. 2 March 2011.

Publications in Progress

Book Chapter

'Capability Maturity of Construction E-Business Processes' chapter for the book titled 'Advances in Construction ICT and e-business'.

Journal Paper 1

'Establishing a Construction E-Business Process Categorisation' (Journal – Automation in Construction) - *Submitted*

Journal Paper 2

'Development of a Construction E-Business Capability Maturity Model' (Target Journal – ASCE Journal of Construction Engineering and Management) – *In Progress*

Presentations and Posters

Research poster titled '*Identification of Construction E-Business Capability Maturity Characteristics*' at Northumbria Research Conference 2014, 21-22 May 2014.

Pecha Kucha presentation titled '*Identification of Construction E-Business Capability Maturity Characteristics*' at Northumbria Research Conference 2014, 22 May 2014.

Presentation titled '*Development of a Capability Maturity Model for Construction E-Business Activities*' at Construction Economics and Management (CEM) Research Group symposium, 14-15 May 2014.

Research poster titled '*Construction E-Business Capability Maturity Model'* at Northumbria University Faculty Showcase 2013, 1 May 2013.

Presentation titled '*Development of a Construction E-Business Capability Maturity Model*' at Construction Economics and Management (CEM) Research Group meeting, 12 June 2012.

Appendix II – Interview guidelines of Expert Forum – Phase I

EXPERT FORUM – PHASE I

DEVELOPMENT OF CONSTRUCTION E-BUSINESS CAPABILITY MATURITY MODEL (CEB-CMM)

Interview Number :

Interview date and time :

Interview location :

Purpose of the Interview:

CEB-CMM is an e-business capability maturity model which aims to systematically identify current status of ICT implementation of construction organizations. To develop the CEB-CMM model components; initially, construction business processes have to be identified and categorised. The purpose of this first round interview is to verify and refine construction processes and process categories identified from literature.

Section 1: Background Information

1. Name
2. Organisation name
3. Organisation type
4. Organisation size
5. Designation
6. Expertise area
7. Experience

Section 2: E-business in Construction

8. What is your understanding of e-business?
9. What are your views about the e-business initiatives in your organisation and in the industry?

Section 3: Construction Business Processes

10. What is your opinion on following categorisation of processes into categories?

Level of Agreement	*Level of Confidence*
1 – Strongly disagree	*1 – Very uncertain*
2 – Disagree	*2 – Uncertain*
3 – Neutral	*3 – Neutral*
4 – Agree	*4 – Confident*
5 – Strongly agree	*5 – Very confident*

What is your level of agreement on each process and its classification? And what is your level of confidence on your responses? Please explain reasons behind your responses.

Construction Processes	Process Categories					Level of Agreement					Level of Confidence				
	Preparation and Brief	Planning and Design	Tendering and Procurement	Construction	Use and Aftercare	1	2	3	4	5	1	2	3	4	5
Identify business needs	x														
Identify project requirements	x														
Develop Project Brief	x														
Undertake feasibility studies	x														
Risk assessment	x														
Prepare initial project programme		x													
Preliminary cost planning		x													
Preparation of concept design		x													
Preparation of developed design		x													
Preparation of technical design		x													
Determine procurement strategy			x												
Determine contract strategy			x												
Preparation of contract documents			x												
Tender process			x												

Construction Processes	Process Categories					Level of Agreement					Level of Confidence				
	Preparation and Brief	Planning and Design	Tendering and Procurement	Construction	Use and Aftercare	1	2	3	4	5	1	2	3	4	5
Project management				x											
Project team coordination				x											
Project planning, tracking and monitoring				x											
Change management				x											
Cost management				x											
Quality control				x											
Payments				x											
Record keeping				x											
Claims management				x											
Dispute resolution				x											
Project performance review					x										
Update project information					x										
Facilities Management					x										

11. What is your opinion on considering aforementioned construction processes in CEB-CMM?
12. Do you have any other comments regarding the above classification?

Thank You

Appendix III – Interview guidelines of Expert Forum – Phase II

EXPERT FORUM – PHASE II – Industry Experts

DEVELOPMENT OF CONSTRUCTION E-BUSINESS CAPABILITY MATURITY MODEL (CEB-CMM)

Interview Number :

Interview date and time :

Interview location :

Purpose of the Interview:

The purpose of this second round interview is to refine the findings of first round interviews and verify construction e-business capability maturity characteristics identified from literature.

Section 1: First Round interview Findings

Following Table presents the verified construction process categorisation. Please provide your views and comments on it.

Process Category	**Processes**
Preparation and Brief	Identify business needs
	Identify project requirements
	Develop project brief
	Undertake initial feasibility studies
	Initial risk assessment
Planning and Design	Determine procurement strategy
	Determine contract strategy
	Prepare initial project programme
	Preliminary cost planning
	Preparation of concept design

Process Category	**Processes**
	Preparation of developed design
	Preparation of technical design
Tendering	Preparation of tender documents
	Invitation to tender
	Tender submission
	Tender evaluation
Construction	Post-contract project management
	Post-contract project team coordination
	Post-contract project planning, tracking and monitoring
	Post-contract change management
	Post-contract cost management
	Quality control
	Interim payments
	Site record keeping
	Claims management
	Dispute resolution
Handover and Aftercare	Project performance review
	Update project information
	Facilities management

Section 2: E-business Implementation

1. How important do you consider e-business implementation to the construction industry?
2. According to your views, what are e-business divers and barriers?
3. In your organisation, which type of e-business initiatives you have on following process categories?

Preparation and Brief	
Planning and Design	
Tendering	
Construction	
Handover and Aftercare	
Other	

Section 3: E-business Maturity

4. This question describes 5 different maturity levels and their characteristics that may be applicable for a construction organisation. Please let me know your opinion on those characteristics and any other comments on them.

   What is your level of agreement on each characteristic and what is your level of confidence on your responses? Please explain the reasons.

Level of Agreement	*Level of Confidence*
1 – Strongly disagree	*1 – Very uncertain*
2 – Disagree	*2 – Uncertain*
3 – Neutral	*3 – Neutral*
4 – Agree	*4 – Confident*
5 – Strongly agree	*5 – Very confident*

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
1	Most processes operate manually.											
	E-business initiatives within the organisation are unplanned.											
	Organisation does not provide stable environment to support e-business processes.											
2	Basic e-business processes are established.											
	Established successful e-business processes are recognisably repeated within organisation practice.											
	Established e-business processes are isolated and are not integrated within the organisation.											

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
3	E-business processes are well established and understood.											
	Standardised e-business processes are used constantly across the organisation for all projects.											
	Different e-business processes are integrated within the organisation.											
	Provide necessary training for staff regarding e-business processes.											
4	Establish quantitative indicators for measure e-business process performance.											
	Organisation quantitatively measures and monitors e-business process performance.											
	E-business processes are quantitatively understood and controlled.											
	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems											

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
5	Focused on continuous improvement of e-business capabilities.											
	Causal analysis and resolution.											
	Identify new innovative technology improvements and deploy suitable approaches.											

5. Would you like to propose any additional maturity characteristics regarding construction e-business processes?
6. Do you have any other final comments or suggestions?

Thank You

EXPERT FORUM – PHASE II – Academic Experts

DEVELOPMENT OF CONSTRUCTION E-BUSINESS CAPABILITY MATURITY MODEL (CEB-CMM)

Interview Number :

Interview date and time :

Interview location :

Purpose of the Interview:

The purpose of this second round interview is to refine the findings of first round interviews and verify construction e-business capability maturity characteristics identified from literature.

Section 1: First Round interview Findings

Following Table presents the verified construction process categorisation. Please provide your views and comments on it.

Process Category	**Processes**
Preparation and Brief	Identify business needs
	Identify project requirements
	Develop project brief
	Undertake initial feasibility studies
	Initial risk assessment
Planning and Design	Determine procurement strategy
	Determine contract strategy
	Prepare initial project programme
	Preliminary cost planning
	Preparation of concept design
	Preparation of developed design

Process Category	**Processes**
	Preparation of technical design
Tendering	Preparation of tender documents
	Invitation to tender
	Tender submission
	Tender evaluation
Construction	Post-contract project management
	Post-contract project team coordination
	Post-contract project planning, tracking and monitoring
	Post-contract change management
	Post-contract cost management
	Quality control
	Interim payments
	Site record keeping
	Claims management
	Dispute resolution
Handover and Aftercare	Project performance review
	Update project information
	Facilities management

Section 2: E-business Implementation

7. How important do you consider e-business implementation to the construction industry?
8. According to your views, what are e-business divers and barriers?

Section 3: E-business Maturity

9. This question describes 5 different maturity levels and their characteristics that may be applicable for a construction organisation. Please let me know your opinion on those characteristics and any other comments on them.

   What is your level of agreement on each characteristic and what is your level of confidence on your responses? Please explain the reasons.

Level of Agreement	*Level of Confidence*
1 – Strongly disagree	*1 – Very uncertain*
2 – Disagree	*2 – Uncertain*
3 – Neutral	*3 – Neutral*
4 – Agree	*4 – Confident*
5 – Strongly agree	*5 – Very confident*

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
1	Most processes operate manually.											
	E-business initiatives within the organisation are unplanned.											
	Organisation does not provide stable environment to support e-business processes.											
2	Basic e-business processes are established.											
	Established successful e-business processes are recognisably repeated within organisation practice.											
	Established e-business processes are isolated and are not integrated within the organisation.											

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
3	E-business processes are well established and understood.											
	Standardised e-business processes are used constantly across the organisation for all projects.											
	Different e-business processes are integrated within the organisation.											
	Provide necessary training for staff regarding e-business processes.											
4	Establish quantitative indicators for measure e-business process performance.											
	Organisation quantitatively measures and monitors e-business process performance.											
	E-business processes are quantitatively understood and controlled.											
	Organisation e-business processes are compatible and capable to incorporate with other partnering organisations' ICT systems											

Maturity Level	Maturity Characteristics	Level of Agreement					Level of Confidence					Remarks
		1	2	3	4	5	1	2	3	4	5	
5	Focused on continuous improvement of e-business capabilities.											
	Causal analysis and resolution.											
	Identify new innovative technology improvements and deploy suitable approaches.											

10. Would you like to propose any additional maturity characteristics regarding construction e-business processes?
11. Do you have any other final comments or suggestions?

Thank You

Appendix IV – Interview guidelines of Case Studies

DEVELOPMENT OF CONSTRUCTION E-BUSINESS CAPABILITY MATURITY MODEL (CEB-CMM)

Interview Number :

Interview date and time :

Interview location :

Section 1: Background Information

12. Name
13. Organisation Name
14. Organisation Type
15. Organisation Size
16. Designation
17. Please describe your role within the organisation and give a brief outline of your responsibilities.

Section 2: E-business Implementation

In this study, we define 'e-business' as the use of Information and Communication Technologies (ICT) to carry out general business activities.

18. According to your views, what are drivers of e-business processes?
19. What are the barriers you face when performing e-business processes?

