A WASTE MINIMISATION FRAMEWORK FOR THE PROCUREMENT OF DESIGN AND BUILD CONSTRUCTION PROJECTS

by

Inoka Shyamal Withana Gamage

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Dedication

This thesis is dedicated to my patents Mr. & Mrs. Withana Gamage

and my wife Mrs. Shanika Ekanayaka

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Abstract

Both construction Waste Minimisation (WM) and construction procurement activities play an effective role in attaining sustainability by giving due consideration to the environment, community and social conditions in delivering built assets. The construction industry has a major impact on the environment, both in terms of resource consumption and increasing waste production. Recent figures published by the UK government reveal that construction and demolition activities produce approximately 32% of total waste generated: three times the waste produced by all households combined. However, the current and on-going research in the field of construction WM and management focuses mainly on onsite waste quantification and management; and stakeholders' source identification. Little research has been undertaken to evaluate the relationship between Construction Procurement Systems (CPS) and construction waste generation. However, literature emphasises the need for research in this context.

This research aims to develop a Procurement Waste Minimisation Framework (PWMF) to enhance WM practices by evaluating the relationship between CPS and construction waste generation. Objectives of the research include: examine construction WM drivers, WM approaches, waste origins and causes; critically review and evaluate current CPS and sustainable procurement practices in the UK; assess the relationship between CPS and construction waste generation; investigate and synthesis Procurement Waste Origins (PWO); examine the most suitable CPS that could potentially embed and sustain WM; develop and validate the PWMF.

This research has adopted a survey research design and mixed methods sequential procedure. Data has been gathered through a cross sectional, self-administered postal questionnaire survey (N=258 distributed, n=65 received) and semi-structured interviews (N=17) with procurement managers and sustainability managers from the top 100 UK contracting organisations and quantity surveyors from the top 100 UK quantity surveying organisations. Data analysis techniques include: descriptive statistics; non-parametric tests; and constant comparative method. The PWMF has developed based on the findings of literature review, questionnaire survey and semi-structured interviews and adopting key concepts of problem solving methodology. The PWMF validation method includes: validation questionnaire (N=8) and follow-up semi-structured interviews (N=6) with procurement managers, sustainability managers and quantity surveyors.

Key findings which emerged from the study include: CPS do have an impact on waste generation in construction; integrated CPS have major potential to integrate WM strategies; four PWO identified (i.e. uncoordinated early involvement of project stakeholders; ineffective communication and coordination; unclear allocation of WM responsibilities; and inconsistent procurement documentation) and associated sub-waste causes; and the developed PWMF enables to diagnose potential waste origins and causes, and WM improvement measures for design and build projects. The study has made recommendations which, if adopted, will lead to significant improvements in WM practices and sustainable procurement practices in construction. The content should be of interest to contractors, clients, and organisations dealing with procurement, waste and sustainability.

Key words: Construction procurement systems, Design and build; Waste minimisation, Procurement waste origins, Sustainability, UK.

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List of Abbreviations

3D	Three Dimensional
4D	Four Dimensional
AEC	Achieving Excellence in Construction
ANOVA	ANalysis Of VAriance
BERR	Department for Business Enterprise and Regulatory Reform
BIW	Business Information Warehouse
BOO	Build, Operate, Own
BOOT	Build, Operate, Own, Transfer
BoQ	Bills of Quantities
BOT	Build, Operate, Transfer
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
C & D	Construction and Demolition
CDE	Construction, Demolition, and Excavation
CFC	Chloro Fluoro Carbon
CIB	International Council for Research and Innovation in Building and Construction
CIOB	Chartered Institute Of Building
CIRIA	Construction Industry Research and Information Association
CPIM	Construction Process Improvement Methodology
CPS	Construction Procurement Systems
CRiBE	Centre for Research in the Build Environment
D & B	Design and Build
DBFO	Design, Build, Finance, Operate
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DRIVE	Define, Review, Identify, Verify, Execute
DTI	Department of Trade and Industry
EC	European Commission
EU	European Union
GC	General Conditions of Contract
GDP	Gross Domestic Product

ICE	Institution of Civil Engineers
IQR	Inter-Quartile Range
ISO	International Organization for Standardization
IT	Information Technology
JCT	Joint Contract Tribunal
KPI	Key Performance Indicator
M & E	Mechanical and Electrical
NEC	New Engineering Contracts
NHS	National Health Service
OECD	Organisation for Economic Co-operation and Development
OGC	Office of Government Commerce
PFI	Private Finance Initiative
PhD	Doctor of Philosophy
PM	Procurement Manager
PPP	Private Public Partnerships
PQQ	Pre-Qualification Questionnaire
PWMF	Procurement Waste Minimisation Framework
PWO	Procurement waste Origins
QS	Quantity Surveyor
QUAL	Qualitative
QUANT	Quantitative
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Charted Surveyors
SM	Sustainability Manager
SPSS	Statistical Package for Social Sciences
SWMP	Site Waste Management Plans
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
US	United States
USA	United States of America
VM	Value Management
WM	Waste Minimisation
WRAP	Waste Resources Action Programme

1. Introduction

1.1. Context

In recent years, sustainable development has become a growing concern throughout the world. Sustainable development is commonly accepted as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). It is widely accepted that the construction industry is a key contributor to socio-economic development as well as a major user of energy and natural resources. The UK (United Kingdom) construction industry is worth over £100 billion a year that accounts for 8% of Gross Domestic Product (GDP) and provides employment for around 3 million workers (BERR, 2008). On the other hand, the UK construction industry accounts for 45% of energy generated, to power and maintain buildings, and 5% to construct them and it is estimated that construction accounts for approximately 40% of all resource consumption and produces about 40% of all waste (CIOB, 2007). Additionally, approximately 50% of the UK's total carbon dioxide emissions come from buildings (BERR, 2008).

Sustainable construction is defined as the creation and responsible management of a healthy built environment based on resource efficient and ecological principles (Kibert, 1994). Therefore, 'Sustainability' is becoming a central concern in the built environment. In this pursuit, it has been targeted to reduce consumption of energy, water and materials, waste and pollution. The means of achieving these areas have been identified as procurement, design, innovation, people and better regulations (BERR, 2008). Moreover, education and training, environmental management systems, green building and design, green procurement, green roof technologies, lean construction, prefabrication and waste management are also considered as major methods for the promotion of sustainable construction (Bakhtiar, 2008). On the other hand, there have been several indicators which have emerged for measuring the effectiveness of sustainable construction. Particularly, it has been noted that the evaluation and correct selection of different Construction Procurement Systems (CPS) is necessary for ensuring better sustainable performance in construction (Ngowi, 1998; Pollington, 1999; Addis and Talbot, 2001; Sterner, 2002; OGC, 2007a). Also, Waste Minimisation (WM) is regularly identified as a key performance indicator of sustainable performance in construction (Spence and Mulligan, 1995; BERR, 2008; Kibert, 2008).

Construction activities during the construction process generate an enormous amount of waste including construction waste, demolition waste and excavation waste. United Nations (UN) reports that Construction and Demolition (C & D) waste typically constitutes from 5% to 15% (in terms of weight) of the solid waste stream of industrialised nations although available data on the quantities of C & D produced in developing countries are very limited (UNEP, 2003). However, estimated quantities of C & D generated fluctuate between 0.05 and 1.0 kg/cap/day (UNEP, 2003). In the past two decades, there have been alarming figures reported from different parts of the world with regard to the amount of total waste generation in construction. For example this was estimated at 9% (by weight) of purchased materials in the Netherlands (Bossink and Brouwers, 1996); facilities floor area from 20% to 30% Kg/m^2 in USA (Peng et al., 1997); 20% - 30% of weight of total site building materials in Brazil (Pinto and Agopyan, 1994); approximately 15%, by volume in Australia (McDonald and Smithers, 1998); and around 25% of all waste generated in the European Union (EU) (Kloek and Blumenthal, 2009).

Moreover, figures published in the UK revealed that construction, demolition, refurbishment and excavation activities produce around 120 million tonnes of waste every year (WRAP, 2007). The UK's C & D waste production is approximately 34% of total waste generated (OECD, 2008), which is beyond the reported average level of waste generation when compared with the UN statistics for an industrialised nation and EU nation. As such, the 'Waste Strategy for England 2007' has identified the construction industry as a major generator of waste in England (DEFRA, 2007a).

Construction waste creates detrimental effects on the environment and health and safety of workers and/or public as it may contain hazardous matters (UNEP, 2003; Esin and Cosgun, 2007). Construction waste also impacts on economic competitiveness due to extra costs for contractors such as loss of profit due to extra overhead costs; delays and extra work on cleaning; lower productivity (Skoyles and Skoyles, 1987; Ekanayake and Ofori, 2000); and payment associated with the disposal of waste in landfills. Therefore, a contractor organisation that does not consider construction WM can be at a 10% disadvantage in tendering for new work (Guthrie and Mallett, 1995). This is also a burden to clients, as they have to bear the costs of waste eventually (Skoyles and Skoyles, 1987). For example, recently, it has been demonstrated that clients can gain benefits tackling construction waste to reduce project costs, typical savings (net of costs) of around 0.2% to 0.7% of construction value (varying by project type) (WRAP, 2010a). Despite the direct effects of construction waste with regard to the environment and economy it may create social development issues such as elevating inflation on construction outputs and health and safety problems.

A seminal report of the UK construction industry highlighted that “there is plenty of scope for improving efficiency and quality simply by taking waste out of construction” (Egan, 1998, p.15). Similarly, there is a consensus in the literature that source reduction is the best and the most efficient method for minimising waste generation and eliminating waste disposal problems (McDonald and Smithers, 1998; Formoso et al., 2002; UNEP, 2003; Esin and Cosgun, 2007; WARP, 2007; Osmani et al., 2008). Moreover, economical, industrial, environmental, and government policy and regulatory drivers significantly impact on the industry practices with regard to WM (Osmani et al., 2008, Jaillon et al., 2009).

Despite the main emphasis of early WM approaches, it appears that most research studies on WM and management mainly focus on the construction stage where these approaches attempt to address the issues after waste generation such as on site waste management plans, on site waste sorting and methods of recycling (McDonald and Smithers, 1998; Poon et al., 2001; Chen et al., 2002). Similarly, a substantial number of studies have attempted to evaluate waste source and causes focussing on all project stages (Gavilan and Bernold, 1994; Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Kulathunaga et al., 2005). However, only a limited number of research studies investigate WM in terms of design stage (Keys et al., 2002; Kelly and Hanahoe, 2008; Osmani et al., 2008; WRAP, 2009).

There is a small but growing body of literature highlighted which argues that procurement stage and CPS could have an influence on construction waste generation (Chandler, 1978; Emmitt and Gorse 1998; McDonald and Smithers, 1998; Ekanayake and Ofori, 2000; Begum et at., 2007). So far, however, little research has emerged with empirical evidence and it has offered contradictory findings about the relationship between CPS and construction waste generation (McDonalds and Smithers, 1996; Jaques, 2000; Johansen and Walter, 2007; Tam et al., 2007a). Thus, it appears that waste generation due to the selected CPS has received little attention in research. Therefore, there is a potential opportunity to further investigate the relationship between CPS and construction waste generation.

1.2. Research Justification

Albeit physical construction waste visible in the construction stage of a project, causes of construction waste relates to construction project life cycle (Osmani et al., 2008). Literature reveals that waste causes are related to three main stages of construction projects: design; tender and contract; and construction (refer to section 3.2.5 for a detailed list of waste causes). For instance,

- Waste causes related to design stage: changes during construction period, selection of low quality materials and products (unclear specifications) (Ekanayake and Ofori, 2000; Poon et al., 2004a; Osmani et al., 2008); detailing errors/lack of information and complexity of reading the drawing (Gavailan and Bernold, 1994; Ekanayake and Ofori, 2000; Osmani et al., 2006; 2008); lack of attention paid to standard sizes available on the market, designers' unfamiliarity with alternative products (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000); and lack of attention paid to dimensional coordination (Ekanayake and Ofori, 2000; Chen et al., 2002; Poon et al., 2004a; Kulathunga et al., 2005).

- Waste causes related to tender and contract stages: errors in contract/tender documents (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Osmani et al., 2008); contract documents incomplete at commencement of construction (Ekanayake and Ofori, 2000; Kulathunga et al., 2005; Osmani et al., 2008); and contract type (e.g. in cost plus contracts, the client bears full cost of materials supply to onsite, hence limited control over material wastages) (Skoyles and Skoyles, 1987; Baldwin et al., 1998) and tendering method (e.g. open-competitive tendering encourages the main contractor to submit bids based only on their own assumptions as to risk and as to errors or omissions in the client/consultant brief)(Skoyles and Skoyles, 1987; Baldwin et al., 1998; WRAP, 2010b).

- Waste causes related to construction stage can be categorised according to onsite activities: procurement (i.e. material) (e.g. materials not in compliance with specification) transportation (e.g. insufficient protection during loading and unloading), material storage (e.g. inappropriate site storage space), material handling (e.g. supply materials in loose form/unpacked supply), on-site management and planning (e.g. planning deficiencies for required material quantities), site operation (e.g. poor craftsmanship/use of wrong materials) and residual (e.g. off-cuts from cutting materials to length) (Gavailan and Bernold, 1994; Bossink and Brouwers, 1996; Ekanayake and Ofori 2000; Kulathunga et al., 2005; Osmani et al., 2008).

Although the above categorisation shows a large number of waste causes are related to design, tender and contract, and construction stages, the contribution of each cause to total construction waste generated is yet unknown.

A number of research approaches are evident in the field of construction WM and management. However, the majority of construction WM and management studies have been given the focus to on-site waste management. For instance, these studies focused on implementing waste management plans during the construction stage (McDonald and Smithers, 1998; Hao et al., 2008; Tam, 2008), waste auditing and assessment (Chen et al., 2002), and waste sorting methods and techniques (Poon et al., 2001). However, both the 'tender and contract', and 'design' stage have been given less consideration in WM and management research. There are only a few recent studies that attempted to investigate design stage waste causes (Keys et al., 2002; Kelly and Hanahoe, 2008; Osmani et al., 2008; WRAP, 2009). Also, those who attempted to target waste causes of 'tender and contract' stage recommended the inclusion of new contractual requirements targeting WM (CRiBE, 1999; Greenwood, 2003; Dainty and Brooke, 2004; Tam et al., 2007a).

Previous studies in WM and management research have noted the importance of an investigation into the impact of CPS and waste generation. These studies emphasised the way that differing CPS may affect the generation of waste on-site as a result of the different interrelationships involved in alternative procurement processes (McDonald and Smithers, 1998); control of waste should be seen as a continuing process at all stages in the life of a building and therefore, there is a need for a re-assessment of building procurement in order to control construction waste, focusing on individual responsibility and communication within 'temporary' procurement teams (Emmitt and Gorse, 1998); and a necessity to 'promote appropriate clients CPS' where contractors' experience in methods and sequence of construction can help in the decision-making process during the design stage to avoid material wastage (Ekanayake and Ofori, 2000). Similarly, Teo and Loosemore (2001) recommended that it is important to explore the impact of procurement and contractual systems upon attitudes towards waste. There is also a growing requirement of using CPS that involves contribution of contractors in the design stage for restraining material waste (Chandler, 1978; Begum et al., 2007; Jorgensen and Emmitt, 2009; WRAP, 2010b).

In response to the above, only a limited number of studies have attempted to investigate the relationship between CPS and waste generation. There is also a clear discrepancy between their findings. Studies conducted by Jaques (2000) in New Zealand, and McDonald and Smithers (1996) in Australia concluded that alternative procurement routes (i.e. allow rigid integration of design and construction processes) did not have any significant advantages over the traditional route (i.e. allow rigid separation of the design and construction processes) in terms of WM. Contradictory to the latter, studies conducted by Johansen and Walter (2007) in Germany and Tam et al. (2007a) in Hong Kong indicated that CPS have an impact on waste generation. Particularly, these two studies suggested that integrated CPS as having high potential to minimise construction waste generation. Interestingly, these studies fail to give an in-depth evaluation of the findings of the relationship between two areas under consideration. However, each of these studies has been undertaken with a different focus and context. Moreover, these studies are based on different CPS that are grounded in different definitions, cultural and legislative structures. Thus, this restricts the opportunity of comparing the outcomes of aforementioned research.

Furthermore, there is no study found in the UK context about the relationship between CPS and waste generation. Recently, Waste Resources Action Programme (WRAP, 2009; 2010a; 2010b; 2010d) developed several guidelines for material WM and attempted to link with key stages of the construction process (e.g. Procurement requirements for reducing waste and using resources efficiently; Cutting the cost of waste in NHS construction; Early contractor procurement - an effective context for designing out waste in construction projects; Designing out Waste: a design team guide for buildings). Yet, these guidelines consider little in the context of CPS. Also, currently, there is no clear evidence in literature relating to WM methods, frameworks or models that directly consider CPS. Thus, this context emphasises a need for thorough investigation to explore the relationship between CPS and construction waste generation, which is the focus of this research.

1.3. Aim and Objectives

The aim of the research is to develop a Procurement Waste Minimisation Framework (PWMF). This framework intends to enhance WM practices in large construction projects that undertake by the UK top 100 contractor organisations (by annual turnover) and quantity surveying organisations (by number of chartered quantity surveyors). Focusing on the relationship of CPS and construction waste generation allows to map waste origins and WM improvement measures specific to procurement systems.