Section 3: E-business Capability and Maturity

20. In your organisation, which type of e-business initiatives you have on following process categories? Explain how you initiated and progressed with these initiatives.

Preparation and Brief	
Planning and Design	
Tendering	

Construction	
Handover and Aftercare	
Other	

21. How those aforementioned e-business processes were introduced at first?
22. How did they developed their e-business profile? (Different stages of implementation, advancements to existing systems etc.)
23. Explain the current level of e-business usage in your organisation? (For projects, within organisation, level of integration etc.)
24. How they maintain current e-business systems?
25. Do you have any procedures to measure and monitor e-business process performances?
26. What are the special characteristics of your organisation e-business practices?
27. What are your views about the e-business implementation within your organisation?
28. In which ways do you think that your organisation can improve further to increase its' e-business capability?
29. Do you have any other final comments or suggestions?

Thank You

Appendix V – CeB-CMM Validation Questionnaire

Construction E-Business Capability Maturity Model (CEB-CMM) Validation Questionnaire

Organisation Name :

Evaluators Role :

Date :

Please use the provided Construction E-Business Capability Maturity Model (CEB-CMM) tool (CEB-CMM-Tool.xls) to assess the e-business capability maturity levels of your organisation construction processes and answer the following questions.

Section 1 - Results of the E-Business Capability Maturity Map

1. What are the e-business maturity levels of your organisation?

Process Category	Maturity Level					
	Not Applicable	1 Initial	2 Repeatable	3 Defined	4 Managed	5 Optimising
Preparation and Brief						
Planning and Design						
Tendering						
Construction						
Handover and Aftercare						

2. Are you satisfied with the maturity scores of your organisation e-business profile? Please provide reasons.

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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Section 2 - Ease of Use and Clarity of the CEB-CMM Model

3. Are you satisfied with the ease of use of the CEB-CMM model? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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4. Are you satisfied with the clarity of the CEB-CMM model? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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5. What are your suggestions to improve the usability of the CEB-CMM model?

Section 3 - Review of the CEB-CMM Model

6. Are you satisfied with the appropriateness of the CEB-CMM model as a tool to measure the e-business capability maturity of construction e-business processes?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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7. Are you satisfied with the applicability CEB-CMM model for your organisation e-business practices? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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8. Are you satisfied with the process categories proposed in the CEB-CMM model? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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9. Are you satisfied with the maturity level characteristics proposed in the CEB-CMM model? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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10. Are you satisfied with the benefits your organisation can obtain by using CEB-CMM? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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11. Are you satisfied with the overall CEB-CMM and its appropriateness to construction industry? Please provide any reasons or comments?

1- Very Unsatisfied	2 - Unsatisfied	3 - Neutral	4 - Satisfied	5 - Very Satisfied

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12. Are there any modifications or improvements you would suggest to the CEB-CMM?

Thank You

Appendix VI – Sample Verbatim Transcript of Expert Forum – Phase I Interview

Switched on the audio recorder after obtaining the verbal consent.

AR : Hello. Shall I start then?

EX : Yes.

AR : Ok. First some background information. I have your name and organisation. And your designation please?

EX : Commercial manager.

AR : Yeah. ok. And your expertise areas?

EX : Commercial and legal.

AR : And you are expertise in quantity surveying as well. Aren't you?

EX : Yes. Quantity Surveyor.

AR : Ok. And may I know your experience in years please?

EX : Yes. 11 years.

AR : Ok.

EX : Yes.

AR : Ok. Then let's straight away go to the questions. This interview is mainly focus on construction processes.

EX : Ahh ha.

AR : Ok. So first, What is your understanding of e-business?

EX : My understanding of e-business.. Umm... In relation to the.. umm.. to manage our businesses via electronic devices which is.. umm.. Im like to say emails.. err.. Like.. things like telecommunication or like that. Isn't it?

AR : Yeah yeah. The use of ICT for business activities. So you agree with it, don't you?

EX : Yeah.. err.. I think you pretty much need to use it for full these days.

AR : Yeah.

EX : Otherwise it is a disadvantage I guess.

AR : Hmm yeah. The next question is about your views about the e-business initiatives in your organisation as well as in the construction industry?

EX : Yeah.

AR : Do you think in the construction we are lagging behind to other industries or do you think that we are ahead of them? What do you think?

EX : Umm.. I think all relating to this company alone, we are.. sometimes.. errr... sometimes when we compare against other IT companies or big international global companies who may use more update information or e-business systems. But.. but we use what.. err... video conferencing now in our main offices, so we can save time on travel along over the country.

AR : Hmm.

EX : We can see everyone on the screen now. And we've got.. err.. we are moving away from boxes of storage of paper to have them all electronically. So towards having a more paper free environment.

AR : Hmm. Yeah.

EX : So.. web based initiatives and other collaborative systems.

AR : Hmm.

EX : Our system is called 'GOOBLE'. And 'BIW' for drawings. You can upload drawings and come and change these drawings from tender to construction and everything is pretty much electronically now. And this saves time and a bonus. Time and money goes together.

AR : Yeah.

EX : So.. I think we are pretty much using what the construction industry has available to be fair.

AR : Hmm yeah.

EX : Umm.. and we are quite up to date. From my point of view, I think some companies.. uum.. if you ask local companies, family run businesses, umm.. Probably more like sub-contractors who haven't got this level of e-business capabilities what the bigger companies got.

AR : Hmm.

EX : So you need to consider large, national and international contractors as well. I am imaging you are trying to have a look what comes in next and devices and systems to local smaller contractors who aren't get to.. errr.. probably the investments they said the drawback from their point of view.

AR : Hmm.

EX : Cost.. money to have all these systems in place. But in our place we are gonna reach the benefit of having them in place to do your business quite well.

AR : Yeah. Ok. Thank you for your views. Let's move to section 3. It is all regarding the basic construction processes.

EX : Yeah.

AR : Here main purpose was to identify construction business processes and categorise them into categories. So here RIBA plan of work and OGC guidelines were reviewed to identify and categorise construction processes. They are categorised to five process categories from preparation and brief to use and aftercare. And this is based on the tradition procurement system not design and built or partnering. I want to know your views regarding this classification.

EX : Hmm. Ok.

AR : So under each process you can tell me our level of agreement in a scale of 1 to 5 where 1 is you strongly disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is strongly agree.

EX : Yeah.

AR : And confidence level means your confidence level regarding the answer you've given as your agreement level. So first under preparation and brief category, first five processes, identify business needs, identify project requirements, project brief, feasibility studies and client risk assessment.

EX : So you categorise them under preparation and brief?

AR : Yes. If you have any other comments or views you ca tell them for me to change this better as well.

EX : Identify business needs.. umm I think that is.. err... business plan.. which is useful to deveop the plan.

AR : Hmm.

EX : I would say I would agree that it is preparation and brief. But..

AR : And another thing if you think that any of these processes might applicable to other categories as well you can tell that to me.

EX : Yes I think it is. I think identify business needs is spreading probably to tendering and procurement as well.

AR : Hmm.

EX : Because you need to choose which type of project is going to tender for, like those things are based on what client needs.. business needs.

AR : Hmm.

EX : In the business plan you put business needs. I think they all are linked. So preparation and brief to tendering and procurement for me.

AR : Ok.

EX : So.. score.. level of agreement 4-Agree and my level of confidence on my opinion?

AR : Yes.

EX : Ok. I'm on 4-Confident.

AR : Ok. And Identify project requirements?

EX : Identify the project requirements.. errr... well.. preparation and brief.. yeah I agree. So it is 4-Agree and Im very confidence in that, so 5-Very Confidence.

AR : Ok. And develop project brief?

EX : Develop project brief.. umm I think that's also planning and design as well. I agree that is preparation and brief, but also planning and design. So for level of agreement Im gonna go for 5-Strongly Agree and 5-Very Confidence.

AR : Ok. Undertake feasibility studies?

EX : Undertake feasibility studies.. umm... this is doing at very high level. With concept design along with the cost estimate. They'll find out whether the project is feasible to carry out.

AR : Hmm.

EX : Therefore I think its probably a design one, planning and design.

AR : Hmm.

EX : I will say I am very confident and sure, its 5-Strongly Agree and 5-Very Confident.

AR : Ok.

EX : Risk assessment.. err.. We would do a risk assessment at.. from our point of view, contactor, we would do a risk assessment prior to a tender.

AR : Hmm. Ok.

EX : Because before we submit the tender, we need to allow certain amount of risk and to cover. So I would probably say that is tendering and procurement from our point of view. But then if you are thinking from a client prospective, probably it would be different.

AR : Yeah.

EX : So ill say 3-Neutral for both agreement and confidence.

AR : Ok. So next under planning and design category, prepare initial project programme?

EX : Project programme.. Yeah.. Err.. in planning and design.. yeah 5-Strongly Agree and 5-Very Confident.

AR : Ok. And.. preliminary cost planning?

EX : Preliminary cost planning.. I would say 4-Agree and 4-Confidence as well.

AR : Ok. And the next three processes are basically design processes, concept design, developed design and technical design?

EX : Concept design.. this is the right one is't it? Its 5-Strongly Agree and 5-Very Confident.

AR : Ok.

EX : Preparation of developed design.. Umm that.. I guess you gonna develop your design depending on what type of procurement you have. If its traditional its on planning and design stage but if it is design and build you develop the design at construction phase.

AR : Hmm.

EX : So I would say from our point of view, subjected to the procurement roots, umm.. 4-Agree and 5-Very Confident.

AR : Ok.

EX : And for technical design i would say the same. 4-Agree and 5-Very Confident.

AR : Ok. And then the Tendering and procurement category. Under that determine the procurement strategy and determine the contract strategy?

EX : Determine the procurement strategy.. umm I think that.. when client get a job he would tell you what and how he want to do, like is he want traditional or design and build or partnering. So I would probably suggest that one to be in Preparation and brief stage.

AR : Hmm.

EX : I don't agree that is on tendering because it is the start. So 2-Disagree and 4-Confident.

AR : And.. Determine the contract strategy?

EX : I think it is hand in hand with procurement strategy. So I would say same 2-Disagree and 4-Confident.

AR : And preparation of contract documents?

EX : Umm.. preparation of contract docs.. I guess that would be tendering and procurement. Yeah. So I 4-Agree and 4-Confident.

AR : Next Tendering process?

EX : Yeah it is in the right box, 5-Strongly Agree and 5-Very Confident.

AR : And next the Construction category. Project management, project team coordination, project planning tracking and monitoring, change management, cost management, quality control, payments, record keeping, claims and dispute resolution?

EX : Umm... I think project management is... Umm I think 'site management' is a good term to use. Because then it in only in construction phase. Project management is since start.

AR : Ahh yeah. Ok. I think proposed a good term to use.

EX : Hmm. And.. project team coordination and...errrr.. you see the.. Hmm.. I think personaly the project management, project team coordination, project planning tracking and monitoring.. those three there are really go from planning and design, tendering and procurement and construction phases.

AR : Hmm.

EX : Construction is only site work. Isn't it?

AR : Hmm.

EX : So I think I probably put for those three I 4-Agree and 4-Confidence.

AR : Ok.

EX : Change management.. I would say that is construction. So 5-Strongly Agree and 5-Very Confidence.

AR : Cost management?

EX : Cost management.. errr.. on site it would be construction. Yeah. 5-Strongly Agree and 5-Very Confidence.

AR : Ok.

EX : Quality control.. yeah.. onsite. 5-Strongly Agree and 5-Very Confidence.

AR : Hmm.

EX : Payments.. Probably you might do payments in the initial stage.. payments for design team or client team. Umm.. So I'll put 4-Agree and 5-Very Confident.

AR : Ok.

EX : Record keeping.. yeah. 5-Strongly Agree and 5-Very Confidence. Claims management 5-Strongly Agree and 5-Very Confident.

AR : Hmm. Ok. Dispute resolution?

EX : This can drag to the next phase as well I think. If there is a large defect of the project, it quite often get the clients'.. put the claim against the contractor to remedy that or trying to claim that money. That would be via the courts probably. So I agree this for construction and use and aftercare. So 4-Agree and 4-Confident.

AR : Ok. Next use and aftercare category.. Project performance review, update project information and facilities management?

EX : Umm.. yeah I agree with all of them. So 5-Strongly Agree and 5-Very Confidence for all way down.

AR : Ok. Then last question. Apart from the identified construction processes, do you think any other processes or would you like to suggest anything additional for processes and categories?

EX : Umm.. let me think.. I think its quite complete. Its pretty much covered everything.

AR : Hmm.

Health and safety is the one that buzz in to my mind. But you know you us it in various processes. You can out it as prepare the health and safety plan.

AR : Hmm.

EX : In our company we've got quite good record of health and safety. Checks and regulations. Processes and policies which we lawful comply with. In the event of a health and safety issue, when.. err.. so the one on site have to provide records of what has happened. So we've got some e-business type IT system which tracks all these things and report what is the frequency rate is on injuries and so on. I guess that is a large part of construction.

AR : Ok. So which phase do you think health and safety would apply?

EX : I think health and safety should include in early stage.. we do the design with safety in mind and design the access and maintenance for high rise buildings. And obviously during the construction phase safety of workforce.

AR : Ok. Thank you very much for suggesting it. And it is good to know that you use ICT systems for health and safety management and for sure I will get back to you if I need to know anything further regarding it.

EX : No problem. Any time.

AR : Finally do you have any other comments regarding the classification or any other thoughts?

EX : Umm... I think it's pretty much from start to finish. I agree with it. All in there.

AR : Alright. Ok then thank you very much for your time.

Appendix VII – Sample Verbatim Transcript of Expert Forum – Phase II Interview

Industry Expert

AR : Hello.

EX : Hello.

AR : I would like to thank you again for your time given for the interview.

EX : Ok.

AR : Ok. Let's straight away go to the questions. I want to know more about your organisation type and size.

EX : Ok.

AR : So type of organisation? Are you a contractor or consultant or?

EX : Err... We do Consultancy.

AR : Ok. and type of work? Both civil and building?

EX : Yeah. We do both.

AR : Ok. The size?

EX : How do you categorise the size?

AR : Here use the categorisation according to the number of employees. If its less than 10 its micro. 10-50 small. 50-250 medium and more than 250 Large.

EX : Large.

AR : Right. Ok. Next section is regarding the e-business implementation.

EX : Umm.

AR : How important do you consider e-business implementation to the construction industry?

EX : Ahh... it is important to a certain extent. But it all depends on the type and scale of the project. Because like you know, if it's a big organisation yeah they will invest lot of money in developing e-business.

AR : Hmm.

EX : But if it is a small company, I don't think they will be too keen other than looking email and everyday computers and things.

AR : Do you mean that smaller companies might limit their usage to basic ones?

EX : Yeah. I think they will be using PCs and Excel and Email.. umm..like that.

AR : Ok. And what do you think about e-business drivers and barriers?

EX : Drivers will be like.. they can save the data centrally, anyone can access them whenever they want. That's a big advantage. And everyone can get latest drawings and things easily if you store them in a central database.

AR : Ok.

EX : And it will be very useful for very big projects. Can manage projects easily with e-business.

AR : Hmm.

EX : And the barriers will be for small firms. They might not have sufficient funds to invest in e-computer systems.

AR : Ok.

EX : And the other thing is.. for example we got our own system and some client got their own systems. So when we work with them some client want us to work with their software or desires. Then we can't use our ones. We have to have them and sometimes incompatibility issues are there as well. That will be a barrier.

AR : Ok. And for the next section I want to know which types of e-business initiatives you have in your organisations.

EX : Ok.

AR : First one, for Preparation and Brief?

EX : Umm for that.. probably MS Word. And sometimes we use Skype to discussions with clients.

AR : Ok. And for Planning and Design?

EX : Drawings we use AutoCAd. Sometimes just to look and measure, we use Auto Desk Design.

AR : Ok.

EX : And for Planning we use Primavera 6. That's the most popular one.

AR : Ok. And for Tendering and Procurement?

EX : Umm... E-Procurement.. And tender portals. But sometimes when we publish it, we publish it both online and paper. I think you need not to stick to one media. We publish the tender notice in the paper as well to get a better response.

AR : Ok. And what type of things you use for Cost Management?

EX : For cost management we got few in-house software. One is CATO (Computer Aided Taking Off). Then INTEGRRA. And we got another one called LifeTime which we use to do the life cycle costing.

AR : Ok.

EX : And we also use the BCIS website, which is the RICS for estimating data and everything. And we use NBS prelims.

AR : Ok. And for Contract management?

EX : Umm.. we use an specific one called 'e-Change' and that is for change management. And we got two like NEC digital and JCT digital. They are electronic versions and allow us to change the clauses according to the requirements to draw the contract document.

AR : Ok. For Project Management?

EX : Umm... we have moved away from using MS Project. Not completely moved, we sometimes using it. But now we use the concept of Project Controls. There we got two measures, SPI (Schedule Performance Index) and CPI (Cost Performance Index). Then there is a way of calculating these indexes.

AR : Ok.

EX : We just use excel spreadsheets for that. What we do is you measure it in monitory term, measure it.. the schedule performance and cost performance. For example if its less 1 for schedule performance, it means we are behind the schedule. If its more than 1, it is good which means we are ahead the target. And the cost index also same.

AR : Ok. and for Documentation Management?

EX : We've got a system called 'Documentum'. It stores all the documents from the Client and the Contractor.

AR : Is this a collaborative one or a separate one for your company?

EX : No this is a Client one for the project where everyone collaborate.

AR : Ahh ok. And for Use and Aftercare?

EX : Umm.. Personally I haven't use any software. But there might have some. There are some ones in the company, but I have no personal experience using them.

AR : Ok. And for Facilities Management?

EX : I am thinking of BIM for that.

AR : Yeah. Ok.

AR : Ok. And in the next section is maturity levels and e-business characteristics for them. These are extracted from existing literature as conceptual characteristics. I need your opinions and agreement levels on them.

EX : Ok.

AR : So shall I explain them and then you can give me your answers?

EX : Umm.. yeah. Ok.

AR : Ok. First the level 1 is the initial level. When an organisation is at level 1, their e-business processes are not planned. So most of their processes operate manually.

EX : Umm yeah I agree and Im confident. It can happen.

AR : Ok. And then their e-business initiatives within the organisation are not planned as well as the organisation does not provide suitable environment like necessary infrastructure to support e-business processes.

EX : Umm these could be yes or no. Ill go for neutral here.

AR : Ok.

EX : Because even though they do lot of things manually, they might be know about what capabilities are there, but not using them for financial or client reasons.

AR : Ok. And then next level. When organisation moves to level 2, their basic e-business processes are established.

EX : Umm.. Yeah. I strongly agree and very confident for thta.

AR : And if they recognise in the established processes they are repeated them in other projects as well. So the successful practice is repeated.

EX : Yeah. This also true. I agree and confident.

AR : Ok. And at this stage, even though they have some established e-business processes, they are and are not integrated within the organisation. They might be isolated for each process.

EX : Umm... I am not sure about this. Neutral.

AR : Ok. And then the next section. Level 3. When an organisation moves to level 3, within the organisation e-business processes become well established and understood from the people.

EX : Umm.. for this I am disagree. Because it might be well established, but well understood by limited number of people, not all. May be top management doesn't have a clue and operational people know about it.

AR : Hmm. Ok. And Standardised e-business processes are constantly used for all projects in the organisation.

EX : Umm.. For all projects.. No. I disagree. It will depend on size of the project and for some projects you can't use standardised ones. Because all these software comes with a cost, cost of license fee and all. So it depends on the number of people whom going to use and the location.

AR : Ok.

EX : The key word here is All. That’s why I disagree.

AR : Ok. And all the e-business processes are integrated within the organisation. And organisation provides necessary training for staff regarding existing or new e-business processes.

EX : Umm for these I'll say Neutral. I am not agree or disagree. Organisations don't provide training for everyone. They learn on the job.

AR : Ok. Next levels are level 4 and 5 which are considered as higher maturity levels.

EX : Ok.

AR : At level 4, an organisation would establish quantitative indicators for measure e-business process performance. From the quantitative measures they measures and monitors e-business process performance. And according to the results, the processes are processes are quantitatively understood and controlled.

EX : Umm for me the problem is 'Quantitative' part. I am not exactly clear why only Quantitative. For normal construction processes we have KPIs. WE establish milestones like how many days to finish a task and then measure it. But for e-business I am not sure.

AR : For example, say using e-tender portal and measure we completed the process less than one month by using the e-portal rather than following the traditional way.

EX : Umm.. In that case, what you do is comparing the computer or technology with manual. This is not comparing the processes. I mean you compare traditional process verses e-process, but not two e-processes like two alternative ones. So that's why I am not sure.

AR : Hmm.. Alright. Ok.

EX : And my other concern is why only quantitative? Why not qualitative? You can have both. You can use qualitative KPIs and benchmark it.

AR : Hmm.

EX : I think you have to introduce both qualitative and quantitative KPIs. Both are important and possible to introduce. Thats important for you to have both, once you progress through these levels and you can look back to them after some time and see how you progressed.

AR : Hmm ok. I'll consider that. And in this level, organisation e-business processes are capable of incorporate with other organisation systems as well if needed.

EX : That also I am Neutral. The reason being, you are trying to incorporate or integrate systems. But unless they are using the compatible software you can't integrate.

AR : Hmm.

EX : And also it depends. Because if you have in house software, they might not have all the capabilities to integrate with another one. So that disadvantage is there.

AR : Ok. And next the level 5 is considered as the optimizing level where organisation is focused on continuous improvement of e-business capabilities.

EX : I'll say Neutral. Because it should not just continuous improvement, you have to maintain what has achieved. So you might have to say 'focus on maintain and continuous improvements'.

AR : Ok.. And causal analysis and resolution?