In this pursuit, the following objectives are considered.

1. Examine construction WM drivers, WM approaches, and waste origins and causes.

2. Critically review and evaluate current CPS and sustainable procurement practices in the UK.
3. Assess the relationship between CPS and construction waste generation.
4. Investigate and synthesis Procurement Waste Origins (PWO).
5. Examine the most suitable CPS that could potentially embed and sustain WM.
6. Develop a PWMF.
7. Validate the developed PWMF.

1.4. Research Methodology Overview

The study was undertaken by selecting the best methods and procedures that would effectively address the research problem and objectives. Hence, this study could be placed in the pragmatism knowledge claim position (Creswell, 2007; Tashakkori and Teddlie, 2009). In pragmatism, knowledge claims arise out of actions, situations and consequences rather than antecedent conditions (Creswell, 2003) and concerns with application - 'what works' - and solutions to the problems (Patton, 1990).

The strategies of inquiry for this study involved both quantitative and qualitative strategies. This research approach helps to neutralise the disadvantages inherent in any single research method or cancel the disadvantages of other research methods (Creswell, 2003; Saunders et al., 2007). This research adopted survey strategy and mixed methods sequential procedure in order to induce knowledge from the participants (refer to section 2.6, decision choices for determining a mixed methods strategy of inquiry) where the study begins with a quantitative method with a large sample to investigate broad issues related to the research literature. Subsequently, the research followed a qualitative method by exploring issues raised from the quantitative study in detail with individuals. The sections below outline the data collection and data analysis methods used in this study.

1.4.1. Literature Review

This study aims to examine the relationship between CPS and construction waste generation. In this pursuit, a comprehensive literature survey was conducted using a hierarchical approach. The review focussed on three areas of literature: construction waste; CPS; and the relationship between CPS and construction waste generation. Moreover, a literature review of research methodology was undertaken to adopt a suitable research methodology for this research. The literature searches were based on related terminology encountered while reviewing the publications (e.g. Construction waste, CPS, sustainability, WM). While reading relevant literature, citations within publications were searched to access further relevant publications. Only literature available in English was included in the search. Both printed (i.e. books, journals, theses, reports, databases and magazines) and electronic publications (i.e. the academic information system of Loughborough University, Google scholar and government statistics publishers) were used in the review. The literature review directed to the understanding of the research gap, enabled the research objectives to be set up and refined, and identified information, tools and techniques (i.e. research methods) that could be utilised in the study.

1.4.2. Questionnaire Survey

The literature review revealed a number of issues that needed to be further investigated in terms of the relationship between CPS and construction waste generation: the impact of CPS and the procurement stage on construction waste origins; the identification of key PWO; and potential CPS for WM. A quantitative questionnaire survey was undertaken in order to capture broad views on the relationship between CPS and construction waste generation. The questionnaire contained four key sections: current sustainable construction practices, current CPS practices, impact of CPS on waste generation, and future trends and improvements. Data was collected using a 'cross sectional, self-administered postal questionnaire survey.' Questionnaires (N=258) were distributed among the selected professionals who were involved in the procurement process, from the top 100 UK contracting organisations (i.e. Procurement Managers (PM) and Sustainability Managers (SM)) and top 100 UK quantity surveying companies (i.e. Quantity Surveyors (QS)). The selection of respondents for the study was based on mixed methods purposive sampling strategy (refer to section 2.6 and section 2.7). It was expected that the selected top 100 UK organisations would be experienced in different CPS and engaged in major issues in WM and management and would therefore gain better inputs for the questionnaire.

1.4.3. Semi-Structured Interviews

The questionnaire survey revealed several issues that need to be further examined in the context of the relationship between CPS and waste generation. Therefore, a qualitative study was conducted in order to explore further mainly the critical issues raised from the results of the questionnaire survey. In the questionnaire survey, approximately 58% of respondents reported that 'Design and Build' (D & B) system was selected in most or all current projects of UK top 100 contracting and quantity surveying organisations. Furthermore, the questionnaire results showed that D & B procurement system has an increasing trend in use and is the most suitable procurement system that could potentially embed and sustain WM. Therefore, a particular focus was given to D & B system in order to explore PWO and associated improvement measures to enhance WM practices. The interview template contained four sections: background information; sustainable practices of D & B procurement system and its significance on waste generation; D & B procurement related waste origins and suggestions to minimise construction waste; and further thoughts. Information was gathered through seventeen (N=17) follow up semi-structured interviews. Interview respondents (i.e. PM, SM and QS) were selected from the same respondent sample of questionnaire survey (refer to section 2.8).

1.4.4. Data Analysis

SPSS (Statistical Package for Social Science) software version 16 was used for the questionnaire data analysis. The quantitative findings of the questionnaire survey were reported using descriptive statistics and non-parametric measures. These two methods were adopted in quantitative data analysis due to two reasons: (1) identify and prioritise key issues that need further investigations during follow-up interviews; and (2) the data generated through scaled questions were considered as having ordinal nature (refer to section 2.9.1). Descriptive statistics were used to analyse data which originated from different questions by computing counts (numbers or frequency) and proportions (percentages) as appropriately. Non-parametric measures were used to determine whether responses differed between respondents groups (i.e. PM, SM and QS). Qualitative data that originated from open-ended questions of questionnaire survey and semi-structured interviews were analysed using the Constant Comparative Method (Lincoln and Guba, 1985). This method enabled the constant comparison of different qualitative data to see which concepts they best fit with and helped to find contrasts between theme categories that emerged (refer to section 2.9.2). Qualitative analysis was conducted manually as the amount of data appeared to be manageable without qualitative data analysis software as the investigated issues, to some extent, were distinct from each other. Quantitative data of PWMF validation questionnaire (refer to section 1.4.6) was analysed and presented using descriptive statistics: computing counts and proportions. SPSS software version 17 was used as the data analysis software. The PWMF validation interview data (refer to section 1.4.6) was analysed using the similar approach of the Constant Comparative Method. Microsoft Excel 2003 and Microsoft Visio Professional 2007 were used as aid for data manipulation and data presentation during the data analysis process as appropriate.

1.4.5. Framework Design and Development Methodology

The Procurement Waste Minimisation Framework (PWMF) for D & B projects was developed based on the findings of the literature review, the questionnaire survey and semi-structured interviews. Application of the general problem solving methodology to the findings of the study helped to arrange the findings into a logical sequence, thereby setting the basis for the PWMF development (refer to section 2.10.1). The PWMF diagnoses four PWO clusters (i.e. uncoordinated early involvement of project stakeholders; ineffective project communication and coordination; unclear allocation of waste minimisation responsibilities; and inconsistent procurement documents) and attempts to propose potential improvement measures for WM that originated from the results of the study. The developed PWMF has two levels. The High-level PWMF that is generic, of which vertical access represents four PWO and horizontal access represents procurement WM process (i.e. diagnosis and target parties/areas for improvement measures). The four Low-level PWMF components follow the same logic as the High-level PWMF. Each Low-level PWMF represents a major PWO cluster and diagnosis sub-PWO and specific WM improvement measures. The PWMF contents are linked and guided through a coding system aiming for better comprehension of the framework contents.

1.4.6. Framework Validation: Questionnaire and Interviews

The PWMF validation aimed to refine and examine the appropriateness of the proposed PWMF for D & B projects. The study further helped to explore potential strategies for the proposed PWMF implementation. A combination of quantitative and qualitative study was conducted in order to validate the developed PWMF in terms of its clarity, information flow, and appropriateness and practicality of contents (refer to section 2.10.2). The validation process involved three stages: Pre-validation discussions with seven construction management researchers at Loughborough University; and eight validation questionnaires (N=8) and six follow up semi-structured interviews (N=6) with selected PM, SM and QS. The respondent sample was drawn from those who were previously involved in the study for questionnaire survey and semi-structured interviews. The proposed PWMF was further refined and presented based on the PWMF validation results.

Figure 1.1 illustrates a summary of the adopted research methods and data analysis process and the outcomes of each stage of the study.

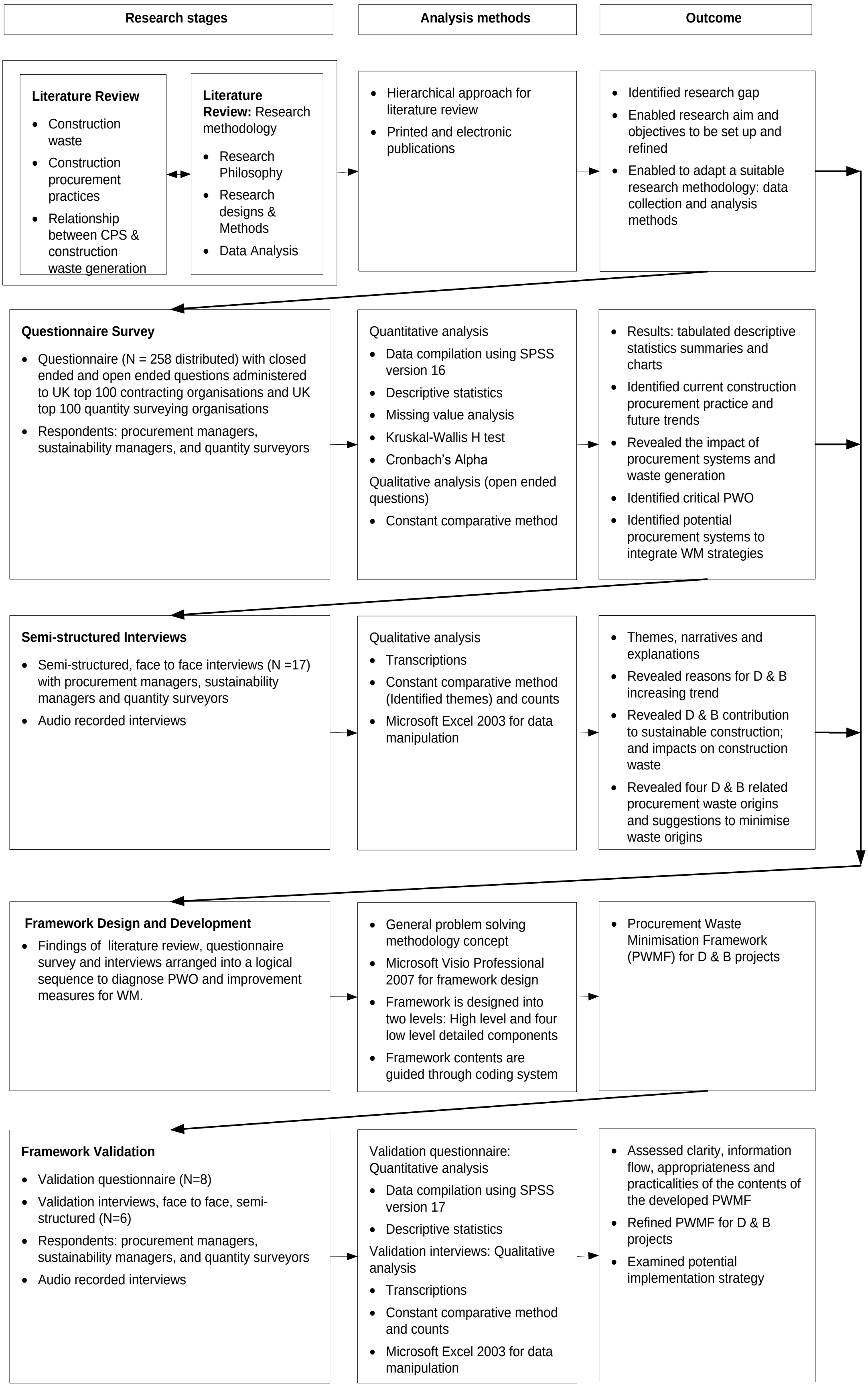

Figure 1.1. Research process: stages, analysis methods and outcomes

1.5. Contribution of the Research

This research has explored the relationship between CPS and construction waste generation thereby developed a PWMF for large scale D & B construction projects that undertake by the UK top 100 contractor organisations and quantity surveying organisations. Thus, the outcome of research allows for an enhanced understanding of how CPS impacts on construction waste generation. The specific contributions of this research as follows.

- The current study has provided a novel perspective for construction WM research emphasising that it cannot ignore the influence of selected CPS and its effects on waste origins of design, tender & contract, and construction.

- The findings of the study contribute to literature on WM and CPS to enhance sustainable construction practices;

    - the study has identified four PWO (i.e. uncoordinated early involvement of project stakeholders; ineffective communication and coordination; unclear allocation of WM responsibilities and inconsistent procurement documentation) and associated sub-waste origins; and

    - the research has proposed several measures to minimise identified four PWO and their sub-waste origins.

- The findings have implications for the development and implementation of guidelines, legislation, and policies for WM and sustainable procurement; and potential to incorporate with standard documents in practice (e.g. RIBA Plan of Work, JCT contract conditions).

- The study has forwarded a PWMF for projects procured using D & B procurement system. The PWMF provides the basis that need for WM within D & B projects guiding through not only to diagnose potential waste causes but also suggesting potential measures for WM;

    - the PWMF contents have positive implications towards early involvement of project stakeholders, effective communication and coordination, clear allocation of WM responsibilities and enhanced procurement documentation; and

  - the PWMF tends to support the effective project management process.

- The current study contributes to present debates of suitability of mixed methods research by demonstrating its application in construction management.

1.6. Thesis Structure

By using a hierarchical structure, the thesis is organised as follows. The structure of the thesis is made up of eight chapters.

Chapter 1 presents an overview to the thesis. The chapter begins by describing the context of the research and states the aim and objectives of the study. Subsequently, an overview of the research methodology and key contribution of the research are presented. The chapter ends with a guide that provides organisation of the thesis.

Chapter 2 presents the research methodology and starts with an overview of research methodology that covers research philosophy, research strategies, and research methods. Consequently, the chapter describes the adopted research methodology of the study and it covers: research methods (i.e. questionnaire survey, semi-structured interviews, PWMF development and validation methods); sampling and administration of research method processes (e.g. questionnaire administration); and data analysis techniques.

Chapter 3 presents a critical review of literature, which sets out the context of the research. The chapter comprises three main sections: construction waste; construction procurement; and the relationship between CPS and construction waste generation.

Chapter 4 presents the results of the questionnaire survey. The chapter covers survey background information, current construction procurement practices, relationship between waste generation and CPS, and future trends and improvements. The chapter also reports potential CPS to integrate WM strategies. A summary of the chapter is presented including emerging issues and themes.

Chapter 5 presents interview results and, provides analysis of interviews including background information, design and build procurement practices: trends and contribution to sustainability, impact of D & B procurement system on waste generation, PWO and suggestions to minimise waste origins.

Chapter 6 presents the PWMF design, development and validation. The chapter discusses the PWMF development methodology; describes the structure of the framework and its key components. The chapter presents the PWMF validation results emanating from validation questionnaire and semi-structured interviews. The chapter also provides a summary of the key improvement measures that emerged, outlines key actions taken to amalgamate measures proposed and potential implementation strategies for the PWMF.

Chapter 7 presents a discussion of the emerging themes of the research within the context of literature.

Chapter 8 presents the study's conclusions and recommendations. The chapter includes a summary of the research findings, specific contributions to the knowledge, recommendations, and further research. The chapter also acknowledges the limitations of the research.

2. Research Methodology

2.1. Introduction

This chapter outlines the way in which the work was carried out in order to achieve the study's aim and objectives. The first three sections of the chapter consider the literature on the philosophical perspectives of research, an overview of research strategies, and an overview of research designs and methods. Each of these sections sets the context in order to construct a research methodology for the study.

Subsequently, the chapter presents the adopted research methodology for the study and discusses the study's underlying philosophical assumptions and their stance, and research design and methods. The chapter then discusses data collection: questionnaire survey, semi-structured interviews, and framework development and validation. Each of these sections describes how the research process was undertaken to collect the required data: instrument design and testing, strategy for sampling respondents, and administrative processes of data collection. The chapter also presents the adopted process for data analysis, which contains two sections: quantitative data analysis and qualitative data analysis.

2.2. Research Philosophy

The term 'research' refers to a careful and systematic process of inquiry to find answers to problems of interest (Tan, 2002). Specifically, a research study's purpose is to investigate problem(s) systematically and thoroughly aiming to describe, predict, explain or interpret phenomena. Therefore, research is known as a form of systematic enquiry that contributes to knowledge and good research needs to be systematic, organised, critical, analytical, and able to communicate findings effectively (Sekaran, 2003). Consequently, a 'scientific mode of enquiry' is essential for finding answers to problems of interest. However, 'scientific modes of inquiry' refers to the fact that there is more than one-way of doing science (Tan, 2002) and thus this links to the debate of methodology (i.e. the science of finding out) (Babbie, 2007). Although, the terms 'method' and 'methodology' could be seen as related concepts, the meanings of those terms are different. Thus, 'methods' of research are the actual techniques or procedures used to gather and analyse data related to some research question or hypothesis (Blaikie, 1993). This includes techniques or procedures such as engaging people in conversation, getting participants to fill out questionnaires, document surveys, getting records and observing behaviour. The term 'methodology' is defined as a particular procedure or set of procedures (Creswell, 1998). Moreover, it is the analysis of how research should or does proceed (Blaikie, 1993). Specifically, formation of methodology addresses three questions (Creswell, 2003):

- What knowledge claims are being made by the researcher?
- What strategies of inquiry will inform the procedures?
- What methods of data collection and analysis will be used?