EX : Hmm. I think this should come earlier. So Im not agreeing or disagreeing. Neutral. Its not good to wait until the end or until this level to do causal analysis. You shouldn't wait until this level. It should be at level 2 or 3.

AR : And finally Identify new innovative technology improvements in the market and deploy the suitable ones.

EX : Yes I agree with this one.

AR : Ok. And finally would you like to propose any additional maturity characteristics?

EX : Umm.. I think you might introduce and develop some benchmarks to measure whether you achieved each maturity level. And also think about how these can adopt into different situations.

AR : Umm.... Ok. I'll think about them.

EX : And then the maturity of organisation verses the project. You have to make clear which is you are focusing. The important aspect is not mixing those two. Because business or the organisation might have level 5 IT capability, where some of their projects have level 2 capabilities. So you have to be very clear of what you are going to measure.

AR : Hmm. Ok. And do you have any final comments or suggestions?

EX : Umm.. I think I mentioned everything before.

AR : Ok. Thank you very much for your time today. And thank you very much for all your comments, thoughts and suggestions as well.

EX : Ok.

Academic Expert

AR : Hello.

EX : Hello.

AR : Shall I start if you are ready?

EX : Yeah. sure.

AR : Ok. First thank you very much for your time today. This interview purpose is regarding the construction e-business maturity characteristics.

EX : Hmm.

AR : Ok. I'll explain you further abut that when we go to that section. And first section is some background information on your views on e-business.

EX : Ok.

AR : How important do you consider e-business implementation to the construction industry?

EX : I think e-business implementation is extremely important.

AR : Ok.

EX : Because firstly it change from working style or kind of an environment to working in a collaborative environment. It does important for organisations really, because it recognise that working in collaboration or collaborative approach.

AR : Hmm.

EX : So you are thinking beyond your organisation to the requirements of your stakeholders. yeah.

AR : Yeah.

EX : And those presents challenges to implementation which extend again the boundaries of one organisation. And that why its very important.

AR : Hmm yeah. According to your views what are the e-business drivers and barriers for construction organisations?

EX : Well, drivers originally started off as been suggested in reports such as Egan and Lathem to begin with.

AR : Hmm.

EX : And which were particularly driven by the needs to actually improve the current practice.. then current practice which was to do with... umm.. reduced performance compared to other industries. The fact that the industry contributed to around 10% of the GDP at the time which was significant amount and therefore needed to improve its performance.

AR : Hmm.

EX : So that was the main driver. It was to getting over with the issues associated with fragmentation. And looking towards much more collaborative partnering environment, which really was why we had initiatives such as e-business.

AR : Ok. As barriers what you can think of?

EX : I think the barriers... as any technology would have.. in the first instance to do with the technology itself. Because you need your legacy to compatible with the new changes that you are introducing.

AR : Hmm.

EX : And again the framework of working from an individual organisation to a collaborative organisation. You need processes in place seamlessly.

AR : Hmm.

EX : Again the People. Because the people are effected directly by the change. And if you look at the change management strategy, to move from a states core to a new status score, you always are going to be met with the resistance. That can only be avoided if you have right procedures in place for training people and improving their understandability. So that the awareness is improved.

AR : Hmm.

EX : It's a multiple level set of barriers which need to be considered.

AR : Ok. And in the next section is maturity levels and proposing e-business characteristics for them. I need your opinions and agreement levels on them.

EX : Hmm.

AR : So shall I explain them and then you can give me your answers?

EX : Yes I think so.

AR : Ok. First the level 1 is the initial level. When an organisation is at level 1, their e-business processes are not planned. So most of their processes operate manually.

EX : Ok. I think for this one I would say neutral. Because I think now we've moved from that so this might not be completely relevant. You might have to name as ad-hoc rather simply manually. Because what you would find may be some parts are manual and some parts are automated. But there might be no integration between the two.

AR : Ok.

EX : So I would say neutral and confident.

AR : Ok. And then Their e-business initiatives within the organisation are not planned as well as the organisation does not provide suitable environment like necessary infrastructure to support e-business processes.

EX : e-business initiatives within the organisation are unplanned.. Yeah that is likely. So I agree and confident.

AR : Ok.

EX : And organisation does not provide stable environment for e-business.. Umm.. how this differ from the previous one?

AR : Its like necessary infrastructure to support e-business processes.

EX : Ahh ok. Here what you have to do is clearly explain which aspect is unplanned? Like is is unplanned process, unplanned technology or.. likewise. Because e-business is not simply only about process. It is not only simply about technology. It does not simply about governance or authority and its not simply about the people. Ok? Because unplanned term can cover lot of aspects. Ok.

AR : Yeah. Ok.

EX : And Agree and I'm confident. But for that I'll say this need better distinction from the previous one.

AR : Ok. And then next level. When organisation moves to level 2, their basic e-business processes are established.

EX : Hmm.

AR : And if they recognise in the established processes they are repeated them in other projects as well. So the successful practice is repeated.

EX : Can you explain with an example?

AR : Yeah. Ok. It is like first you do e-tendering for one of your projects and if you see any success of it, then e-tendering is used to other projects as well.

EX : Ah ok. I agree with that. Ill say neutral as confident. Because I think it might vary from organisation to organisation. If its a forward looking one, they might have different approach differ to lagers.

AR : And at this stage, even though they have some established e-business processes, they are and are not integrated within the organisation. They might be isolated for each process.

EX : Ok. And not integrated.. does this means islands of automation? Because I think this is what you are explain. I think the last one you can explain or expand further. For me these sounds like little islands of automation where sub processes are automated but not interlinked. Ok?

AR : Ok.

EX : Umm... for this section I agree and confident. My only comment is you might need to explain this little bit differently as I explained.

AR : Ok. And then the next section. Level 3. When an organisation moves to level 3, within the organisation e-business processes become well established and understood from the people.

EX : Yeah. I would agree with that. And also I would say I am very confident with that.

AR : And Standardised e-business processes are constantly used for all projects in the organisation. And all the e-business processes are integrated within the organisation.

EX : Yeah. That also sounds right. So I am agree and confident.

AR : And at the same time organisation provide necessary training for staff regarding existing or new e-business processes.

EX : Yeah. I can see this as the first time you recognise the people other than processes. I think people should have recognised and considered even more at earlier stages when the processes are not established.

AR : Ok.

EX : And I think this has to be considered at level 2. Because people understood the processes because training is provided for them. Isn't it? So I think this has to be considered earlier at level 2. Here at level 3 you could say like continuous training or further training of the previous level.

AR : Ok.

EX : So I would say disagree with high level of confidence.

AR : Ok. Next level 4 and 5. They are considered as higher maturity levels. At level 4, an organisation would establish quantitative indices for measure e-business process performance.

EX : Ok. So this is more about KPIs. Isn't it?

AR : Yeah. So from the quantitative measures they measures and monitors e-business process performance. And according to the results, the processes are processes are quantitatively understood and controlled.

EX : Yeah. Ok. I agree with this level as this means they are monitoring and controlling their performances. But my issue is why only quantitative measures? Why not qualitative measures? Because if you think about it, if you look at the technology implementation cycle, usually the implementation failures occurs from result of multiple set of factors.

AR : Hmm.

EX : Not simply something that can measure quantitatively, that might be due to attitude or behavioural which is more qualitative. And if we don't have

measures in place for qualitatively recognising where is those issues are, no matter how much of measurement that... quantitative measure is only going to tell you that ohh no we are not performing well.

AR : Hmm.

EX : But it won't give you any explanation as to why. So you might see a dip or a spike in your analysis because it is measured by numbers. But you don't understand why that spike exists. You see what I mean?

AR : Yeah.

EX : So my response is neutral or disagree because I think as much as you need to introduce qualitative measures as well so you get a true picture of what's actually happening. And I am confident on my response.

AR : Ok.

EX : Because understanding the reasons behind findings and measures are more important.

AR : Yeah. And finally at this stage, organisation is capable of incorporate with other partnering organisations' ICT systems if needed.

EX : This is very important. And I think this would come at early maturity level, Level 3. Because 4 is too late. You should make sure at early that you are working in a collaborative environment.

AR : Ok.

EX : For example take e-tendering. When you do so, you are working with your stakeholders. Their incompatibility will have an impact on your outcome. So I would move it up. And I am disagree and confident.

AR : Yeah. And next the level 5 is considered as the optimizing level where organisation is focused on continuous improvement of e-business capabilities. And they do Causal analysis and resolution for their e-business problems.

EX : Yeah.

AR : And they Identify new innovative technology improvements in the market and deploy the suitable ones.

EX : Ok. For this level I agree with all and I am confident as well. Because this is usually what you do at optimising level. And regarding the causal analysis, you have to be aware of other analysis methods and their suitability or appropriateness for in the context of e-business ok.

AR : Ok.

EX : And I am agree and confidence with my responses.

AR : Ok. And finally would you like to propose any additional maturity characteristics?

EX : I think we discussed and covered all. Only thing is I think other aspects like people, technology and governance structure should also be considered with the processes.

AR : Ok. And any final comments or suggestions?

EX : Hmm nothing specially.

AR : Ok. Thank you. Thank you very much for your time today and for all your comments and views.

EX : Not a problem. I wish you good luck. Looking forward to see your final product.

AR : Ok. Thank you. Bye.

EX : Bye.

Appendix VIII – Sample Verbatim Transcript of Case Study Interview

AR : First of all thank you very much for your time.

R5 : My pleasure.

AR : Ok. We can discuss through the other questions.

R5 : Ok.

AR : Can you please describe me your role within the organisation? And a brief outline of your responsibilities?

R5 : As commercial manager, I am responsible for the entire commercial department of the North East. And legal matters in the North East as well. Things like contract administration and dispute resolution as well.

AR : Ok. And next section is regarding the e-business. e-business is defined as the use of ICT for conducting business processes.

R5 : Ok.

AR : According to your views what are the advantages of having these e-business processes in your day to day work?

R5 : I would say speed. Speed of transactions. Whereas once upon a time a letter would take 2 days to get to somebody. But an email take seconds.

AR : Hmm.

R5 : It saves a lot of time. Time is money. So now drawings and specifications and other contract information can get pursue between consultant parties in a day or in 5 minutes. Where in past it takes days and then the consultants may mark up on drawings and send comments back. And that would take same time. So its instant with e-business.

AR : Hmm.

R5 : And it reduces the length of the time that we get a project from consultant to construction phase in which therefore speed saves a lot of money as well. Time, money and speed. And you find consultancy easy and more efficient.

AR : Hmm.

R5 : And it reduces the overall cost of the project. And I think its environmental. You g*et al*l the benefits of paperless by using emails, which reduces the carbon, CO2.

AR : And then about the challenges you face when you use these tools and work with them?

R5 : I find culture changes as the most difficult. What I meant by that is people used to do things in a certain way because they have always done them that way because they've always done them like that.

AR : Hmm..

R5 : And there is a lot of learning and development need for them. And its money and we need to train and coach people. For example take BIM. To use it to full extent, you need to train people. So I think learning and training is the first and foremost.

AR : Ok.

R5 : And then make sure these things get implemented. Because it is difficult to change business processes once they used to do it. Its quite difficult to change.

AR : Hmmm.

R5 : We've got few systems. We've got NGB, which is a good system, but we don't use it to full capacity. Because people are not using it.

AR : It is due to the people attitudes towards those systems or?

R5 : Umm... I think so.. I think its because people don't know.

AR : You mean they are not trained to use the systems?

R5 : Yeah.

AR : Ok.

R5 : We've got a system called 'Gooble'.

AR : Hmm.

R5 : The benifit of Gooble is its web based. So its not server based.

AR : Like sky drive?

R5 : Yeah. But the probleem is people dont use it properly. When they save project information, they just drag and drop the folder into their folder in server. But the proper way is that they have to do it through Gooble.

AR : Ok. So usually who manages that system? Do you pay subscription chargers?

R5 : Yeah. We pay. But its an in house system developed for us. So maybe we've paid for it already.

AR : Ok. And in the next section, can you please explain me the e-business initiatives for these processes and any other processes you have in your organisation? How you established and progressed?

R5 : Ok. Preparation and Brief. Umm have video conferencing facility in the board room. Or the old conference telephone call system. Emm and Email.

AR : Hmm.

R5 : Do you always use them or do you have face to face meetings as well with some projects?

R5 : Umm.. It depends on the client. We usually agree with him how we would do the meetings. Sometimes we go and meet them and sometimes we use these.

AR : Ok.

R5 : And also if you get a big contract where people are from different counties. And then you have to go for video conferencing.

AR : Ok. Usually who initiate using these systems? Is it the client or you?

R5 : I think every client been different. Some like public authorities require use of BIM. And its going to be a certain level of BIM at a certain date.

AR : Yeah its in 2016.

R5 : I think ultimately someone is going to pay for that. So depend on the client you got, if its a developer who just basically wants to build the project for the cheapest possible because he is going to sell it and he want to make as much money as can. So he is not going to pay for implementing BIM on that project. He just want to build it fast and cheap.

AR : Hmm.

R5 : And where public authorities build new hospital may want to finish the whole design first and implement BIM. I guess it comes down from the government regulations.

AR : Ok.

R5 : Planning and Design.. I guess it would be BIM or AutoCAD mainly.

AR : Ok.

R5 : Tendering and procurement.. Ummm we use tender portals. Specially now we got NEPO, North East Procurement Organisation I think its called. They have a portal which all the things have to come from. Newcastle council and all.

AR : Ok.

R5 : All the documentation, procurement legislations and everything comes and goes back forth through this portal.

AR : Ok. For cost management?

R5 : Cost management we do have an electronic cost management system called INTUTER. Other ones we've used before is COINS. Both of these are similar and like financial management systems. It includes all the costs associated generate in a project and overhead wise.

AR : Ok.

R5 : It a live system. /we update it monthly basis.

AR : Ok. Do you use it for every project or for some selected ones?

R5 : We use it for every project.

AR : Ok. And Contract management?

R5 : Ummm.... we have got some good system in place called 'INFO TRACKER'. It is something like for site management. It keeps all the site records, who wasin that day, what was the weather like, how many men were there and everything.

AR : Alright. Ok.

R5 : Its really a good system. At the end of month, senior management can print the report and it says all the details. All the records are there, so it is a good tool for contract management.

AR : Ok. Project management?

R5 : We use programming software to produce the programmes with critical paths and all. Im not sure about the name. Sorry.

AR : Thats ok.

R5 : For documentation management we've got BIW. Its a very good collaborating system for projects as well.

AR : Hmm. Ok. Do you use it for every project?

R5 : Ummm No. Only for bigger schemes. For smaller scheme projects you pretty much put the information into Gooble and that's it.

AR : Hmm. Ok.

R5 : However at the end of a project, all the information is copied and saved into Gooble as well because it is our main thing.

AR : Ok. For use and aftercare, do you have anything?

R5 : Umm.. Yeah we've got a really good system Anushi. Its our BMS, Building Management System. We've got after care.. and.. umm.. its got quite a different parts to it. They've got one for after care and clients love it.

AR : Hmm.

R5 : What happens is you open a new job for client. Because traditional way is they report defects through emails. Sometimes those emails are just staying in someone's mailbox who left the company. But in this system now, its an online thing. They log on with their details and if client get to know a defect he just inform it via the system and he can g*et al*l the updates and track the progress. Its a live system.

AR : Ok.

R5 : When we finish with that we have to close the job. And client also has to close it.

AR : Ok. SO is this connected with Gooble, or do you save these details as well in Gooble under each project?

R5 : Umm.. that is how it should be. But at the moment No. These two systems are not interlinked.

AR : Ok.

R5 : Also its worth from the e-business point of view that we've actually just been through a process of.. we had big containers, hundreds of them full of project documents and correspondences. All the details of old projects. But now we just keep few important correspondents only and everything is online and paperless. So thats a very big advantage for us.

AR : Yeah.

R5 : Certainly from a storage point of view, yes. We've achieved alot. We evoleved from it. We scanned all the document we had and kept only the important ones and shred the rest.

AR : Ok.

R5 : And we've got facilities management segment, but its not big in the business at the moment.

AR : Ahh ok.

R5 : We've just indroduced it to our business and the intention is to use it to win more projects. So we are still working on it.

AR : Ok. And other than the ones you mentioned, are there any additional e-business initiatives?

R5 : Ummm.. I think I've covered everything.

AR : And are there documents available explaining e-business processes and practices?

R5 : Yes. We've got the system called TOOL BOX. Its web based and within our intranet. All the documents are saved there. It covers almost every protocol in the process match. And this is shared and integrated for all our branches under XXX group.

AR : Ok. what do you think about the ICT implementation in your organisation?

R5 : I think its good. I really do. I think may be big companies may have certain new initiatives. But I would certainly say XXX our group do invest quite a lot of money on ICT and to make sure their systems are up to date.

AR : Hmm.

R5 : Pretty much everyhting we do is electronic these days.

AR : Right. And then in which ways do you think that your organisation can improve further to increase its e-business capabilities?

R5 : Umm.... I don't know.

AR : Do you have a separate IT section for the company?

R5 : Yes we do have. They look after all the technical aspects of them. And mainly infrastructure fixing and maintain things. And if we want specific changes in our systems, we hire separate professional companies.

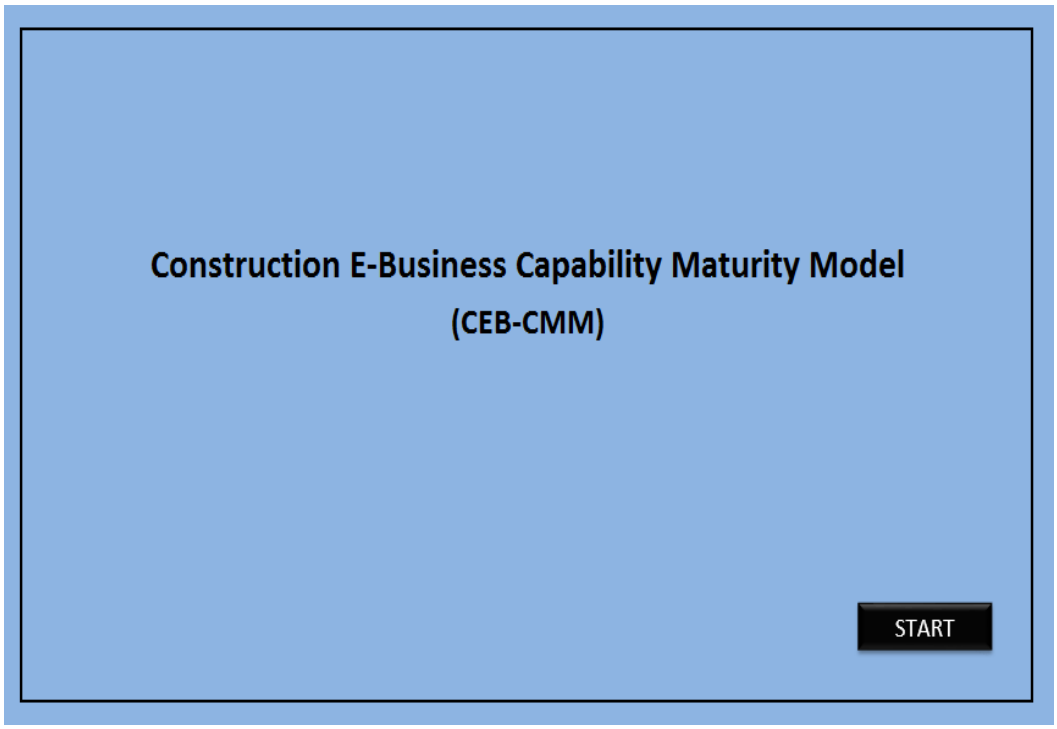
AR : Hmm ok. Do you have any other final comments or suggestions which you would like to make?

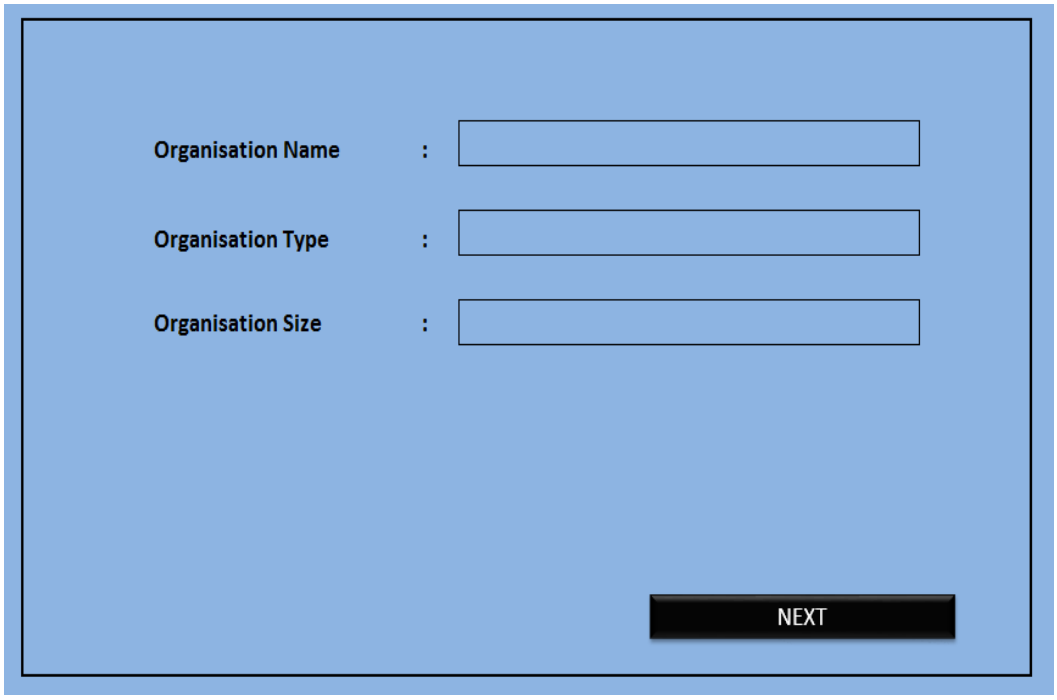
R5 : Umm.... Not at the moment.