Therefore, methodology does not refer to simply a set of methods; rather it refers to general philosophies of science and detailed research methods (Saunders et al., 2007). In particular, methodology is comprised of methods, the technical practices used to identify research questions, collect and analyse data and present findings, and the sets of conceptual and philosophical assumptions that justify the use of particular methods (Payne and Payne, 2004). According to the concept of the 'research onion', methodology includes philosophy, approaches, strategies, methods choices, time horizons, data collection and analysis techniques and procedures (Saunders et al., 2007).

Easterby-Smith et al. (2002) noted there are at least three reasons for understanding the philosophical issues of a research. First, it can help to clarify research designs. Second, knowledge of philosophy can help the researcher to recognise which design will work and which will not. Third, knowledge of philosophy can help the researcher to identify and even create designs that may be outside the researchers past experience. In addition to that, research philosophies guide the researcher to consider research constraints of different subjects or knowledge structures (Easterby-Smith et al., 2002). Therefore, the aforementioned reasons emphasise the importance of knowledge of philosophical views in order to address different issues in research.

In reviewing literature related to research methods, there are two main philosophical perspective traditions that can be identified: positivism and interpretivism. These traditions are based on different stances of ontology, epistemology, and axiology. The root definition of ontology is "the science or study of being" (Blaikie, 1993, p.6) and it refers to nature of reality (Tan, 2002; Creswell, 2007; Fellows and Liu, 2008). Epistemology is "the theory or science of the method or ground of knowledge" (Blaikie, 1993, p.6) that is how the researcher knows reality (Tan, 2002; Creswell, 2007). Axiology refers to the role of values in the research. This involves values, ethics, and belief systems of a philosophy; and also involves assumptions about the value that the researcher attaches to the knowledge (Creswell, 2007). Furthermore, axiology is a brand of philosophy that studies judgements about value (Saunders et al., 2007).

In the debate on reality, positivists (objectivists) argue that reality exists independent of the mind and they tend to stress objective knowledge, empirical regularities and deductive tests (Tan, 2002). It is also assumed that investigation is value free; therefore, the researcher remains detached, neutral and objective (Darke et al., 1998). Conversely, interpretivists (or subjectivists) believe reality depends on the perspective of a person or the subject. More specifically, this approach is based on an ontology in which reality is subjective: a social product constructed and interpreted by humans as social actors according to their beliefs and value systems (Darke et al., 1998). Therefore, interpretivism suggests that the research is value-laden (Silverman, 1998; Healy and Perry, 2000). Moreover, subjectivists believe that there is no concept of 'the truth'. Instead, they believe in the concept of 'multiple truths'. Consequently, subjectivists tend to use the interpretive, qualitative or idiographic approach to science (Tan, 2002). Moreover, subjectivism rejects the notion of value free research and is not concerned with the repeatability of an explanation (Darke et al., 1998). Having outlined the two main philosophical traditions underpinning research, it is notable that there is literature evident for other philosophical perspectives: for instance, realism, functionalist, and pragmatism indicated in the idea of the research onion (Saunders et al., 2007).

Although the positivist and interpretivist approaches outlined above have been traditionally considered as containing irreconcilable differences, Lee (1991) has suggested that it is possible to combine the both positivist and interpretivist approaches and provide different views of the same phenomena. The comprehensiveness of real-world situations means one philosophical stance is unlikely to present a complete view of a certain issue. Moreover, different philosophical stances provide different aspects of the real world. For instance, Minger (1997, p.9) viewed the adaptation of a specific philosophical tradition as viewing the world through "a particular instrument such as a telescope, an X-ray machine or an electron microscope". This example highlights that while each of these instruments reveals certain features, it is blind to other features. Thus, Minger (1997) viewed that it is wrong to accept completely the assumptions of one paradigm. Therefore, these arguments support multiple views of reality (multi - paradigm research).

In line with the latter, the literature identifies the philosophical stance of 'pragmatism' (Murphy, 1990; Patton, 1990; Creswell, 2007; Saunders et al., 2007; Tashakkori and Teddlie, 2009). Pragmatism is a worldview that arises out of actions, situations and consequences rather than antecedent conditions (Creswell, 2009). Moreover, pragmatists focus on the outcome of the research and a concern with applications - 'what works' - and solutions to problems (Patton, 1990). Therefore, pragmatists take the view that the important aspect of research is the problem being studied and the questions being asked about particular problems rather than merely a focus on methods (Saunders et al., 2007; Creswell, 2009). According to Cherryholmes (1992) and Murphy (1990) (cited in Creswell, 2007, p.23) basic directions to pragmatism are as follows:

- no commitment to any one system of philosophy and reality;
- individual researchers have a freedom of choice. They are 'free' to choose the methods, techniques, and procedures of research that best meet their needs and purposes;
- pragmatists do not see the world as an absolute unity. In a similar way, mixed methods researchers look at many approaches to collecting and analysing data rather than subscribing to only one way (e.g. qualitative or quantitative);
- truth is what works at the time; it is not based in a dualism between reality independent of the mind or within the mind;
- pragmatist research looks to the 'what' and 'how' to research based on its intended consequences-where they want to go with it;
- pragmatists agree that research always occurs in social, historical, political and other contexts; and
- pragmatists believed in an external world independent of mind as well as those logged in the mind and the need to stop asking questions about the reality and laws of nature.

Consequently, pragmatism applies to mixed methods research in that inquiries draw liberally from both quantitative and qualitative assumptions (Creswell, 2007; Saunders et al., 2007; Tashakkori and Teddlie, 2009). However, as the philosophical underpinning for mixed methods studies, Tashakkori and Teddlie (1998) and Patton

(1990) conveyed the importance for focusing attention on the research problem and then using a pluralistic approach in order to drive knowledge about the problem. Creswell (2007, p.23) provides a summary of pragmatist perspective research: "In practice, the individual using this (pragmatism) worldview use multiple methods of data collection to best answer the research question, will employ both quantitative and qualitative sources of data collection, will focus on the practical implication of the research, and will emphasise the importance of conducting research that best addresses the research problem".

The choice of research methods in management and social sciences embodies the researcher's assumptions (i.e. philosophical perspective) about the nature of the social world, the nature of the knowledge to be obtained and the methods of gaining knowledge (Creswell and Clerk, 2007; Saunders et al., 2007). These philosophical assumptions are important, because they direct the researcher to select the most appropriate research methods for a context. Two main philosophical perspectives; positivism and interpretivism are traditionally and respectively, connected with quantitative and qualitative research methods while multi-paradigm research and pragmatism perspectives emphasise the possibility of using multi or mixed methods in research.

2.3. Research Strategies

Research strategies connect the researcher to specific approaches and methods for collecting and analysing data (Denzin and Lincoln, 2000). Research strategies may be categorised as quantitative methods, qualitative methods, and combined qualitative and quantitative methods. Subsequent sections provide an overview to each of these research strategies.

2.3.1. Quantitative Strategy

Quantitative approaches tend to be inclined towards positivism and seek to gather factual data, to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously (Fellows and Liu, 2008, p.27). Hence, quantitative research is "empirical research where the data is in the form of numbers" (Punch, 1998, p.4). Often, the purpose of quantitative research is to verify a theory rather than develop one. Thus, quantitative research tends to employ a deductive research approach that entails the development of a conceptual and theoretical structure prior to its testing through empirical observation (Gill and Johnson, 2002). In this approach, the researcher may have deducted a new hypothesis by analysing and synthesising ideas and concepts already present in the literature (Remenyi et al., 1998). Thus, research hypotheses and/or questions may often be grounded in a theoretical framework based on literature reviews of past studies and is used to search for causal relationships between different variables.

Robson (2002) noted five sequential stages through which deductive research progresses: deducting a hypothesis from the theory; expressing the hypothesis in operational terms; testing the operational hypothesis; examining the specific outcome of the inquiry; modifying the theory in light of the findings (if necessary). The deductive approach only requires measurement of specific concepts in hypothesis (Blaikie, 2000). Thus, in most cases, a hypothesis is tested by collecting quantitative data targeting a large population sample. This is not to say that a deductive approach may not use qualitative data (Saunders et al., 2007). Creswell (1994) also noted that quantitative research generally involves the collection and analysis of data using statistical procedures. In this regard, experiments and surveys are generally the most commonly used research designs used to gather quantitative data. At the end of the study, the results are expected to be generalised to the population (Blaikie, 2000; Robson, 2002; Saunders et al., 2007). Thus, in a quantitative deductive research approach, research is expected to pursue the principles of scientific rigour, and the researcher should be an independent observer.

2.3.2. Qualitative Strategy

Qualitative approaches seek to gain insights and to understand people's perception of the world (Fellows and Liu, 2008). Thus, qualitative research is "empirical research where the data is not in the form of numbers" (Punch, 1998, p.4). Qualitative research tends to employ an inductive approach, which is opposite to the approach of deduction; it is the movement from data or facts to theory. The inductive approach is likely to be concerned with the context of specific events. Thus, a study may be based on a small sample of respondents, but may need a different kind of data in order to establish different views of phenomena and be more likely to work with qualitative data (Easterby-Smith et al., 2002). The inductive approach requires a collection of large quantities of data; possibly the measurement of many concepts in order to justify the generalisation. Blaikie (2000) characterised four main stages of an inductive approach: all facts are observed and recorded without selection; collected facts are analysed, compared and classified without using hypotheses; from the analysis, generalisations are inductively drawn as to the relation between the facts, and generalisations are subjected to further testing. However, generalisation of the theory will not be expected with the inductive approach due to the context specific nature of the research inquiry (Saunders et al., 2007) as “the theory that is inductively developed will be fitted to the data, thus more likely to be useful, plausible and accessible to practitioners” (Gill and Johnson, 2002, p.40). Creswell (2007) noted five approaches to qualitative research: narrative research, phenomenology, grounded theory, ethnography and case study. In a qualitative-inductive approach, the independence of the observer is not strictly observed, instead the researcher is considered to be part of the research process.

2.3.3. Combining Quantitative and Qualitative Research Strategies

Although research approaches are divided into two main groups: qualitative and quantitative, the literature stressed the importance of not considering them as two rigid divisions and argues that combining qualitative and quantitative methods is possible, as it enables the researcher to gather benefits from both approaches (Gill and Johnson, 2002; Yin, 2003; Bryman, 2006; Tashakkori and Teddlie, 2009). Philosophical assumptions underpinning qualitative and quantitative strategies represent two extremes (discussed in section 2.2 and section 2.3), thus in practice research problems rarely fit completely with either of the above. Therefore, employing mixed methods, research problems can be understood better rather than using one (Amaratunga et al., 2002; Bryman, 2006; Stewart and Cash, 2006; Creswell and Clark, 2007). Consequently, research stands to benefit from philosophical assumptions underlying both qualitative and quantitative strategies. Combining qualitative and quantitative methods provides an opportunity to collect data that is suited to the research question rather than being restricted to methods associated with one strategy. Also, combining two strategies enables researchers to benefit from the advantages associated with each strategy with the possibility of avoiding the weakness of each (Morgan, 2006).

Miles and Huberman (1994) suggested four possible research designs that employ research methods associated with both strategies as shown in Figure 2.1. In the first research design, qualitative and quantitative data is collected together at the same time. In the second research design, a multi-wave survey is conducted parallel to continuous fieldwork. The third and fourth research designs are focused on studies one after another to collect data. Thus, the third research design involves qualitative exploration at the beginning and subsequently leads to a study to collect quantitative data such as the development of a questionnaire and thereafter again a qualitative study to confirm the findings of preceding stage(s). The final research design is the reverse appeal of the third design where the sequence of research design is quantitative, qualitative and quantitative respectively.

Combining qualitative and quantitative approaches could also be done at different stages of a research; data collection, data analysis or data interpretation stages (Creswell, 2003; Bryman, 2006; Bryman, 2007). This is often referred to as "triangulation" which is broadly defined Denzin (1978, p.291) as "the combination of methodologies in the study of the same phenomenon". Thus, it can take the form of data triangulation (i.e. use of several sampling strategies), investigator triangulation (i.e. use of more than one researcher to gather data and interpret data), theoretical triangulation (i.e. use of more than one theoretical position in interpreting data) and methodological triangulation (i.e. use of more than one method to collect data) (Denzin, 1970; Bryman, 2007).

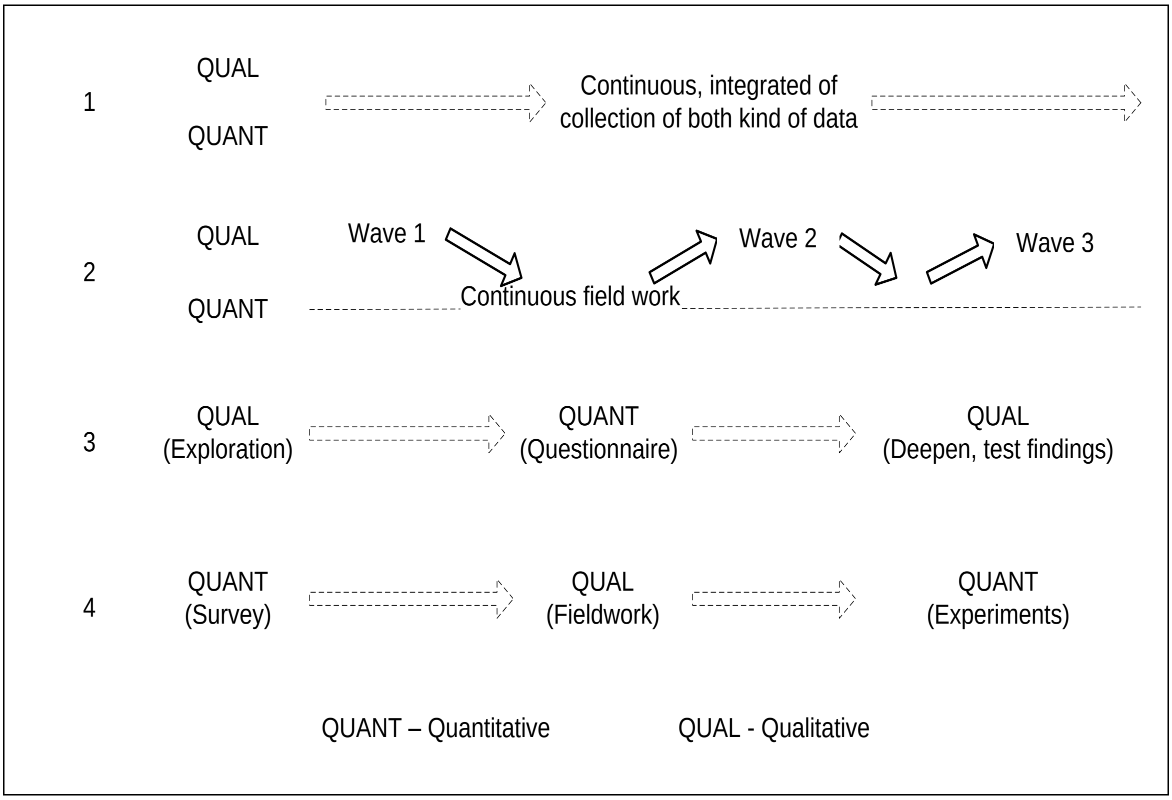

Figure 2.1. Illustrative designs linking qualitative and quantitative data

(Miles and Huberman, 1994, p.41)

The major limitation of mixed method research is the difficulty of integrating qualitative and quantitative aspects of research. Moreover, Bryman (2007) provided several amplifications of lack of integration of qualitative and quantitative research findings drawing from the use of mixed methods; these are as follows:

- quantitative findings and qualitative findings may target different audiences; an author's preference for one method over the other may lead to an emphasis on findings relating to the preferred method;
- quantitative and qualitative components of research often have different timelines for analysis and writing, therefore making integration difficult;
- the basic assumptions underlying both the quantitative and the qualitative method are seen to be fundamentally different, reconciling the two sets of assumptions can be difficult;
- time and other resources needed in order to conduct a mixed methods research may be difficult to obtain;
- competence in different techniques of data collection and analysis is necessary if maximum integration of qualitative and quantitative findings is to be achieved; and
- the nature of the data obtained in research that adopts a mixed methods approach may suggest more compelling results of the qualitative component than the quantitative component and vice versa.

The above discussed research strategies (i.e. qualitative, quantitative and mixed methods) have differences mainly in terms of their philosophical stance, research designs, data collection methods and analysis techniques. Therefore, these strategies form three methodological traditions. Table 2.1 presents key contrasts among the three methodological traditions based on eleven dimensions (Tashakkori and Teddlie, 2009, p.22).