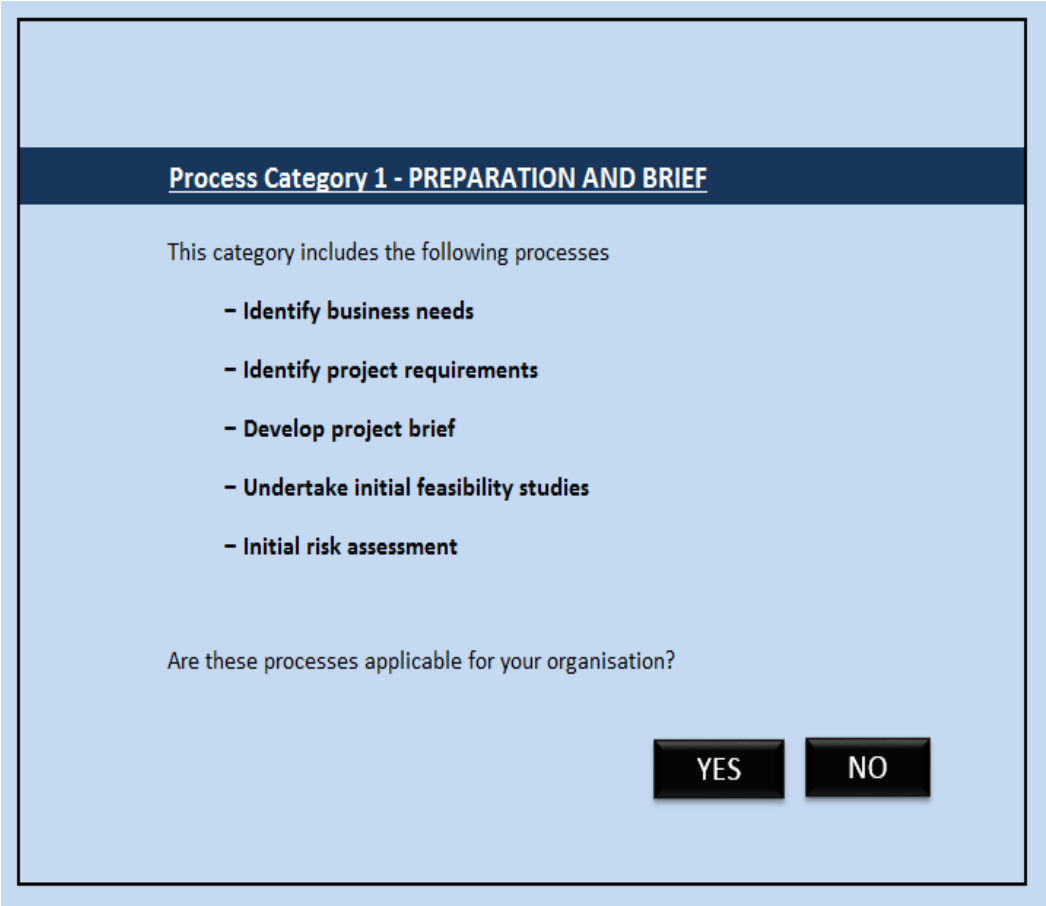
AR : Ok then Thank you very much for today.

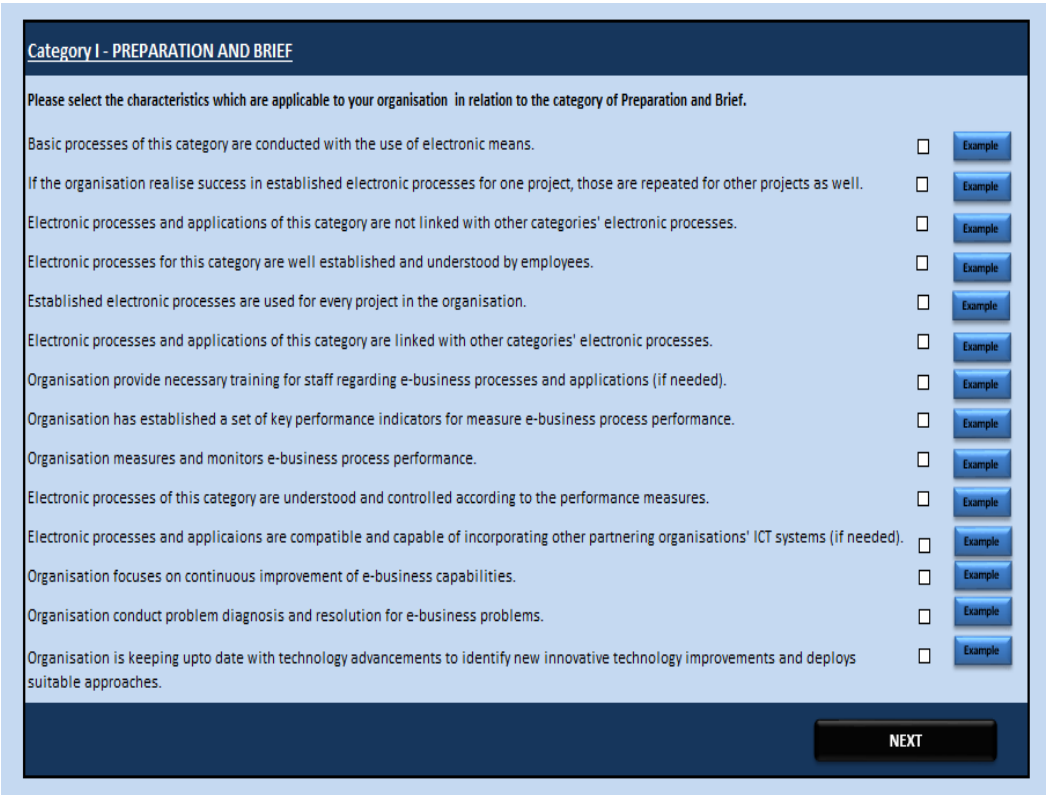
R5 : No problem. Good luck.

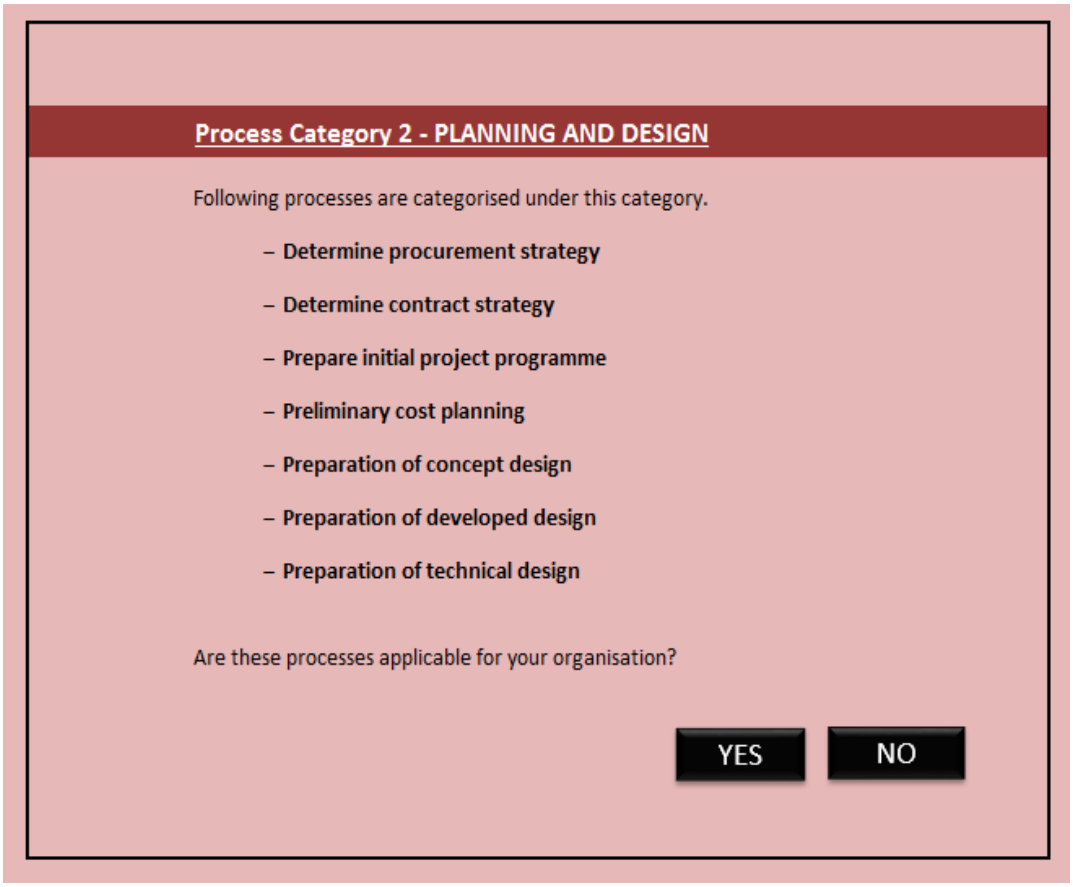
Appendix IX – User Interface of CeB-CMM






Process Category 1 - PREPARATION AND BRIEF
This category includes the following processes
– Identify business needs
– Identify project requirements
– Develop project brief
– Undertake initial feasibility studies
– Initial risk assessment
Are these processes applicable for your organisation?
YES
NO


Category I - PREPARATION AND BRIEF
Please select the characteristics which are applicable to your organisation in relation to the category of Preparation and Brief.
Basic processes of this category are conducted with the use of electronic means.
If the organisation realise success in established electronic processes for one project, those are repeated for other projects as well.
Electronic processes and applications of this category are not linked with other categories' electronic processes.
Electronic processes for this category are well established and understood by employees.
Established electronic processes are used for every project in the organisation.
Electronic processes and applications of this category are linked with other categories' electronic processes.
Organisation provide necessary training for staff regarding e-business processes and applications (if needed).
Organisation has established a set of key performance indicators for measure e-business process performance.
Organisation measures and monitors e-business process performance.
Electronic processes of this category are understood and controlled according to the performance measures.
Electronic processes and applicaions are compatible and capable of incorporating other partnering organisations' ICT systems (if needed).
Organisation focuses on continuous improvement of e-business capabilities.
Organisation conduct problem diagnosis and resolution for e-business problems.
Organisation is keeping upto date with technology advancements to identify new innovative technology improvements and deploys suitable approaches.
Example
NEXT