Table 2.1. Dimensions of contrast among the three methodical traditions

(Tashakkori and Teddlie, 2009, p.22)

Dimension of contrast	Qualitative position	Mixed methods position	Quantitative position
Methods	Qualitative	Mixed methods	Quantitative methods
Researchers	QUALs	Mixed methodologists	QUANs
Paradigms (philosophical stance)	Constructivism (and variants)	Pragmatism; transformative perspective	Post positivism positivism
Research questions	Qualitative research questions	Mixed methods research questions	Quantitative research questions; research hypotheses
Form of data	Typical narrative	Narrative plus numeric	Typically numeric
Purpose of research	(often exploratory) plus confirmatory	Confirmatory plus exploratory	(often confirmatory) plus exploratory
Role of theory; logic	Grounded theory; inductive logic	Both inductive and deductive logic; inductive-deductive research cycle	Rooted in conceptual framework or theory, hypothetico-deductive model
Typical studies or designs	Ethnographic research designs or others (case study)	Mixed methods designs, such as parallel and sequential	Correlational; survey; experimental; quasi experimental
Sampling	Mostly purposive	Probability, purposive and mixed	Mostly probability
Data analysis	Thematic strategies: categorical and contextualising	Integration of thematic and statistical; data conversion	Statistical analysis; descriptive and inferential
Validity/trust worthiness issues	Trustworthiness; credibility; transferability	Inference quality; inference transferability	Internal validity; external validity

2.4. Research Designs and Methods

One of the most significant phases of a research project is to decide on the way in which the research will be carried out (data collection) and the data to be analysed. Tan (2002) attempted to define the research design as the plan for getting from the research question to the conclusions. Specifically, a research design sets out guidelines that link together the elements of methodology adopted for a study; relating the paradigm to the research strategy and then the strategy to the methods for collecting empirical data (Denzin and Lincoln, 2000, p.22). Thus, the term 'research design' describes the ways in which the data will be collected, analysed in order to answer the research questions posed and so provide a framework for undertaking the research (Bryman and Bell, 2003, p.32). Further, Bryman (2004) stated that a choice of research design reflects decisions about the priority being given to a range of dimensions of the research process such as:

- expressing a causal connection between variables;
- generalising to larger groups of individuals than those actually forming part of the investigation;
- understanding behaviour and the meaning of that behaviour in its specific social context; and
- having a temporal (i.e. over time) appreciation of social phenomena and their interconnections.

On the other hand, research methods can be identified as techniques for data collection. They can involve a specific instrument such as the completion of questionnaire, a structured interview schedule, observation techniques analysis of past documents and simulation. Thus, research methods can be associated with different kinds of research design.

2.4.1. Research Designs

Several authors introduce research designs with different terminologies. For instance, Bryman (2004) stated five research design types: experimental, cross sectional, longitudinal, case study and comparative study. Saunders et al. (2007) named 'research design' as 'research strategies' within the concept of the research onion, which comprises seven strategies: experiment, survey, case study, action research, grounded theory, ethnography, archival analysis under the spectrum of research deductive and inductive research approaches. On the other hand, Tan (2002) noted six common types of research designs: case studies, surveys, experiments, co-relational research, causal-comparative research and historical research. Similarly, Yin (2003) considered five research design types: experiment, survey, archival analysis, history and case study. The latter author stated that each design has peculiar advantages and disadvantages depending on three conditions: the type of research question, the amount of control that the investigator has over actual behaviour events; and the focus on contemporary as opposed to historical phenomena. Saunders et al. (2007) noted that no research strategy/design is inherently superior or inferior to any other and often allocating those from a deductive approach to an inductive approach is simplistic.

However, the same author mentioned that the choice of research strategy/design will be guided by research question(s), objectives, the extent of existing knowledge, the amount of time and other resources available and philosophical underpinnings. Yin (2003) noted that each of the research designs can be used for exploratory, descriptive and explanatory research. Furthermore, strengths and weaknesses of the various research designs may overlap. Thus, it is necessary to consider all research design strategies in an inclusive and pluralistic fashion and to draw on them according to a given situation. Table 2.2 summarises various research designs discussed in the literature. The forthcoming section introduces types of research designs: experiment, survey, case study and other research designs.

2.4.1.1 Experiments

Generally, experiments are undertaken on a sample of the population and within a controlled environment in order to test whether there is causal relationship between the variables under investigation (Baker, 2001). Indeed, experiments are known as the scientific method and with its practice of formulating and testing hypotheses through carefully designing and testing (Blaxter et al., 2001). Experiments may be suitable in order for exploratory and explanatory research to answer ‘how’ and ‘why’ questions (Saunders et al., 2007). However, experimental design could not be feasible in many management research studies due to several reasons such as ethical reasons – working with people, willingness to participate in experiments, difficulties in arriving at a representative sample, or it may be costly and there may be complexities associated with experiment designs and conducting environments (Saunders et al., 2007).

2.4.1.2 Survey

A survey is a systematic method of collecting primary data based on a sample (Tan, 2002). It is considered to be a very popular and common strategy in business and management research and is conducted on a wider population using economical data collection methods such as questionnaires (Saunders et al., 2007). Usually, the purpose of a survey is not to consider a specific case in depth but to capture the main characteristics of the population at any instant, or to monitor changes over time (Tan, 2002). Surveys are appropriate in terms of answering the ‘who’, ‘what’, ‘where’, ‘how much’, ‘how many’ questions in research. Furthermore, surveys provide a basis for the following: suggesting possible reasons for a particular relationship between variables; producing models of these relationships; and generating findings that are representative of the population, lower cost with representative sampling (Saunders et al., 2007). The survey design allows the collecting of both quantitative and qualitative data depending on the data collection method. However, in most circumstances data collected through surveys provides opportunities using statistical analysis. The main weaknesses of surveys are as follows: they do not demonstrate causality (particularly opinion survey) (Fink, 2010); there are problems over issues of truthfulness and accuracy due to difficulties in checking first hand understanding of respondents (Blaxter et al., 2001); and progress could be delayed due to dependency on others' responses for information (Saunders et al., 2007). However, these weaknesses can be minimised by a proper survey design and administration. In designing a survey, data may be collected by employing a number of methods: questionnaires, structured interviews and structured observations.

2.4.1.3 Case study

A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009). It highlights the fact that case studies can be useful when the boundaries between the phenomenon being studied and the context within which it is being studied are not clearly evident. In addition, case studies can be used to test theories, guided by a hypothesis (Tan, 2002). Thus, case studies allow to find answers to 'why', 'how' and 'what' types of research questions. Further, case studies are most often used in explanatory and exploratory research (Gerring, 2007; Saunders et al., 2007). Data can be collected using a number of methods which may include; interviews, observations, documentary evidence, and questionnaires. A distinctive feature of the case study or between several case studies is the use of multiple sources of evidence to examine the case holistically (Gerring, 2007; Yin 2009) and in-depth study of the case. Thus, triangulation is also possible within case studies (Yin, 2009). The weaknesses of the use of case studies are: the complexity of a case can make analysis difficult; difficulties in assessing where the context begins and ends (Blaxter et al., 2001); and difficulties in generalising findings (Gerring, 2007; Yin, 2009).

2.4.1.4 Other research designs

There are a number of other research designs evident in research such as comparative design, grounded theory, ethnography and archival analysis. Comparative research designs seek to identify, analyse and explain similarities and differences that have occurred between two or more groups/societies (Hantrais, 1995). Grounded theory is a strategy whereby data is collected without an initial theoretical framework and theory is developed from the collected data itself (Fellows and Liu, 2008). Ethnographic research is highly rooted in social science that focuses on cultural interpretation, for the purposes of description or extension of theory and is characterised by the high level of involvement of the researcher, with the subject of research (Saunders et al., 2007; Riemer, 2008). Archival analysis is used to analyse records to understand or draw lessons about the past, present and future (Tan, 2002).

Table 2.2. Types of research designs

(Compiled from literature)

Research design	Explanation	Form of research Question	Generally suitable for	Research strategy (typical forms)	
				Quantitative	Qualitative
Experimental design	Use for causal research, but number of variables is small and controllable	How and why?	Exploratory, Explanatory.	Most research using an experimental design employ quantitative comparisons between experimental and control groups with regard to the dependent variable	No typical form. However, qualitative data on a qua-experimental research
Survey design	Cross sectional design: Entails the collection of data on more than one case and at a single point in time; quantifiable data in connection with two or more variables	Who, what, where, how many, how much?	Descriptive, Exploratory, correlation and interpretative.	Survey research or structured observation on a sample at a single point in time. Content analysis on a sample of documents	Qualitative interviews or focus groups at a single point in time. Qualitative content analysis of a set of documents relating to a single period
	Longitudinal design: Usually sample is surveyed at least more than on one occasion			Survey research on a sample on more than one occasion, as in panel and cohort studies. Content analysis of documents relating to different time periods	Ethnographic research over a long period, quantitative interviewing on more than one occasion, or qualitative content analysis of documents relating to different time periods
Case study design	A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident	How, why, and what?	Exploratory, Explanatory and Descriptive	Survey research on a single case with a view to revealing important features about its nature	The intensive study by ethnography or qualitative interviewing of a single case
Other designs	Comparative: seeks to explain differences that have occurred between two or more groups	Why and how?	Explanatory - differences	Survey research in which there is a direct comparison between two or more cases, as in cross-cultural research	Ethnographic or qualitative interview research on two or more cases
	Grounded theory: seeks to empirically collect data in order to build a general theory to fit the data	Why and How?	Explanatory, Exploratory	n/a	Involves observation techniques, in-depth in person or focus group interviews
	Ethnography: seeks to study particular cultural group or phenomenon	What and Why?	Exploratory, descriptive	n/a	Involved multiple forms: observation documents, people, events, artefacts or fieldwork. Unstructured interviewing.
	Archival analysis: seeks to understand or draw lessons about past to present and future.	How, What and why?	Exploratory and Explanatory	Document surveys	Examines contents and historical data that are accumulated documents or archives
Exploratory: defining questions and hypotheses for a further study; Descriptive: giving a complete description of phenomenon within its context; Explanatory: explaining, which causes/produces which effects.					

Source: Bryman (2004), Yin (2003) and Tan (2002)

2.4.2. Research Methods

The term methods of data collection can be found in the literature interchangeably with research methods or data collection techniques. A variety of data collection methods is available such as questionnaires, interviews, observation techniques, the analysis of past documents and simulation. Data collection methods can be identified according to the type of data (i.e. qualitative data or quantitative data) produced. For instance, Blaikie (2000) attempted to indicate data collection methods that produce quantitative data: structured observation, questionnaire (self-administered), structured interview, content analysis of documents and quantitative data: observation (participant unstructured), interviews (semi-structured and unstructured), oral/ life histories, focus group interviews, content analysis of documents. The choice of a method may depend upon the purpose of the study, the resources available, skills of the researcher (Kumar, 1999) and the advantages and disadvantages of each method.

2.4.2.1 Questionnaires

Questionnaires collect data by asking people to respond to exactly the same set of questions (Bernard, 2000). Questionnaires can be used in descriptive or explanatory research (Saunders et al., 2007). The same author noted that the choice of questionnaire influences a number of factors in a research. These are:

- characteristics of the respondents;
- importance of reaching a particular person as respondent;
- importance of respondents' answers not being contaminated or distorted;
- size of sample;
- types of questions needed to ask to collect data;
- number of questions needed to ask to collect data;
- time availability to collect data;
- financial implications of data collection and entry; and
- ease of automating data entry.

A questionnaire may be self-administered or it may be administered over the phone, in person or web-based (Bernard, 2000). Moreover, types of questionnaires can be classified by way of administering: mailed questionnaires (post or emails) (Fellows and Liu, 2008), collective administration and administration in public places (Saunders et al., 2007). Each of these methods has its own merits and drawbacks. The questionnaire method offers greater anonymity in terms of collected data and is less expensive (Kumar, 1999; Sekaran, 2002). However, the questionnaire method has its own drawbacks such as limited application, low response rates, self-selecting bias, lack of opportunities to clarify issues, limited opportunities for spontaneous responses, and also a possibility of consulting others in terms of providing responses (Kumar, 1999; Saunders et al., 2007).

2.4.2.2 Interviews

An interview can be described as a 'purposeful conversation' (Bogdan and Biklen, 1982). The interview method allows the researcher to collect data interacting person to person between two or more individuals with a specific purpose in mind (Sekaran, 2002). Thus, interviews can be most appropriate for complex situations, visual demonstrations are required and instant feedback is desirable (Kumar, 1999). According to King (1994), the interview method is best suited where:

- a study focuses on the meaning of particular phenomena to the participants;
- individual perceptions of processes within a social unit are to be studied prospectively using a series of interviews;
- individual historical accounts are required of how a particular phenomenon developed;
- exploratory work is required before a quantitative study can be carried out; and
- quantitative study has been carried out, and qualitative data are required to validate particular measure or to clarify and illustrate the meanings of the findings.

Moreover, the interview method provides advantages such as high response rate, the usefulness of gathering in-depth and supplementary information, and the opportunity to explain questions/further clarifications (Kumar, 1999). However, the interview method has its own demerits such as being time-consuming, expensive, the quality of data/information gathered depending on the quality of interaction and quality of interviewer, and the fact that the researcher/interviewer may be biased (Kumar, 1999; Sekaran, 2002; Saunders et al., 2007). Interviews can be classified into three forms: structured interviews, semi-structured interviews and unstructured interviews (Fellows and Liu, 2008).

In an unstructured interview the interviewer does not enter the interview setting with a planned sequence of questions to be asked of the respondent. Unstructured interviews are usually conducted in order to "obtain definite ideas about what is, and is not important and relevant to particular problem situations" (Sekaran, 2002, p.236). Interviewing is a flexible method to conduct where the interviewer briefly introduces the topic, raises questions without using predetermined questions and records the replies of the respondent (Fellows and Liu, 2008). The main purpose of the unstructured interview is to bring out some preliminary issues to the respondents and probe into several factors in the situation that might be central to the broad problem area. This helps the researcher to determine variables/issues that may need further investigation (Sekaran, 2002). However, unstructured interviews provide in-depth information where it may difficult for analysis compared to structured interview information (Kumar, 1999).

Semi-structured interviews have a degree of structure in implementation which can be achieved by constructing an interview schedule (Sekaran, 2002). Semi-structured interviews are more formal than an unstructured interview in that there are a number of specific topics around which to build the interview (Naoum, 1999). Thus, at least in part, all interviewees receive some questions in common. Also, semi-structured interviews allow flexibility to the interviewer to make maximum use of the opportunities offered to enrich the data: interviewer can formulate question while carrying out the interview; and enable the use of a theoretically informed interview pro-forma to build structure into the data collection process (Fellows and Liu, 2008).

In a structured interview, the interviewer asks predetermined questions as specified in the interview schedule. The structured interview seeks high levels of reliability and repeatability (David and Sutton, 2004). Thus, the same questions set a use for every respondent in the same manner. Therefore, structured interviews provide uniform information allowing comparisons to be made (Kumar, 1999). In most instances, findings of structured interviews allow the researcher to describe or quantify certain phenomena, or identify a specific problem, and evolve a theory of the factors that influence the problem or find answers to research questions (Sekaran, 2002).

Interviews can be conducted face to face, or can be telephone and computer based. The literature emphasises that the appropriateness of each method in different circumstances depends on their advantages and disadvantages (Sekaran, 2002; Novick, 2008). Table 2.3 summarises some of the advantages and disadvantages associated with interview conducting methods. Bugher (1980) noted that the person-to-person interview is best for obtaining in-depth opinions as people are remarkably honest and frank when asked their opinions within a context that is properly structured: when the respondent knows the purpose of the interview; when the questions are properly worded; and complete anonymity is guaranteed with respect to the interviewee's responses.

Table 2.3. Advantages and disadvantages of types of interview conducting methods

(Compiled from literature)

	Advantages	Disadvantages
Face to face	▪ Can establish rapport and motivate ▪ Enable to clarify questions, clear doubts, and new questions ▪ Able to capture nonverbal cues ▪ Possible to use visual aids to clarify issues	▪ Consumes personal time ▪ Expensive when wide geographic region is covered ▪ Interviewers need to be trained ▪ Can introduce interviewer bias
Telephone	▪ Decreased cost and travel ▪ Ability to reach geographically dispersed respondents ▪ Increased interviewer safety ▪ Decreased space requirements ▪ Ability to take notes unobtrusively ▪ Permit more anonymity ▪ Allow respondents to feel relaxed ▪ Able to disclose sensitive information	▪ Limited telephone coverage ▪ Absence of visual or nonverbal cues ▪ Risk of unilateral termination of the interview without warning or explanation ▪ Lower response rates ▪ Short interview duration compared to face to face interviews
Computer based	▪ Easy to conduct ▪ Can reach globally or wide geographical area ▪ Enhanced accuracy of collected data due to software usage ▪ Helps sequencing interview questions	▪ Requires computer literacy ▪ Respondents must have access to the facility ▪ Entails heavy initial investment

Source: Sekaran (2002) and Novick (2008)

2.4.2.3 Observations

Observations can be explained as a purposeful, systematic and selective way of watching and a selective way of watching and listening to an interaction or phenomenon as it takes place (Kumar, 1999). Saunders et al. (2007) stated that observation can be used to get the root of 'what is going on' in a wide range of social settings. There are two types of observation: participant observation and non-participant observation. Participant observation is a method, which the researcher participates in the live and activities of those whom researcher studying (Sekaran, 2002; Saunders et al., 2007). The non-participant observation researcher is not involved in the activities of the group but remains a passive observer, watching and listening to its activities and drawing conclusions from them (Kumar, 1999; Sekaran, 2002). One advantage associated with the method is that the researcher himself can get to what actually happens in a situation. However, disadvantages include the fact that the observing sample may change their behaviour becoming aware that they are being observed, observations may observer biased and interpretation may vary depending on the observer (Kumar, 1999; Saunders et al., 2007).

2.4.2.4 Analysis documents

Analysis documents could involve document sources such as government and semi-government publications, past research, personal records and mass media. Disadvantages associated with analysis documents could be validity and reliability issues, personal bias, the availability of data/documents and in some instances they may not be available in the required format (Tan, 2002).

2.5. Research Bias

Both qualitative and quantitative research approaches seek honest, meaningful, credible and empirically supported findings (Patton, 2003). Thus, 'bias' is a key concern in both qualitative and quantitative research and needs substantial attention to cope with effects of bias on research outcomes. Term 'bias' can be described as "inclination or prejudice for or against one person or group, especially in a way considered to be unfair" (Oxford Dictionary, online). In simple terms, bias means research findings deviate from true findings (Shuttleworth, 2009) and therefore, impact on 'validity' and 'reliability' of research findings. Table 2.4 shows the possible causes of research bias. The contents of Table 2.4 suggest that research bias might arise due to inaccuracies in the manner which research design, administration or presentation of results.

Table 2.4. Causes of research bias

(Compiled from literature)

Type	Explanation
Research design bias	Research studies fail to take into account the inherent biases liable in selected research methods (i.e. qualitative and quantitative methods)
Sampling bias	Research studies fail to take into account inherent bias when sampling process actually happens and therefore, respondents/subjects in the sample being unrepresentative of the targeted population ▪ Omission bias - occurs when certain groups are omitted from the sample ▪ Inclusive bias - occurs when tendency to favour selection of a particular group or a group that have certain characteristics ▪ Volunteer/referral bias - occurs because respondents who volunteer to participate in a study or who are referred to as appropriate for a study ▪ Non - respondent bias - occurs when targeted respondents who do not respond due to unwillingness or inability of the respondent to participate in the study.

Cont.

Type	Explanation
Procedural bias	Research studies fail to administer the research (e.g. Interviews, questionnaires) avoiding adverse conditions ▪ Time frame bias - occurs when research fails to allocate appropriate time frame for respondents to provide their responses. If the allocated time frame is lesser, it leads to unfair amount of pressure is applied to the respondents and forcing them to complete their responses quickly. If respondents are provided a longer time frame, maturation alone could be cause for improvement. ▪ Payments bias – occurs when payments are allocated for respondents' involvement to the research
Measurement bias	Research studies fail to take into account potential errors in the data collection and the process of how the outcome of interest was measured ▪ Instrument bias - occurs when using faulty equipment or instruments with calibration errors ▪ Insensitive measure bias - occurs when the measurement tool(s) (such as experiment equipment, questionnaires and interview templates) used are not appropriate to measure or identify the important differences in the subject being studied. ▪ Verification bias - occurs when the sample used in verification processes or validation studies are restricted only to who have the condition of factor (s) being measured or verified (e.g. to assess a measurement tool (s) or results of the study (e.g. developed model/framework).
Interviewer bias	Research studies fail to consider potential effects on interviewees' views that arise due interviewer's intervention during the interview process. This involves the interviewer may intentionally or unintentionally give clues (e.g. in with body language, or tone of voice) that influence the interviewees into giving answers incline towards the interviewer's own opinions, prejudices and values
Response bias	Research studies fail to take into account that the respondents of the study provide (intentionally or unintentionally) responses that they think that the researcher wants to hear or acquired. This may occur when respondents to the study believe that they understand the study and aware of the expected findings; therefore, they adapt their responses to suit. ▪ Attention bias - occurs when respondents or sample groups to the study are aware of their involvement. This could have effects on behaviour and views provided by respondents or sample groups such as attention received may give more favourable responses or perform better than people who are unaware of the study's intent ▪ Setting bias - occurs when the research (e.g. interview) is conducted at an uncomfortable setting for respondents. Some respondents may not at ease when they are asked to respond at the work place therefore not respond frankly and honestly
Reporting bias	Reporting bias occurs due to an error is made in the way that the results are disseminated. ▪ Positive results bias - occurs when publications and language of publications are based on the direction or strength of the study findings; reports only those that are significant than those that insignificant or unfavourable ▪ Funding bias - occurs when reporting the outcome of industry sponsored research; instances where findings are reported as a favourable outcome ▪ Database bias - occurs when the literature search is based on a database in which the results of indexed are systematically different from those of non-indexed studies ▪ Grey literature bias - occurs when reporting results in journal articles which systematically different from those presented in reports, working papers, dissertations or conference papers

Source: Sekaran (2002); Harman et al. (2002); Patton (2003); Shuttleworth (2009); BMG (2011)

Though it is unavoidable, research design process needs to involve understanding and acknowledging the inherent biases and minimising the effects of them (Ryan and

Bernard, 2003; Shuttleworth, 2009). In quantitative research, there is a higher possibility to check and eliminate research bias (e.g. using statistical methods). However, in qualitative research, the complete elimination of bias is difficult as the qualitative researcher is part of the process (Harman et al., 2002; Sekaran 2002; Shuttleworth, 2009). Therefore, the causes of bias need to be identified and minimised or to be acknowledged when research findings are interpreted and presented.

As shown in Table 2.5, causes of research bias can arise throughout the research process. Therefore, actions for dealing with research bias need to be carefully thought through at research design stage and thereafter, every activity through the research process. In response, Denzin (1989, p.307) argued that "by combining multiple observers, theories methods and data sources can hope to overcome the intrinsic bias that comes from single-methods, single observer, and single theory studies". Patton (2003) mentioned four triangulation methods that can offer strategies for reducing systematic bias and distortion during data analysis. Table 2.5 shows how these triangulation methods relate to this study, therefore reducing research bias and ensuring validity of findings.

Table 2.5. Reducing research bias: Triangulation methods

Triangulation Method		**Triangulation relates to this study**
Methods triangulation	Checking out consistency of findings generated by different data collection methods	▪ Adaptation of a mixed methods research approach: literature review, questionnaire survey, and interviews
Triangulation of sources	Checking out the consistency of different data sources within the same method	▪ Checking and comparing findings of questionnaire survey and interviews, PWMF validation with literature
Analyst triangulation	Using multiple analysts to review findings ▪ Triangulating analysts: having two or more persons independently analyse the same data and compare their findings ▪ Review by study participants: verification of findings using study participants ▪ Expert audit review: assess the quality of data collected and analysis using expert to	▪ Triangulation of analysts was not undertaken in this study (only the PhD researcher involved in the data analysis) ▪ Using mixed methods sequential research approach, the study's participants involved in findings verification at two research stages: follow up interviews and PWMF validation process (i.e. validation discussions, validation questionnaire and validation interviews) ▪ Expert audit review is implicit in this research: can be form of reviews of PhD supervisors; PhD progress assessments at the end of 1st year and 2nd year; and review comments received for submitted refereed conference papers
Theory/perspective triangulation	Using multiple perspectives (perspectives of various stakeholder positions) or theories to interpret data	▪ Comparing perspectives of procurement managers, sustainability managers and quantity surveyors

(Adapted from Patton, 2003: p. 555 to p. 564)

The next section presents the adopted research methodology for this research. In which different sections present how this study attempts to deal with different causes of research bias.

2.6. Adopted Research Methodology

This section outlines the methodological approach that was adopted for this research. This research aimed to develop a Procurement Waste Minimisation Framework (PWMF) focusing on the relationship between CPS and construction waste generation. In this pursuit, it is essential to determine the following: what knowledge claims are being made from the research; strategies of inquiry; and methods for data collection and analysis. Thus, forthcoming sections discuss how these aspects have been determined as relevant to this research.

A knowledge claim means that researchers initiate the research with certain assumptions about how they will learn and what they will learn during their inquiry (Creswell, 2003). Apropos what methods should be followed in gaining knowledge to address the problem (i.e. epistemology), the researcher is not influenced by a pre-determined view on what is acceptable knowledge. Therefore, this research was not initiated particularly with either a positivist view or an interpretivist view. Furthermore, it was believed that this research was not directed by any theories, either grand or middle-range but rather conditioned by and directed towards the research questions that emerge out of interrogation of the literature. Thus, this research made its priority to understand the research problems and the most suitable approaches and methods to derive knowledge about the problem rather than considering certain methods as being more important. Therefore, the research was expected to choose the methods and procedures that best met the research problem and objectives. Consequently, this research is characterised and can be in the pragmatism knowledge claim position.

The strategy of inquiry for this research is to involve both quantitative and qualitative strategies as it helps to neutralise biases inherent in any single method or cancel the biases of several methods (if selected) for a research. Thus, this research adopted mixed methods sequential procedure, where the study began with a quantitative method with a large sample to investigate broad issues related to the research literature. Further, it was expected to identify key issues and narrow down the research into the most important issue(s). Then, the research followed a qualitative method involving a detailed exploration with individuals regarding issues raised from the quantitative study. Four decisions that go into selecting mixed methods of inquiry are implementation sequence, priority for data collection and analysis, stages of integration of type of data and overall theoretical perspective (Creswell, 2003). In line with this, Table 2.6 shows the decision choices in terms of determining the mixed methods strategy of inquiry for the study. Research strategies implementation was sequential where qualitative strategy followed with qualitative strategy. An equal priority was given to both qualitative and quantitative data with regard to the data collection and analysis; and integration of data was considered with some combination of data collection, analysis and interpretation. As discussed earlier, the theoretical perspective of this research is implicit as the priority was given to understanding the research problems and the most suitable approaches and methods to derive knowledge about the problem.

Table 2.6. Decision choices for determining a mixed methods strategy of inquiry
(Creswell, 2003)

Implementation	Priority	Integration	Theoretical perspective
No sequence Concurrent	**Equal**	At data collection	
Sequential – Qualitative first	Qualitative	At data analysis	Explicit
		At Data interpretation	
Sequential – Quantitative first	Quantitative	**With some combination**	**Implicit**

Decision choices in terms of determining the mixed methods strategy of inquiry for the study

Figure 2.2 illustrates the research plan adopted for the study according to the concept ‘research onion’ (Saunders et al., 2007), by which the research is placed in a pragmatism philosophical stance with combined (deductive and inductive) approaches which uses a survey strategy and mixed methods approach in a cross-sectional study in order to induce knowledge from the participants.

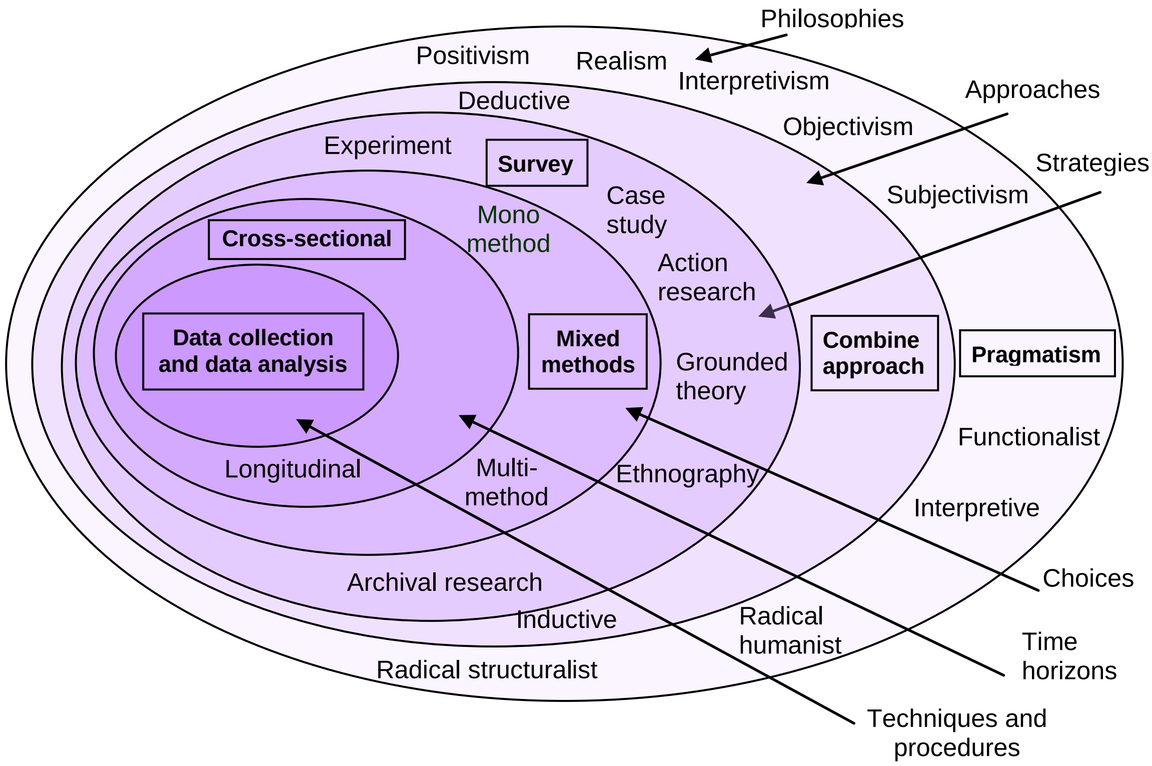

Figure 2.2.The research methodology of the study according to the "research onion"

(Adapted from Saunders et al., 2007)

The purpose of the sequential, mixed methods research design was to obtain mixed data for the issues under investigation. Firstly, the quantitative study was conducted mainly aiming to capture a broad view and to prioritise key issues in the relationship between CPS and waste generation in construction. Therefore, a cross sectional questionnaire survey was carried out. Secondly, the qualitative study was aimed at gaining results in more depth pertinent to key issues emerged from the findings of the questionnaire survey. Thus, semi-structured face to face interviews were conducted by probing into significant results that emerged from the quantitative study. Thirdly, design and development of PWMF was undertaken by encapsulating key findings from the literature review, questionnaire survey and semi-structured interviews. Subsequently, semi-structured interviews and a questionnaire were used to validate the developed PWMF. A detailed description and justification is provided with regard to the research methods selection and data analysis in subsequent sections.

Sampling approach

As discussed above, the study consisted of a sequential, mixed method approach. Therefore, the study was conducted using a 'sequential mixed method sampling strategy'. This sampling strategy involves the selection of a unit of analysis for a mixed method study through the sequential use of probability and purposive sampling strategies: quantitative to qualitative or vice versa qualitative to quantitative (Tashakkori and Teddlie, 2009). Sequential quantitative to qualitative sampling is considered as a common technique in mixed methods research (Kemper et al., 2003; Teddlie and Yu, 2007; Bryman, 2008), whereas information from the first sample (typically derived from a probability sampling procedure) is often required to draw second sample (typically derived from a purposive sampling procedure). However, in this research, purposive sampling strategy was adopted in both occasions i.e. quantitative and qualitative sampling. This was mainly due to the nature of issues to be investigated during the study. The study required respondents who have knowledge and experience related to construction procurement, WM and wider sustainability issues in construction. Thus, the experienced professionals from the UK top 100 construction industry organisations were selected as a sample element for the study. These professionals were selected with regard to their appropriate experience and knowledge in working with large construction projects, and dealing with different procurement system practices and sustainable construction issues such as waste generation/ reduction.

It was also expected to gain multiple perspectives on research issues by including three professional categories to the sample. Intern this helps to cope with research bias and to enhance the validity of findings. Having considered that, the appropriate sample frame for the study was identified as construction PM and SM from the UK top 100 contracting organisations (by annual turnover) (Construction news – Top 100, September 2007 issue) and QS from the UK top 100 quantity surveying organisations (by number of chartered QS) (Building Top 100 Quantity surveyors, 2002 issue 38). A specific sampling method for each data collection method is discussed in sections 2.7.2., 2.7.3., 2.8.2., and 2.10.2.3 respectively (refer to Appendix 2.1 respondents sample distribution for data collection stages).

2.7. Questionnaire Survey

The literature presents neither a clear evaluation nor many research studies into the impact of CPS on waste generation in construction, instead it has emphasised a need for research in this field (section 3.4.1). As a part of the exploratory phase of the research, survey research design was selected to capture a broad view on the research issues. As discussed earlier, a survey is a systematic method of collecting primary data based on a wider population using economical data collection methods such as questionnaires and structured interviews. Furthermore, the research questions were to be investigated in form of 'what' and views were to be captured at once from many respondents. Thus, a cross sectional survey design was considered as an appropriate research design. The cross sectional design is best suited to studies' aim to find out the prevalence of a phenomenon, situation, problem attitude or issue by taking a cross section of it at once (Kumar, 1999; Saunders et al., 2007). Additionally, as the issues and the phases of the research are of an exploratory nature, it was expected to collect both quantitative data and qualitative data. Thus, selection of a survey design for this research was appropriate as it allows the collection of both quantitative and qualitative data, and in most circumstances, data collected through surveys providing the opportunity of using statistical analysis. As discussed in section 2.4.2.1., the type of data collected through surveys depends on the data collection method. As the data collection method of this survey a 'self-administered postal questionnaire method' was selected, as it is an economical method and facilitates the collection of data from a number of respondents scattered over a large geographical area during a certain period of time (Sekaran, 2002; Flower, 2002). Further, the selection was appropriate as the questionnaires could be used in the descriptive or explanatory research.