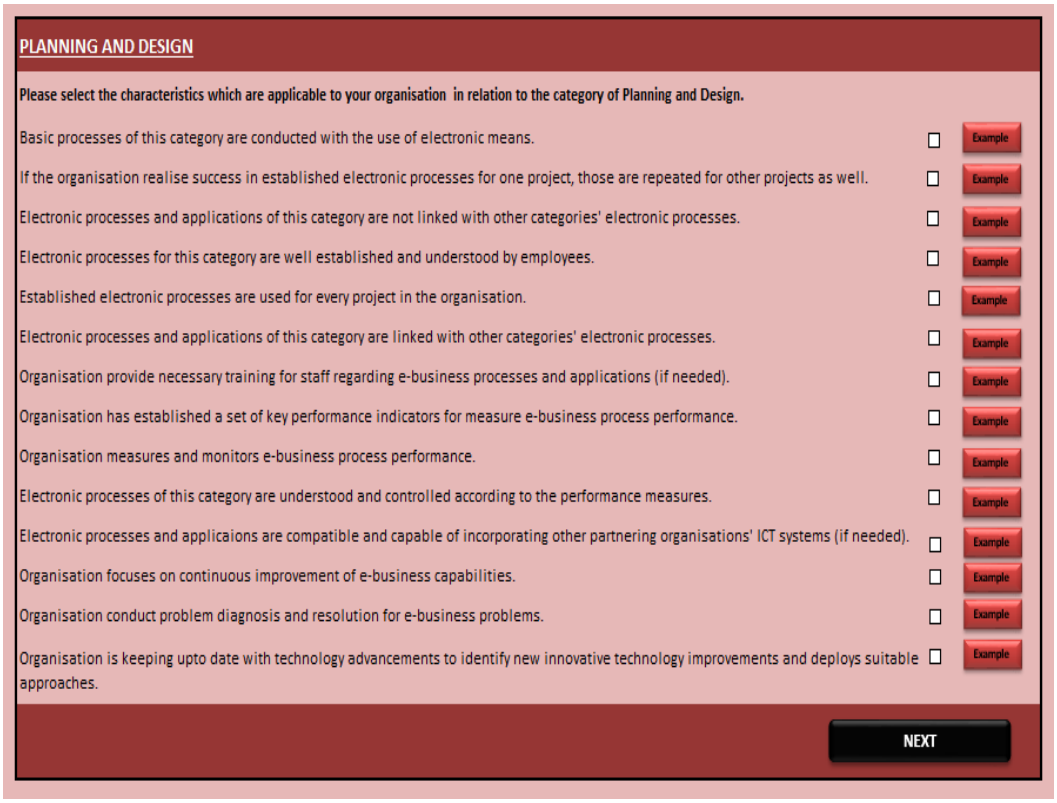
Process Category 2 - PLANNING AND DESIGN

Following processes are categorised under this category.

- **Determine procurement strategy**
- **Determine contract strategy**
- **Prepare initial project programme**
- **Preliminary cost planning**
- **Preparation of concept design**
- **Preparation of developed design**
- **Preparation of technical design**

Are these processes applicable for your organisation?

YES NO

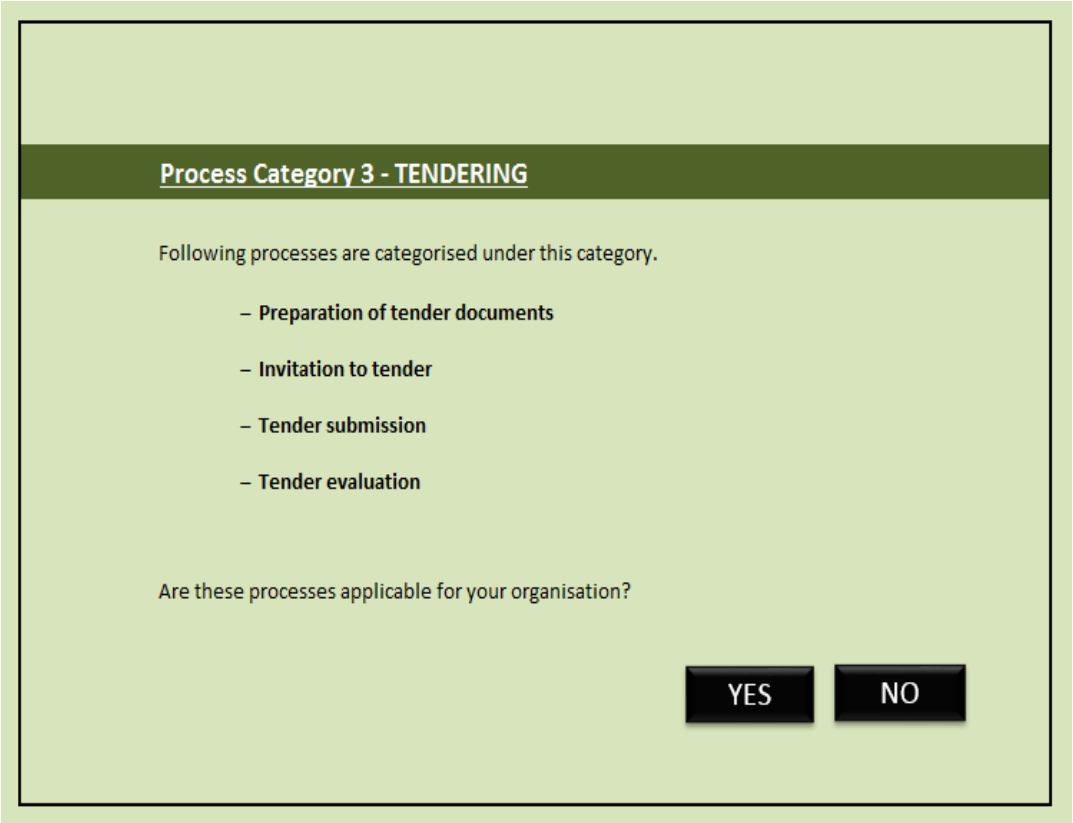


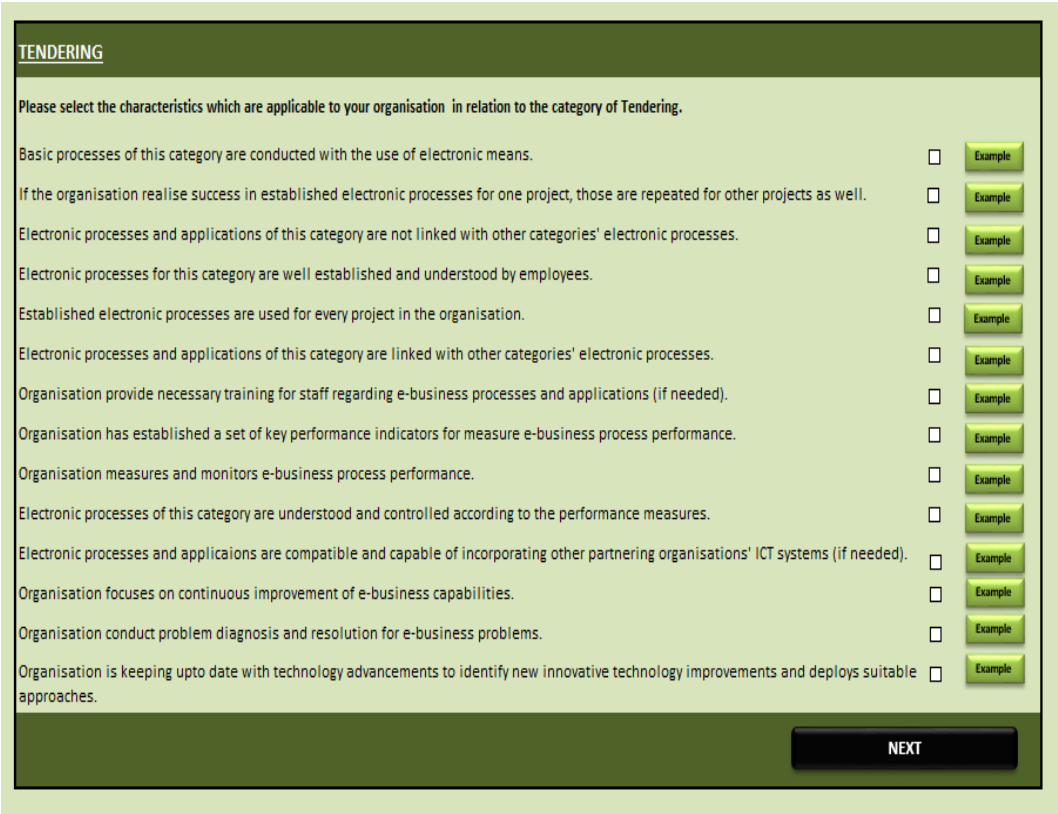
PLANNING AND DESIGN

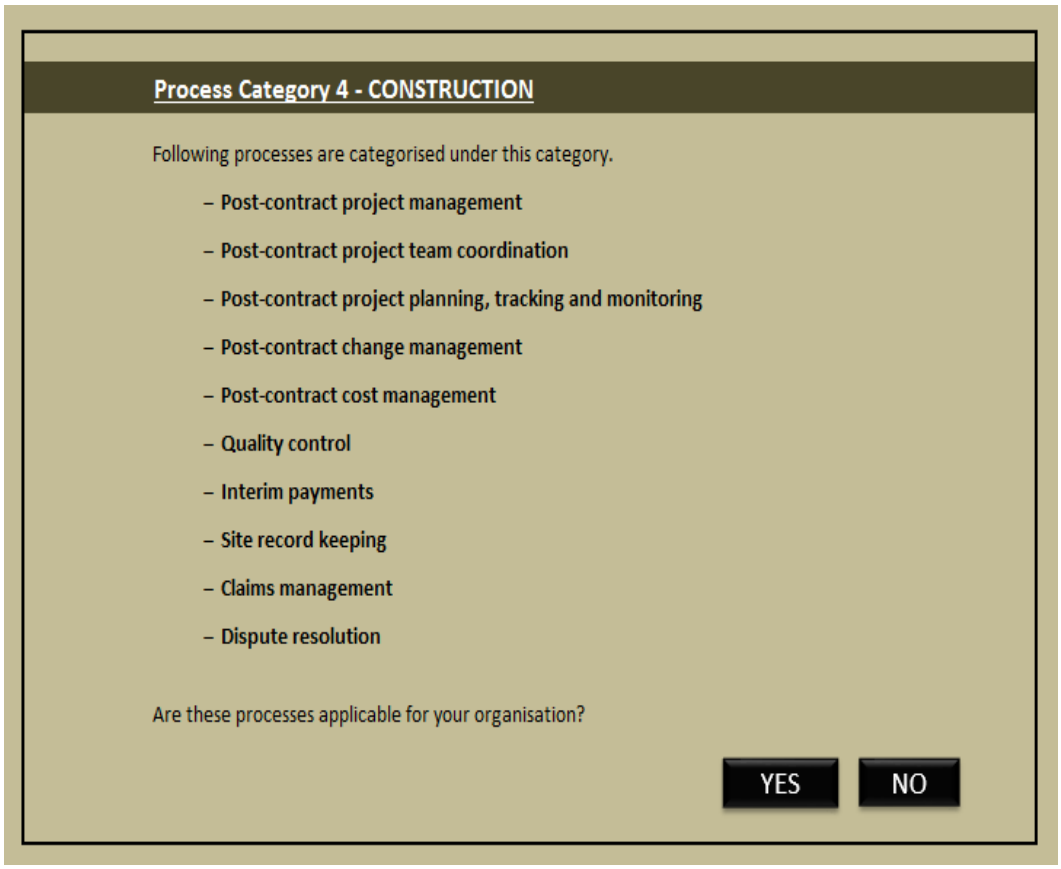
Please select the characteristics which are applicable to your organisation in relation to the category of Planning and Design.