2.7.1. Questionnaire Design and Development

The questions were designed with the aim of capturing 'opinions' (i.e. variables record how respondents feel about something or what they think or believe is true or false), 'behaviour' (i.e. what respondents do – concrete experience (did/do now/will do)) and 'attributes' – respondent characteristics (exploring how opinion and behaviour differ between respondents/to check that data collected are representative of the total population) (Dillman, 2000; Saunders et al., 2007) from the survey respondents. The questionnaire was divided into seven sections including different types of questions (Table 2.7); background (2 questions); current sustainable construction practices (3 questions); current construction procurement practices (3 questions); CPS and waste generation (6 questions); trends and improvements (3 questions); further comments; and further research (2 questions). The final version of the four-page questionnaire was based on five revisions (Appendix 2.2) and a pilot study.

Table 2.7. Type of questions

Question type	Number of questions
Open - ended	5
Category	5
Rating	10
Total	20

2.7.2. Questionnaire Sampling Method

As per the decided sampling frame, the sample should contain respondents sub groups of construction PM, SM and QS. These managers are involved in the procurement process from pre-contract stage to post contract stage at different levels such as procurement system selection decision making processes, procurement documentation, evaluation of most appropriate parties and mechanisms for a particular project.

Stratified sampling was used to select the study respondents sample from the UK top 100 contracting organisations (i.e. PM and SM from each company) and UK top 100 quantity surveying organisations (i.e. QS from each company). Stratified sampling, a variant of simple random sampling, uses a homogeneous population that produces samples with smaller sampling errors than a heterogeneous population (Vaus, 1995). This can be achieved by organising the population into homogeneous subsets - with heterogeneity between subsets – and selecting the appropriate number of elements from each subset (Babbie, 1990). According to Fellows and Liu (2008), this method is appropriate where the population occurs in distinct, groups or strata and the strata may be selected for the purposes of the research (e.g. type of firm). This sampling method is also appropriate for increasing the representativeness of sample and a useful technique that made general statements about the population possible (Love, 2002).

2.7.3. Questionnaire Sample Size

Contact details of respondents were collected mainly through data published on respective company websites. Additionally, companies were contacted over the telephone in instances where the particular contact detail of a respondent was not apparent on company websites. Additionally, a special attention was given to identify respondents by name as this helps to increase the response rate (Flower, 2002). In the survey, 164 questionnaires (two questionnaires for each organisation targeting the PM and SM) were distributed among 82 contracting organisations. Similarly, 94 questionnaires were distributed among 94 quantity surveying organisations (refer to section 2.7.5 and section 4.2.1 for questionnaire survey administration). Other organisations were excluded from the list of UK top 100 contractors and the UK's top 100 quantity surveyors such as mechanical & electrical, plant & equipment; refused to participate in the survey when they were first contacted (e.g. not interested in take part in questionnaire surveys; company policy restrictions); and gave incorrect contact details. In total, as shown in Table 2.8., 258 questionnaires were distributed among 176 organisations, which include both contracting and quantity surveying organisations.

Table 2.8. Number of distributed questionnaires

Questionnaires distributed				**Total**
by company	Contractors		Quantity surveyors	
	82		94	176
by Profession	Procurement managers	Sustainability managers	Quantity Surveyors	
	82	82	94	258

2.7.4. Questionnaire Pilot Study

The questionnaire was tested using a pilot survey. A pilot test helps to improve the response rate as it can eliminate severe potential sources of difficulty, such as poorly worded questions and the lack of space to record answers (Fink, 2006; Fellows and Liu, 2008). Moreover, pilot testing is useful in the refinement of the questionnaire to eliminate problems in answering and recording the data, enabling the researcher to obtain some assessment of the questions' validity (i.e. enables content validity) and likely reliability of the data (Saunders et al., 2007). Thus, a pilot survey was carried out among construction management researchers of the Civil and Building Engineering department at Loughborough University. These researchers have worked in the construction industry as PM, QS, architects and civil engineers.

The number of participants for a pilot survey may vary depending on many factors such as the nature of the research itself, other data collection methods, time and the aim(s) of the research (Fink, 2006). However, the appropriate minimum number of participants for a pilot test is 10 respondents (Fink, 2003). Moreover, Bell (2005) noted that the use of an additional questionnaire to get feedback (i.e. in terms of clarity of instructions, unclear or ambiguous questions, major topic omissions, durations to complete and layout's clearness and attractiveness) could improve the comprehensiveness of a pilot survey. Therefore, 12 questionnaires were distributed to construction management researchers during the pilot study, of which 10 questionnaires were received along with feedback sheets. Consequently, three (3) questions were further modified (reworded) in order to enhance the clarity based on the comments of received questionnaires. Moreover, most of the respondents stated that they had to spend 15 – 30 minutes completing the questionnaire. This helped to determine the appropriate time required for a particular respondent to complete a questionnaire during the main survey.

2.7.5. Strategies Adopted to Increase the Response Rate

Questionnaire surveys tend to provide low response rates. For example, postal questionnaires can expect a 25%-35% useable response rate (Fellows and Liu, 2008) and a 30% response rate is acceptable (Sekaran, 2002). Thus, techniques used in the questionnaire survey design and administration processes are helpful in order to maximise responses (Frazer and Lawley, 2000; Saunders et al., 2007) and in terms of ensuring the largest possible return of completed questionnaires thus enabling meaningful data analysis (Fowler, 2002). Thus, special attention was given to ensure satisfactory response rates from the beginning of survey design to the end of questionnaire administration period. In this regard, some of the techniques mentioned below were adopted from the guidelines of Frazer and Lawley (2000), Fowler, (2002) and deVaus (2002) and that focuses to administer the questionnaire survey expecting a highest possible response rate.

The questionnaire was designed with a variety of questions and limited to four pages after five revisions to minimise response time to the questionnaire. Additionally, a promise was made in the covering letter to send the summary of findings to those who are willing to receive such a report. Furthermore, as mentioned in section 2.7.4., a pilot survey was carried out in order to enhance the clarity and the comprehensiveness of the questionnaire. Subsequently, efforts were made to identify respondents by their names/designations rather than just sending the questionnaire directly to organisations. Additionally, questionnaires were printed on white A3 paper using both sides of the paper so it is similar to reading layout of a book. Also, the questionnaire was printed with the Loughborough University logo in the heading as a way of attracting respondents by ensuring the survey confidentiality. As per the research survey design, the survey was administered during a four week period. Two follow up rounds at the end of the second and third weeks of the survey were conducted during the questionnaire survey administration process (telephone calls and emails). The survey was administered over seven weeks during the period of July 2008 to September 2008.

2.7.5.1 Questionnaire covering letter

A well written covering letter and a good design also ensure a high level of response rate. Thus, a self-addressed return envelope and a covering letter explaining the objective of the research, duration, contact details and a confidentiality and anonymity statement were included along with the questionnaire. Both confidentiality (i.e. relating to data) and anonymity (i.e. referring to organisations and persons) were included as significant components of conducting the research and ensuring the expressed, informed consent of the respondents be obtained and adhered to rigorously (Fellows and Liu, 2008). The covering letter was also printed with the Loughborough University letter heading (Appendix 2.2).

2.7.5.2 Questionnaire response rate

An adequate response rate is essential for a survey in order to draw acceptable conclusions (Fellows and Liu, 2008). The response rate is the number of eligible respondents who actually responded to a survey (numerator) divided by the total number of eligible respondents approached (Frazer and Lawley, 2000; Fink, 2010). Non-respondents for a survey can be mainly due to four reasons: refusal to respond, ineligibility to respond, inability to locate respondents, and respondents located but unable to make contact (Saunders et al., 2007). The active response rate for the questionnaire survey was calculated using the following equation (Saunders et al., 2007):

$$\text{Active response rate (\%)} = \frac{\text{Total number of responses}}{\text{Total number in sample} - (\text{ineligible} + \text{unreachable})}$$

While a detail analysis of calculation of active response(s) rate is presented in chapter 4, section 4.2.2., the following illustrates how the active response rate of 30.4% is arrived at for the overall questionnaire survey:

$$\text{Active response rate (30.4\%)} = \frac{\text{Total number of responses (65)}}{\text{Total number in sample (258)} - (\text{ineligible} + \text{unreachable})\ (44)}$$

2.7.6. Validity and Reliability

A valid questionnaire enables the researcher to collect accurate data; and a reliable questionnaire ensures that data is consistent. Thus, from the questionnaire design stage to the data analysis stage, different measures were taken into consideration in order to ensure data validity and reliability. Fink (2006) noted, “a valid survey is always a reliable, but reliable one is not always valid”. Saunders et al. (2007) also substantiated the same idea and further indicated that reliability was dependent on the robustness of the questionnaire.

Validity refers to the ability of questionnaires to measure what the researcher intends it to measure. In order to ensure entire survey validity, it is necessary to consider content validity, construct validity and criterion related validity (Fink, 2006; Saunders et al., 2007):

- *Content Validity* refers to the extent to which the questionnaire provides adequate coverage of investigative questions. Content validity is usually established by careful definition of research (i.e. the literature review) and discussing with experts or panels of individuals;
- *Construct Validity* refers to the extent to which measurement questions actually measure the presence of construct (i.e. attitude scales, aptitude scales) intended to measure;
- *Criterion Related Validity*, also known as predictive validity, is concerned with the ability of the questions to make accurate predictions.

In this research, *content validity* of the question data was ensured by a thorough literature review and a pilot questionnaire survey. However, *construct validity* and *criterion related validity* were considered less as they need more exploration and may not be applicable (i.e. predictions).

Reliability refers to consistency. Mitchell (1996) noted three ways of assessing reliability: test re-test; internal consistency; and alternative form. Additionally, comparing the data collected with other data from a variety of sources is also a way of ensuring reliability (Saunders et al., 2007). In this research, test re-test was not adopted due to practical difficulties, as it needs to administer the questionnaire twice to the respondents. Data reliability is related to data source; and therefore the identification of the position held by the person who completed the questionnaire is also a way of assuring data reliability (Oppenheim, 1992; Love, 2002). Thus, during the respondents’ selection process the focus was on identifying respondents by designation. Also, efforts were made to select respondents who have detailed knowledge and professional experience in the areas of sustainable procurement process and construction waste issues.

Internal reliability is particularly important in connection with indicators that make up the multiple item scales and indexes (Bryman and Cramer, 2005; Bryman, 2008). It raises the question of whether each scale/index is measuring a single idea and hence whether the items that make up the scale/index are internally consistent. In other words, the score for each item is correlated with the sum of scores for the remaining items in order for each construct or concept to be measured (Tan, 2002). Mathematically, reliability is defined as the proportion of the variability in the responses to the survey that is the result of differences in the respondents. Using reliability analysis (SPSS version 16):

- it can be determined the extent to which the items in the questionnaire or items in a question are related to each other;
- it gives an overall index of the repeatability or internal consistency of the scale as a whole; and
- it enables to identify problem items that should be excluded from the scale.

Cronbach's Alpha (α) (Cronbach, 1951) is a measure of internal reliability (Fink, 2006; Saunders et al., 2007; Bryman, 2008). Specifically, Alpha is a lower bound for the true reliability of the survey (SPSS version 16). Cronbach’s Alpha is the most widely used and elaborated measure currently for internal reliability. Therefore, Cronbach’s Alpha was considered for checking the internal reliability questions. Section 4.2.4 further explains how Cronbach’s Alpha was used for the data analysis and interpretations.

2.8. Semi-Structured Interviews

The adopted data collection method for the second phase of the research was face to face, in person, semi-structured interviews with the selected respondents from the completed questionnaire survey. Interviews are appropriate when quantitative study has been carried out, and qualitative data are required to clarify and illustrate the meanings of the findings (King, 1994; Hannabuss, 1996). Semi-structured interviews were adopted for the study as there was a need to explore the responses obtained in more detail during the questionnaire survey. Semi-structured interviews may be used in order to understand the relationships between variables, particularly those revealed through a descriptive study (Saunders et al., 2007). Hence, it was expected that semi-structured interviews would also help to establish the relationship between CPS and waste generation in construction. The findings of the literature review and questionnaire survey indicated that the majority of current projects are being undertaken using the D & B procurement system; the system has shown a tendency to become popular in future projects; contradictory results emerged from the questionnaire survey (qualitative Vs quantitative) about the impact of D & B procurement system on waste generation; and D & B procurement system has shown a high potential to integrate WM strategies. Thus, the particular aim of in person semi-structured interviews to investigate D & B related PWO and potential WM strategies that can be integrated into D & B approach seeking to develop a WM framework.

2.8.1. Interview Template

The interview template contained four sections: background information (4 questions); sustainable practices of D & B procurement system and its significance on waste generation (3 questions); D & B procurement related waste origins and suggestions to minimise construction waste (6 questions); and further thoughts. All questions contained in section two, three and four were of an open-ended type. Section two and three central questions were directly related to the findings of the questionnaire survey: procurement trend; D & B contribution to sustainable construction; and four procurement waste origins. The final version of the two-page interview template (Appendix 2.3) was based on three revisions and a pilot study.

2.8.2. Interview Sampling Method

The questionnaires' data analysis suggested that the views of the three respondent groups did not differ. Therefore, the same sample frame was used to select respondents for semi-structured interviews. During the questionnaire survey, respondents were asked whether they were willing to take part in a follow-up interview. Consequently, 17 respondents: three PM, eight SM and six QS were willing to participate in follow up semi-structured interviews. However, there could be an element of bias as if sample contained all respondents who had interest on follow-up interviews. As such, the selection of respondents was based on several factors: the respondent's interest in participating in an interview; the position they held in the company; their experience of the profession relevant to both procurement and WM and management; one respondent from each organisation; and travelling facilities to the respondent's organisation location. However, only 14 (out of 17) respondents were available when they were contacted for interviews: three PM, six SM and five QS. Therefore, some other respondents (i.e. those who motioned 'no' to follow-up rounds during the questionnaire survey) were again contacted as appropriate for the selection criteria laid down and asked whether they would like to reconsider their possible involvement in follow up semi-structured interviews. Consequently, five respondents were given consent to participate in follow up interviews: two PM, one SM and two QS. 17 (out of 19) respondents were selected for semi-structured interviews based on their experience: one respondent from each organisation and travelling facilities to the respondent's company location. Table 2.9 presents a composition of the selected interviewee sample.

Table 2.9. Composition of interview respondents sample

<table>
<tr><th colspan="4">Interview Respondents</th><th>Total</th></tr>
<tr><td rowspan="2">by company</td><td colspan="2">Contractors</td><td>Quantity surveyors</td><td></td></tr>
<tr><td colspan="2">11</td><td>6</td><td>17</td></tr>
<tr><td rowspan="2">by Profession</td><td>Procurement managers</td><td>Sustainability managers</td><td>Quantity surveyors</td><td></td></tr>
<tr><td>5</td><td>6</td><td>6</td><td>17</td></tr>
</table>

2.8.3. Interview Process

Three pilot interviews were conducted with construction management researchers of the Department of Civil and Building Engineering at Loughborough University in order to enhance the clarity of questions, assess the time required for each section, test the voice recording devices and act as a practice session prior to actual interview series.

After the initial identification of prospective respondents, a follow-up dissemination of three documents was carried out: an interview schedule, participant information sheet and consent form (Appendix 2.3). These documents were sent to all selected interviewees at least one week prior to the scheduled interview date having an intention to allow interviewees to prepare for the interview questions and importantly aiming to gather a wealth of information relevant to the questions to be raised in the interview (Fowler, 2002).

The interview schedule comprised: aim, interview agenda and all questions to be raised during the interview; a participant information sheet, which gave the contact information of the researcher, a brief background to the research and other information such as how the interview would be conducted (e.g. duration, interview recording/devices) and ethical consideration pertinent to interview parties (e.g. voluntary participation, permission to audio recording) and gathered information during the interview (e.g. confidentiality: how the information collected from interviewees will be treated). A copy of informed consent form was also sent to each respondent that sought a sign off from both the research investigator and interviewee to agree upon to fulfil the Loughborough University Ethical Advisory Committee requirements.

The conversational style adopted to facilitate the discussion of topic which, in the opinion of the interviewees was important. Thus, further probing questions were posed to each interviewee (Hannabuss, 1996). These probing questions explored emergent issues from the literature, results of the questionnaire survey and interviewees' talk it-self. Each interview was audio recorded with the permission of the respondent, as the recorded interviews were very helpful at the analysis stage, through subsequent scrutiny and helped to ensure accuracy and objectivity in recording responses (Hannabuss, 1996; Fellows and Liu, 2008).

It was attempted to strictly follow the time allocation (45 minutes) for each section during the interview: background information (four minutes); sustainable practice of D & B procurement system (six minutes); D & B procurement related waste origins and suggestions to minimise D & B waste (thirty minutes) and further thoughts (five minutes). 17 interviews were conducted over approximately eight weeks during November 2008 to February 2009. Figure 2.3 illustrates the interview process.