Basic processes of this category are conducted with the use of electronic means.	☐	Example
If the organisation realise success in established electronic processes for one project, those are repeated for other projects as well.	☐	Example
Electronic processes and applications of this category are not linked with other categories' electronic processes.	☐	Example
Electronic processes for this category are well established and understood by employees.	☐	Example
Established electronic processes are used for every project in the organisation.	☐	Example
Electronic processes and applications of this category are linked with other categories' electronic processes.	☐	Example
Organisation provide necessary training for staff regarding e-business processes and applications (if needed).	☐	Example
Organisation has established a set of key performance indicators for measure e-business process performance.	☐	Example
Organisation measures and monitors e-business process performance.	☐	Example
Electronic processes of this category are understood and controlled according to the performance measures.	☐	Example
Electronic processes and applicaions are compatible and capable of incorporating other partnering organisations' ICT systems (if needed).	☐	Example
Organisation focuses on continuous improvement of e-business capabilities.	☐	Example
Organisation conduct problem diagnosis and resolution for e-business problems.	☐	Example
Organisation is keeping upto date with technology advancements to identify new innovative technology improvements and deploys suitable approaches.	☐	Example

NEXT


Process Category 3 - TENDERING
Following processes are categorised under this category.
– Preparation of tender documents
– Invitation to tender
– Tender submission
– Tender evaluation
Are these processes applicable for your organisation?
YES
NO


TENDERING
Please select the characteristics which are applicable to your organisation in relation to the category of Tendering.
Basic processes of this category are conducted with the use of electronic means.
If the organisation realise success in established electronic processes for one project, those are repeated for other projects as well.
Electronic processes and applications of this category are not linked with other categories' electronic processes.
Electronic processes for this category are well established and understood by employees.
Established electronic processes are used for every project in the organisation.
Electronic processes and applications of this category are linked with other categories' electronic processes.
Organisation provide necessary training for staff regarding e-business processes and applications (if needed).
Organisation has established a set of key performance indicators for measure e-business process performance.
Organisation measures and monitors e-business process performance.
Electronic processes of this category are understood and controlled according to the performance measures.
Electronic processes and applicaions are compatible and capable of incorporating other partnering organisations' ICT systems (if needed).
Organisation focuses on continuous improvement of e-business capabilities.
Organisation conduct problem diagnosis and resolution for e-business problems.
Organisation is keeping upto date with technology advancements to identify new innovative technology improvements and deploys suitable approaches.
Example
NEXT



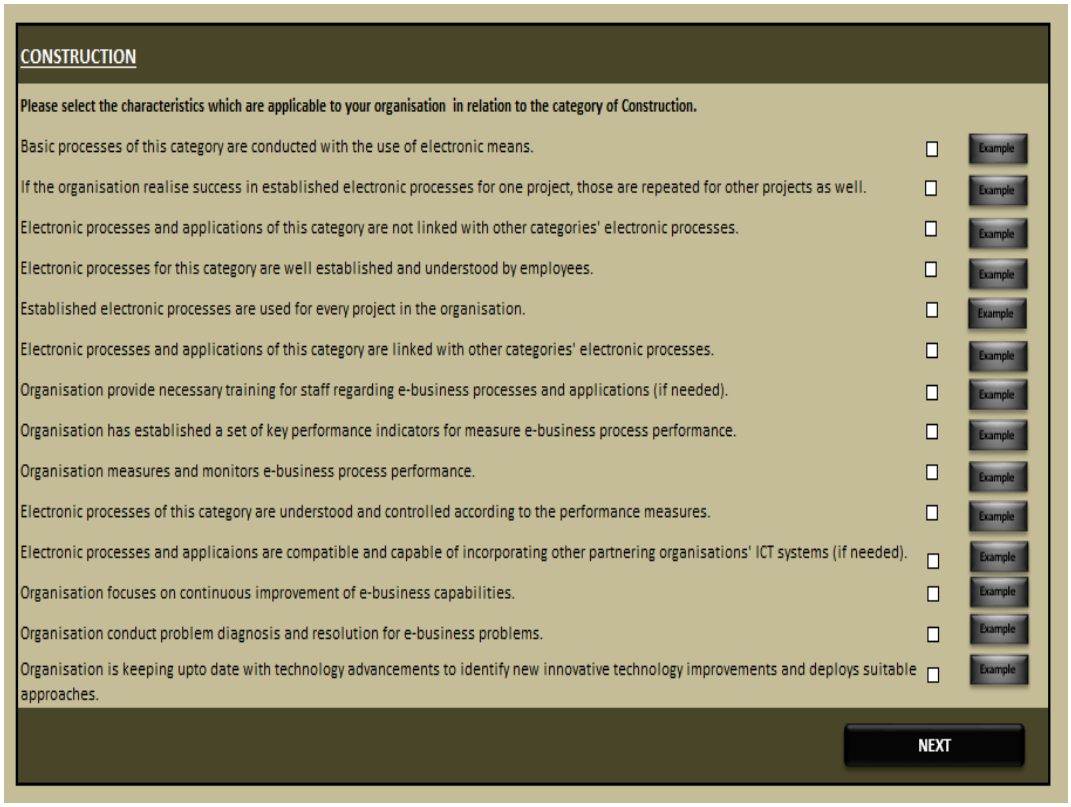
Process Category 4 - CONSTRUCTION

Following processes are categorised under this category.

- Post-contract project management
- Post-contract project team coordination
- Post-contract project planning, tracking and monitoring
- Post-contract change management
- Post-contract cost management
- Quality control
- Interim payments
- Site record keeping
- Claims management
- Dispute resolution

Are these processes applicable for your organisation?

YES NO



CONSTRUCTION

Please select the characteristics which are applicable to your organisation in relation to the category of Construction.

Basic processes of this category are conducted with the use of electronic means.	☐	Example
If the organisation realise success in established electronic processes for one project, those are repeated for other projects as well.	☐	Example
Electronic processes and applications of this category are not linked with other categories' electronic processes.	☐	Example
Electronic processes for this category are well established and understood by employees.	☐	Example
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Electronic processes and applicaions are compatible and capable of incorporating other partnering organisations' ICT systems (if needed).	☐	Example
Organisation focuses on continuous improvement of e-business capabilities.	☐	Example
Organisation conduct problem diagnosis and resolution for e-business problems.	☐	Example
Organisation is keeping upto date with technology advancements to identify new innovative technology improvements and deploys suitable approaches.	☐	Example

NEXT

Process Category 5 - HANDOVER AND AFTERCARE

Following processes are categorised under this category.

- **Project performance review**
- **Update project information**
- **Facilities management**

Are these processes applicable for your organisation?

YES NO

HANDOVER AND AFTERCARE

Please select the characteristics which are applicable to your organisation in relation to the category of Handover and Aftercare.

Basic processes of this category are conducted with the use of electronic means.	☐	Example
If the organisation realise success in established electronic processes for one project, those are repeated for other projects as well.	☐	Example
Electronic processes and applications of this category are not linked with other categories' electronic processes.	☐	Example
Electronic processes for this category are well established and understood by employees.	☐	Example
Established electronic processes are used for every project in the organisation.	☐	Example
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Organisation provide necessary training for staff regarding e-business processes and applications (if needed).	☐	Example
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Organisation measures and monitors e-business process performance.	☐	Example
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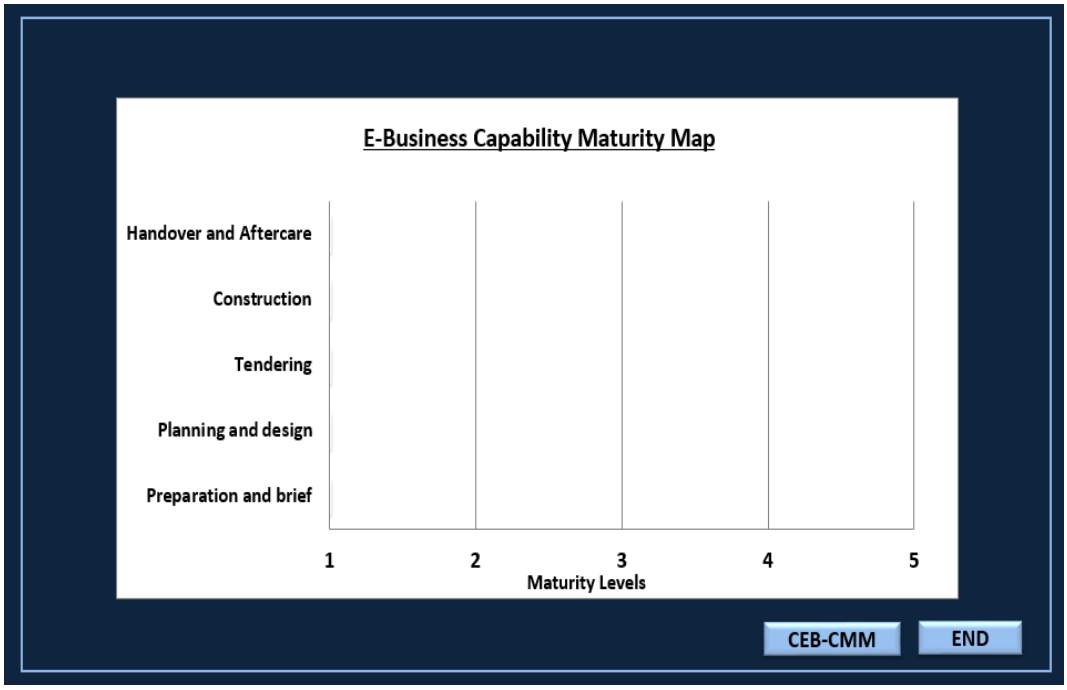
Organisation conduct problem diagnosis and resolution for e-business problems.	☐	Example
Organisation is keeping upto date with technology advancements to identify new innovative technology improvements and deploys suitable approaches.	☐	Example

NEXT


CREATE E-BUSINESS CAPABILITY MATURITY MAP


E-Business Capability Maturity Map
Handover and Aftercare
Construction
Tendering
Planning and design
Preparation and brief
1
2
3
4
5
Maturity Levels
CEB-CMM
END

Thank You for using

Construction E-Business Capability Maturity Model

(CEB-CMM)