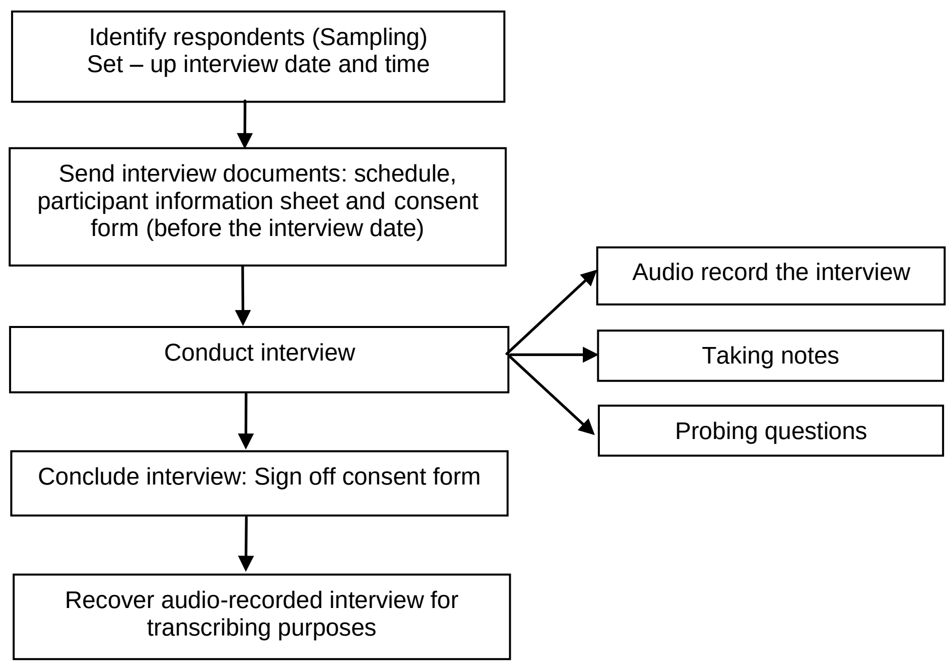

Figure 2.3. Interview process

2.9. Data Analysis

This section presents the data analysis process and techniques used in the study. The subsequent sections describe the analysis process and methods used to analyse quantitative and qualitative data that were collected through the questionnaire survey, semi-structured interviews, framework validation questionnaire and framework validation semi-structured interviews.

2.9.1. Quantitative Data Analysis

Data collected through questionnaire surveys and PWMF validation questionnaires (except open-ended questions) were analysed using quantitative techniques that will be described in forthcoming sections. The data analysis techniques depend on the type of data collected and their scales of measurement: nominal, ordinal, interval and ratio. Therefore, the identification of data scales of measurement is essential prior to a statistical analysis of collected data.

The data generated from different questions of the questionnaire survey in this study belongs to different scales of measurements: data of question number 1.2, 2.1 and 3.1 were considered as nominal data; and experience of the respondents and number of employees of the company were regarded as ratio data. However, a difficulty was raised when deciding the scale for the question data generated using a rating scale; whether those data are considered as ordinal or ratio for the analysis purpose. In this pursuit, it was examined how the data generate through rating scale(s) needs to be treated.

One of the most common rating scales is the Likert scale. As with other scales, the Likert scale is also used either as a summated scale or as an individual scale item. However, whether it is an ordinal or an interval is a subject of much debate (Achyar, 2008). Further, Hodge and Gillespie (2003) stated that treating the Likert scale either as interval or even ratio is unclear, if not doubtful. The Likert scale is widely used in measuring attitude and image (Jacoby, 1971) and often considers as an interval scale. However, some argued that the Likert scale is ordinal in nature; for the reason that, summing ordinal data will not make it interval (Achyar, 2008). Because of the ordinal nature, Elene and Seaman (2007) stated that the Likert scale is most suitable being analysed by non-parametric procedures such as frequencies, tabulation, chi-squared statistics, and Kruskall-Wallis H test.

Clason and Dormody (1994) noted that it is not a question of there being right or wrong ways to analyse data generated from the Likert scale, the main concern needs to be whether it is directed to answering the research questions/objectives meaningfully. Adams et al. (1965, p.100) also mentioned that “nothing is wrong per se in applying any statistical operation to measurements of given scale, but what may be wrong, depending on what is said about the results of these applications, is that the statement about them will not be empirically meaningful or else that it is not scientifically significant”.

The rating scales used in the questionnaire survey and framework validation questionnaire of this study were on a 5 point scale. Despite literature arguments on the appropriateness of scale length, the selection of 5-point scale was mainly based on its popularity in use. Furthermore, the 5 point scale enables respondents to express neutrality. Therefore, the 5-point scale helps to eliminate forced choice for a favorable response (i.e. minimise positive response bias). The question data based on the rating scale were analysed considering the data type as ‘ordinal’.

2.9.1.1 Data analysis software

A number of computer software applications have been developed in order to aid the steps of data analysis. However, computer aided software needs to be used with caution as they have both strengths and limitations (Lee and Fielding, 1991). One of the main advantages of computer aided software is its ability to rapidly handle large volumes of data. By using computer aided software, data can be easily manipulated and displayed in a number of ways (Robson, 2002). This makes the data analysis process more comprehensive, transparent and replicable thus increasing the reliability and validity of the analysis. Importantly, if the computer aided software is used with care, to assist the tedious tasks of data handling such tools can enhance the data analysis process. The SPSS (Statistical Package for Social Science) is one of the most widely used software packages for statistical data analysis. Thus, it was decided to use SPSS software for the quantitative data analysis in this research, expecting that the use of SPSS software makes the data analysis process more comprehensive, transparent, replicable, and also increases the reliability and validity of the analysis. Two versions of SPSS software were used for the data analysis of this research due to software up-grade processes in Loughborough University: SPSS version 16 to analyse questionnaire survey data; SPSS version 17 to analyse PWMF validation questionnaires. The following steps were taken when entering data;

- Data coding and data entering were conducted as specified by the SPSS guidelines.
- Double entry to achieve error free data (such as to avoid data duplication and entering wrong data).

2.9.1.2 Descriptive statistics

Descriptive statistics, as the name implies, describe or summarise the data (Tan, 2002). Descriptive statistics for surveys include counts (numbers or frequency); proportions (percentages); measures of central tendency (the mean, mode and median); and measures of variation (range and standard deviation) (Fink, 2006). The most common descriptive statistics are the mean and standard deviation for the data analysis process. However, mean and standard deviation are invalid parameters for descriptive statistics whenever data are on ordinal scales. Consequently, parametric methods with calculations based on mean and standard deviations would also be invalid for analysing ordinal data (Jakobsson, 2004). This was confirmed by many authors namely Siegal (1956); Tan (2002); Thorkildsen (2005); and Doig and Groves (2006). They further explained that mean and standard deviations found on the scores themselves are in error to the extent that the successive intervals (distances between classes) on the scale are not equal. If parametric techniques of statistical inference are used with such data, any decisions about hypotheses are doubtful. As a result, probability statements derived from the application of parametric statistical tests to ordinal data are in error to the extent that the structure of the method of collecting the data does not have a similar appearance but is genetically different to arithmetic.

As Siegal (1956) stated and Doig and Groves (2006) demonstrated in a student perceptions survey, the allowable operations on the ordinal data resulting from a survey are:

- transformed data on an interval scale;
- the median response to each category; or
- the proportion of responses in each category.

The allowable operation resulting on ordinal data is to transform the data mathematically (i.e. order-preserving transformation) on an interval scale (e.g. transformed the raw ordinal data into logits (log odds units) using Masters' Partial Credit Model; Rasch Model (Doig and Groves, 2006; Hardigan and Carvajal, 2007). An order-preserving transformation is a form of transformation that preserves the ranking of the raw data and produces an interval scale, one that allows the operations of ordinary arithmetic and statistic (i.e. means, standard deviations, parametric tests) operations.

Statistically, the most appropriate way of describing the central tendency of scores in an ordinal scale is the median, since the median is not affected by changes of any scores, which are above or below it as long as the number of scores above and below remains the same (Siegal, 1956, Doig and Groves, 2006). However, the median provides a minimal amount of useful information. Doig and Groves (2006) confirmed the above demonstrating that the respondents' responses missing from the median approach is any indication of the distribution of the responses and there is no way in which a particular respondent's response pattern can be discerned from a form of summary information (i.e. a median distribution chart).

The other operation for reporting ordinal data is the proportion of responses in each category, which is considered as being the most popular method and more informative than the use of median, yet less informative than transformed data on an interval scale (Fink, 2010). This method allows the reporting of a pattern of endorsement of the survey; propositions of categories which do not provide any information on individual respondents or even about sub-groups of respondents. However, non-parametric approaches can be used along with this method to provide information on various aspects (Doig and Groves, 2006), especially to gain such missing information (i.e. information on individual respondents or even about sub-groups of respondents).

In this research, the transformation data on an interval scale was not undertaken for the purpose of ordinal data of the questionnaire survey considering the complex procedure of transforming data on an interval scale. Furthermore, the main objective of the questionnaire survey was to capture a broad view on the issues associated with the relationship between CPS and waste generation, as such a simple and meaningful data representation approach was a priority. Hence, the proportion of responses in each category along with non-parametric tests was considered the main data reporting method in the questionnaire survey and framework validation questionnaire. Mostly, descriptive statistics were used in this research to analyse data related to different questions by computing counts (numbers or frequency) and proportions (percentages) used as appropriate. Therefore, statistical analysis techniques considered in this study were non-parametric procedures. However, taking a pragmatic view means considering in the analysis to answer research questions meaningfully.

2.9.1.3 Missing data analysis

Missing values can result in misleading interpretations and may reduce the precision of calculated statistics (SPSS version 16). Therefore, missing value analysis was conducted for each question of the questionnaire survey as it helps to address several concerns caused by incomplete data. The results of missing value analysis are shown in the Appendix 2.4 for questionnaire data while there were not missing values recorded for the framework validation questionnaire. If missing data values are less than 10% of total data for each section of the question, then the statistical analysis was presented based on a score of non-missing values as the appropriate index while keeping the total sample at unchanged (Bryman and Cramer, 2005).

2.9.1.4 Kruskal - Wallis H test

The non-parametric tests for multiple independent samples are useful for determining whether or not the values of a particular variable differ between two or more groups. The Kruskal-Wallis test is a one-way analysis of variance by ranks. It tests the null hypothesis that multiple independent samples come from the same population. It is appropriate when the test variable is ordinal or when its distribution does not meet the assumptions of standard ANOVA (SPSS version 16). Unlike standard ANOVA, the Kruskal-Wallis test does not assume normality, and it can be used to test ordinal variables. The only assumptions made by the test are that the test variable is at least ordinal and that its distribution is similar in all groups. Thus, the Kruskal-Wallis H test was used to ascertain whether any difference was present between responding groups for the questionnaire survey (i.e. procurement managers, sustainability/environmental managers and quantity surveyors). However, the same test was not undertaken for the framework validation questionnaire due to the small sample size of the framework validation respondents.

The Kruskal-Wallis statistic measures (chi-square) the extent to which the responding group ranks differ from the average rank of all groups. The degrees of freedom (df) for the chi-square statistic are equal to the number of groups minus one. The asymptotic significance (Asymp. Sig.) estimates the probability of obtaining a chi-square statistic greater than or equal to the value of significant, if there are truly no differences between the group ranks (SPSS, version 16). The value of the asymptotic significance level is greater than 0.05, which indicates that there is no difference between respondents' views mean ranking of groups (Tan, 2002; Bryman and Cramer, 2005; Ilozor, 2009).

2.9.1.5 Internal reliability test (Cronbach's Alpha)

Several measures were taken to ensure the reliability of both the questionnaire survey and framework validation questionnaire data from the questionnaire design stage (section 2.7.6). In this research, Cronbach's Alpha values were considered to test how internally reliable the question data of the questionnaire survey was. Cronbach's Alpha calculates the average of all possible split half (split half reliability the items in a scale are divided into two groups either randomly or odd-even basis) and the relationship between respondents' (scores for the two halves is computed) reliability coefficients (Tan, 2002; Bryman and Cramer, 2005; Bryman, 2008). The value of this measure varies between 0 (i.e. denoting no internal reliability) and 1 (i.e. denoting perfect internal reliability) (Bryman, 2008). To compare groups, the reliability coefficient of 0.5 or above is acceptable (Fink, 2006; Bryman, 2008). According to Nunnllay (1978) as well as many writers are accepted that at or over 0.7 (Tan, 2002), the more internally reliable is the scale.

2.9.2. Qualitative Data Analysis

Data collected through semi-structured interviews and PWMF validation interviews (and open-ended questions in the questionnaire survey) were analysed using a qualitative technique: Constant Comparative Method. Figure 2.4 indicates the procedure adopted for analysing the collected field data.

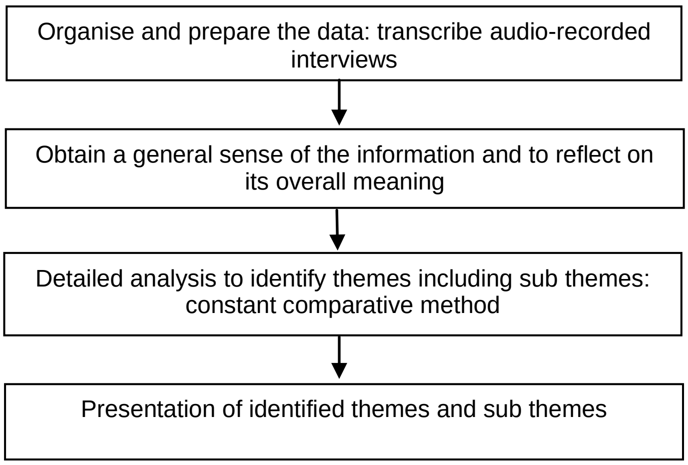

Figure 2.4. Analysis procedure adopted for qualitative data

First, audio recordings of interviews were transcribed with the aid of Express Scribe software (i.e. free dictation software: http://www.nch.com.au/scribe/index.html). Due to the open-ended nature of interview questions, the data transcribed/gathered were of an unstructured nature consisting of long paragraphs, similar concepts in different locations of the text and with unrelated data to the study. Thus, each transcript was read several times in order to clean up and organise the contents of the transcription, to obtain a general sense of the information, and to reflect on its overall meaning.

Second, the Constant Comparative Method was used to analyse data as it allows one to compare different pieces of data, refine or tighten up categories and move on to higher conceptual levels (Bryman, 2008, Tashakkori and Tiddlie, 2009). During data analysis, data was treated as potential indicators of concepts and the indicators were constantly compared to see which concepts they best fit with (Bryman, 2008) and the constant comparative method helps to find contrasts between the theme categories which emerged. The constant comparative method that was advocated by Glaser and Strauss (1967) has four stages:

1. comparing incidents applicable to each category – each 'incident' is compared to a category to which it might (or might not) belong;
2. integrating categories and their properties – comparing 'incidents' to tentative versions of rules that will describe the category;
3. delimiting the theory – reducing the original larger list of categories to a parsimonious set of more inclusive, saturated categories; and
4. writing the theory.

However, in operational terms, the analysis process in this research followed two distinct processes that were presented by Lincoln and Guba (1985): 'unitising' and 'categorising'. During the 'unitising' process, narratives (data) were divided into the smallest pieces of meaningful information (often referred this as 'units of information') under each interview question. For example, it has identified the key waste causing issues (waste origins) associated with procurement documentation. Subsequently, the 'categorisation' process allowed bringing together provisional categories those units of information that relate to the same content; devising rules that relate to each category properties; and rendering each category set internally consistent and entire mutually exclusive. For example, the identified key waste causing issues associated with early involvement of project stakeholders (i.e. during the unitising process) were categorised into three stakeholder categories as client early involvement barriers, contractor early involvement barriers and designers' early involvement barriers.

The analysis was conducted manually, as the amount of data appeared manageable without using qualitative data analysis software. That is mainly because the investigated issues, to some extent, were distinct from each other as the main themes for semi-structured interviews were based on key findings of questionnaire survey. Therefore, data gathered from each question was manageable with manual approach. Microsoft excel 2003 was used for data storing and manipulating purposes (i.e. data formats for unitising and categorising processes). Finally, identified themes and sub-themes were discussed and presented in chapter 5.

2.10. Framework Development and Validation

The third phase of the research focussed on the development and validation of the PWMF for D & B projects. Figure 2.5, illustrates the methodological approach for the PWMF development which indicates the key stages and methods which were followed to develop the PWMF for D & B projects.

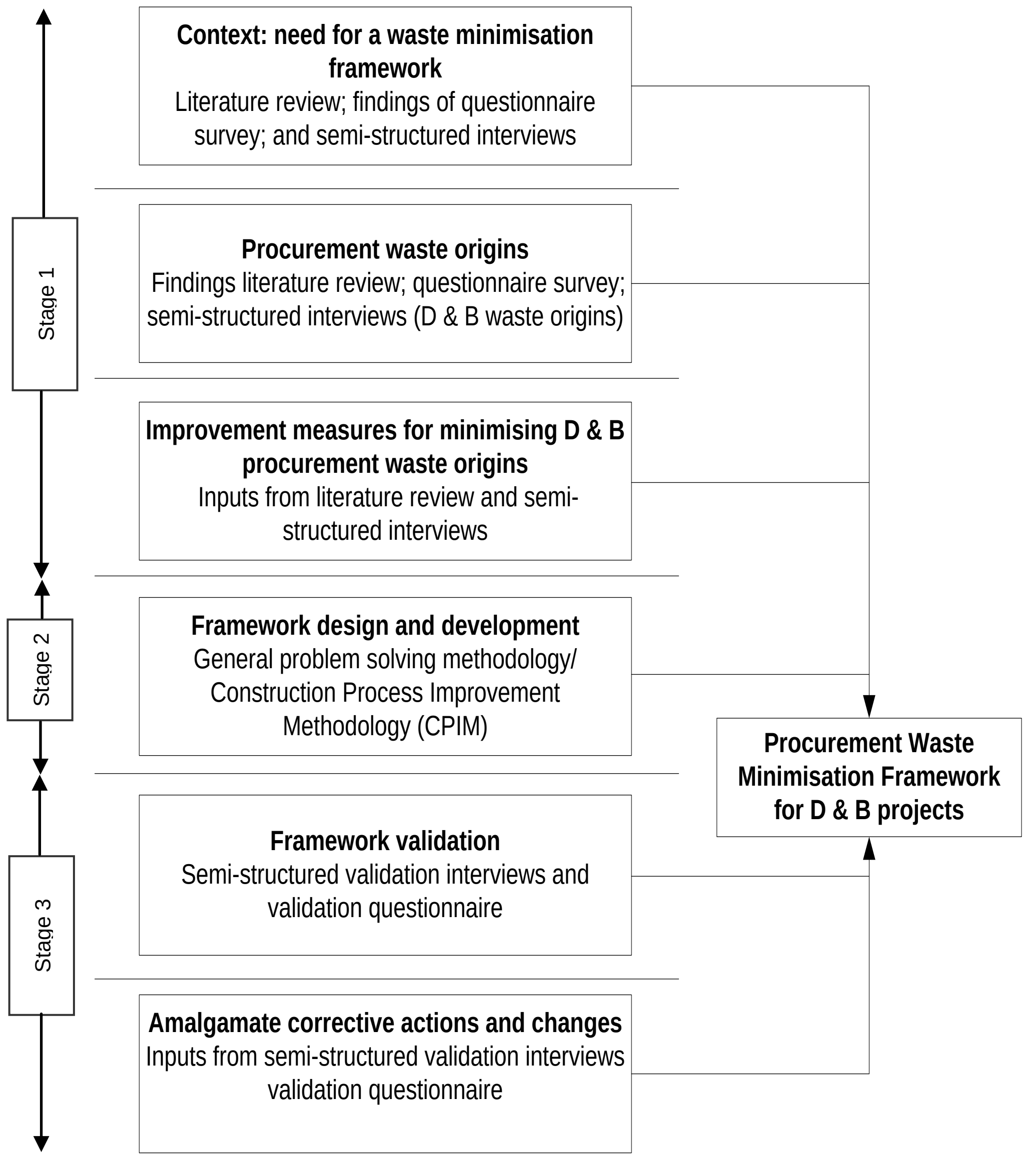

Figure 2.5. Methodological approach for PWMF development

Stage 1 was focussed to the context setting that identified a need for a WM framework; identification of PWO; and identification of improvement measures for minimising PWO. Stage 2 was focussed to PWMF design and development. Stage 3 was aimed towards PWMF validation and amalgamate corrective actions and changes.

2.10.1. PWMF Design and Development Method

There is no clear evidence in literature on WM methods, frameworks or models that consider CPS. The key findings of the questionnaire survey and semi-structured interviews of the research clearly suggested that there is a wide opportunity to develop a mechanism to reduce procurement related waste origins.

The basic concept for the PWMF design and its structure was established based on the principles of general problem-solving methodology. The problem-solving methodology is an approach that can be used to understand the issues pertaining to a situation and to explore means of improving such issues (Straker, 1995; Serpell and Alarcon, 1998). The key principles that were sought by the problem-solving methodology were namely; (1) a diagnostic of current issues (i.e. whether what is happening at present is less than desirable); and (2) an identification of improvement measures for identified issues (i.e. aiming to rectify the situation). These two key principles of problem-solving methodology were used to develop the PWMF: diagnosis of PWO and identification of improvement measures.

The structure of the PWMF comprises three aspects: framework levels; framework axis and coding system. The PWMF was divided into two levels. One page, High-level PWMF aims at a generic diagnosis of PWO and target areas/parties for improvements. One page each, four Low-level PWMF components aim at a specific diagnosis of PWO and improvement measures. The framework axis denotes key procurement waste origins (i.e. horizontal) and procurement WM process that split into diagnosis and improvement measures (i.e. vertical). The PWMF is guided through a coding system which links two main levels of the framework components as well as the contents within each framework. Further explanation about PWMF design and development is presented in Chapter 6, Section 6.2.

2.10.2. PWMF Validation Method

‘Validation’ is ensuring about the credibility by strengthening confidence of research findings (Patton, 2003). Further, validation aims to enhance understanding and explanation (Cronbach, 1984). Messick (1989) mentioned that “validation is essentially a type of scientific inquiry, that a validity judgement is an inductive summary of all available information, with issues of meaning and interpretation central to the processes" (Mishler, 1990, p.418). Therefore, these views suggest that validation is a judgemental process which helps to enhance credibility, explanation and understanding research findings.

Mishler (1990, p.415) noted that "validation is a process through which a community of researchers evaluates the trustworthiness of a particular study as the basis for their own work". Bernard (1994) argued that validation is the collective judgement of the scientific community about the validity of a particular concept and its measures. A similar view can be seen in the literature to the role of researchers and experts' judgements in establishing the validity of findings (Linconln and Guba, 1985; Cronbach, 1988; Straub, 1989; Patton, 2003). Validation process also can involve getting reviews from respondents those who responded at first place for the research (Lincoln and Guba, 1985; Patton, 1990). Furthermore, if respondents are provided an opportunity to examine and comment on the findings, it allows researchers to learn a great deal about the accuracy, completeness, fairness about the final research outcome presented (Patton 2003). Besides, Glesene (1999) described how important study's respondents' feedback to confirm the findings that may help:

- to verify that the research findings have reflected perspective of respondents;
- to inform the problematic sections that, if published (e.g. could be personal or political reasons); and
- to develop new ideas and interpretations.

Therefore, validation refers to evaluation and judgement of the main outcome of research (or the developed instrument) by the involvement of the research community, experts in the field and study's respondents.

Researcher's values and decisions involve in the theme identification process. As such there is always ground for arguments on the validity of identified themes and arrived conclusions (Ryan and Bernard, 2003). As literature indicates, the potential way of addressing such arguments on the validity is to outline in details of the techniques used in the research process, whereas particular reader has the opportunity to understand the context of the research findings and conclusions (Agar, 1980; Patton, 2003). Therefore, the adopted research methodology of this study outlined a number of attempts that were made throughout the research process to ensure richness of validity of findings (e.g. selection of data collection methods, sampling, data analysis, dealing with research bias).

Themes identification and refining itself do not produce a unique solution for the issues investigated in the research (Ryan and Bernard, 2003). Therefore, there are as many ways of seeing and arranging them to gain useful application (s). One such potential way is proposed (i.e. PWMF) in section 2.10.1 by interrogating key themes emerged from this research. Subsequently, there is still question of validity after transformed the findings of the study to a different format. How does one know if the proposed PWMF and the themes identified in it are valid? Based on the above discussion, the validation process of this study involves evaluation and judgement of the developed PWMF by the involvement of (1) researcher (i.e. Initially, the development of PWMF by identifying and synthesising key themes and then analysing the responses of validation respondents); (2) research community (i.e. PWMF refinement discussions with construction management researchers in Civil and Building Engineering department, Loughborough University); and (3) study's respondents (i.e. PWMF validation questionnaire and interviews with PM, SM and QS). The subsequent section describes the process to be adopted for the proposed PWMF validation.

The aim of the framework validation is to refine and examine the appropriateness of the proposed PWMF for D & B projects and to discuss the framework implementation strategy. In light of achieving the above, the four specific objectives of the evaluation were set out: determine the clarity and information flow of the proposed PWMF; determine the information flow and appropriateness of the four PWO and their detailed contents; examine the appropriateness and practicalities of the proposed improvement measures; and identify a potential implementation strategy for the proposed PWMF.

The validation process consisted of three stages: PWMF refinement pilot study (i.e. PWMF pre-validation refinement discussions with construction management researches, Loughborough University), validation questionnaire and face-to-face semi-structured interviews (i.e. a PWMF validation questionnaire followed by a series of semi-structured interviews with PM, SM and QS) (refer to section 2.10.2.3 for the PWMF validation sampling method). While semi-structured interviews were considered as the main validation approach, pre-validation questionnaire was used as a tool to get respondents' attention about the developed PWMF prior to the PWMF validation interviews. The data generated both through PWMF validation semi-structured interviews (qualitative) and PWMF validation questionnaire (quantitative) was used in the framework validation data analysis as both approaches provided a solid basis to framework validation. Consequently, PWMF was finalised by amalgamating corrective actions and changes (Figure 2.5 stage 3) that arose from the results of validation data analysis.

2.10.2.1 PWMF validation questionnaire

The aim of the pre-validation questionnaire was to refine and improve PWMF in terms of clarity, information flow, and contents with regard to generic and detailed components. As shown in Appendix 2.5, the three page questionnaire comprised five sections: background information (respondents' experiences, designation); High-level PWMF validation (clarity and information flow); Four Low-level PWMF validation (improvement measures); implementation strategy and further thoughts. Additionally, two separate questions were forwarded to validation questionnaire respondents: first, to assess the PWO clusters in terms of waste generation severity by ranking them 1 to 4; and second, to assess the impact (High, Medium, Low) that each PWO cluster has on waste generation.

2.10.2.2 PWMF validation semi-structured interview template

The aim of the semi-structured validation interviews was to refine and examine the appropriateness of the proposed PWMF (i.e. in terms of issues raised from the validation questionnaire such as clarity, information flow and improvement measures) and to discuss the framework implementation strategy. Interview questions were in four sections. The first section was aimed at a High-level PWMF validation (clarity of the structure, information flow, appropriateness of the four PWO clusters and their respective contents and appropriateness and practicality of the proposed target areas/ parties for improvements). The second section was focussed on Low-level PWMF components validation [strengths, weaknesses and suggestions (if appropriate) related to waste origins and improvement measures proposed under each PWO cluster]. The third section was aimed to investigate PWMF implementation strategy. The fourth section was focussed on further thoughts: other issues/suggestions that were pertinent to improve the proposed PWMF (Appendix 2.5).

2.10.2.3 PWMF validation respondents sampling method

A similar sampling approach as that discussed in section 2.7.2 was adopted to select respondents for PWMF pre-validation questionnaire and PWMF validation semi-structured interviews. Nine out of seventeen respondents from the second stage data collection (i.e. semi-structured interviews) agreed to participate for the third stage of the study. Out of which, only six (out of nine) respondents were available when they were contacted for interviews: two respondents each from PM, SM and QS. However, as shown in Table 2.10, eight respondents were involved in PWMF validation process. While six out of eight respondents were involved in the study during the previous two data collections (i.e. questionnaire survey and semi-structured interviews), an SM and a PM were joining the study for the first time.

Table 2.10. Composition of PWMF validation respondents sample

PWMF Validation Respondents				**Total**
by company	Contractors		Quantity surveyors	
	4		2	6
by Profession	Procurement managers	Sustainability managers	Quantity surveyors	
	3	3	2	8

2.10.2.4 PWMF refinement pilot study

The PWMF refinement pilot study was aimed to refine the developed PWMF in terms of framework structure and English, clarity of contents, clarity of information flow and gather further suggestions for improvements (Appendix 2.5). Seven construction management researchers (at Department of Civil and Building Engineering, Loughborough University) were involved in the refinement pilot study discussions. The PWMF was further refined based on received comments from the refinement pilot study: for instance formatting and typological errors.

2.10.2.5 PWMF validation process

Five documents were disseminated (i.e. emailed) to eight selected respondents: a covering letter (aim and framework overview), a PWMF pre-validation questionnaire (respondents were asked to complete before the interview date), a PWMF validation interview template, a proposed PWMF and consent form. A similar interview approach as discussed in section 2.8.3 was used to conduct validation interviews. Completed PWMF pre-validation questionnaires were collected before the interview and given responses to the questionnaire were also considered during the interview instances where further explanations are essential. The time allocation was 60 minutes for each interview: High-Level PWMF validation (10 minutes); four Low-level PWMF validation (25 minutes); PWMF implementation strategy (20 minutes) and further thoughts (5 minutes). Six interviews were conducted over approximately three weeks during November 2008 to January 2010.

2.11. Summary

In this chapter, research methodology required in order to achieve the study's aim and objectives has been examined. The chapter has given an account on the overview of literature on research philosophy, research strategies, research designs and methods. Moreover, it has given explanation to the adopted research methodology for the research that included philosophical stance, research strategy, research design, data collection methods, and data analysis process and techniques.

The research has been founded on a pragmatist philosophical stance. Consequently, the study has adopted a combined research strategy: qualitative and quantitative approach. A two stage, sequential mixed methods study has been identified as appropriate to collect both qualitative and quantitative data. In which, cross-sectional postal questionnaire and face to face, semi-structured interviews were considered as data collection methods. While basic concepts of problem-solving methodology are considered for the PWMF development process, both questionnaire and semi-structured interviews are recognised as appropriate for PWMF validation process. Moreover, the chapter has given explanations how the research processes administered (e.g. questionnaire survey, semi-structured interviews, PWMF validation). The chapter also has given an account of the collected data to be analysed: quantitative data using descriptive statistics non-parametric methods and qualitative data using concepts of constant comparative method. The next chapter presents the literature review.

3. Literature Review

3.1. Introduction

This chapter presents the literature review which seeks to examine the relationship between Construction Procurement Systems (CPS) and construction waste generation. The chapter reviews the literature pertaining to three main areas: construction waste; CPS; and the impact of CPS on construction waste generation.

The first section begins by clarifying appropriate definitions and terms of waste, and reviewing the best practicable options to address construction waste related issues (e.g. waste hierarchy). Subsequently, construction Waste Minimisation (WM) drivers and origins and causes of construction waste are examined at length, followed by insights into current construction WM approaches.

The second section examines key aspects of CPS; reviews different definitions of CPS; identifies key stakeholders in the procurement process and procurement selection in construction. Subsequently, it discusses different procurement system classification approaches and introduces current CPS by discussing their processes, organisation, variants to the major CPS; and summarises key advantages and disadvantages of CPS. The section also gives an account of trends in CPS use in the UK.

The third section of the chapter reviews the impact of CPS on construction waste generation. It also synthesises the findings of the previous sections in order to discuss gaps in the literature related to the relationship between CPS and waste generation. It explores sustainable construction procurement; reviews the need to assess the relationship between CPS and waste generation in construction; and explores the relationship between different CPS and waste generation in construction aiming to identify key Procurement Waste Origins (PWO).

3.2. Construction Waste

3.2.1. Definitions

Waste has been identified by the European Council Directive 91/156/EEC as "any substance or object which the holder discards or intends or is required to discard" (Directive 91/156/EEC, Article 1, Letter a). Waste is best defined as any material by-product of human and industrial activity that has no residual value (Serpell and Alarcon, 1998). These definitions apply to all waste irrespective of whether or not it is destined for disposal or recovery operations (Osmani et al., 2005).

The term 'construction waste' is identified in different ways in the literature, which sometimes leads to difficulties in comparing studies and coming to common conclusions. For instance, construction waste can be divided into three major categories: such as material, labour, and machinery waste (Ekanayake and Ofori, 2000; Alwi et al., 2002). However, it is noteworthy that the forthcoming debate is only fussed onto material waste, but not labour or machinery waste.

Waste quantification practices in many countries treat construction waste together with demolition waste (Ekanayake and Ofori, 2000). The issue conveys that the proportion of the total waste generated contributed by construction waste and demolition waste is difficult to generalise, since the proposition between construction waste to demolition waste varies from country to country. For example, it is reported that, in the US, demolition waste is at least double the content of construction-related waste (Peng et al., 1997) and construction waste constitutes 26% of the total amount of waste produced in the Netherlands (Faniran and Caban, 1998). This raises issues about what should actually be accepted as construction waste.

Tchobanoglous et al. (1977) provided one of the more general definitions of construction and demolition wastes, which explain the difference between construction waste and demolition waste. Demolition waste is "waste from raised buildings and other structures". Construction waste is "wastes from the construction, remodelling, and repairing of individual residences, commercial buildings, and other structures". Furthermore, construction wastes are often classified as rubbish and may include dirt, stones, concrete, bricks, plaster, lumber, shingles, and plumbing, heating, and electrical parts (Gavilan and Bernold, 1994). Therefore construction waste variable in composition and waste quantities produced are difficult to estimate. Skoyles and Skoyles, (1987) defined construction waste in a more detailed manner as "a material which needs to be transported elsewhere from purpose of project due to damage, excess, or non use or which cannot be used specifically due to non-compliance with the specifications, or which is a by-product of the construction process”. This definition explains construction waste relating to materials and the way in which generate those as waste (e.g. damage, excess, or non-use). Ekanayake and Ofori (2000) went further by explaining what could be done once the construction waste is generated (i.e. land filling, incineration, recycling, reusing, or composting) in addition to the definition provided by Skoyles and Skoyles, (1987). Further, the definition of Ekanayake and Ofori (2000) has clearly stated how and what could be regarded as construction waste. Therefore, the adopted definition of construction waste for this research is “any material, apart from earth materials and waste from raised buildings and other structures, which needs to be transported elsewhere from the construction site or used within the construction site itself for the purpose of land filling, incineration, recycling, reusing or composting, other than the intended specific purpose of the project due to material damage, excess, non-use, or non-compliance with the specifications or being a by-product of the new construction, remodelling, and repairing processes” (Ekanayake and Ofori, 2000).

Waste Minimisation (WM) has been used as a broad term in different ways. WM can be termed as the reduction of waste at source (NetRegs, 2007). Read et al. (1997) defined WM as “prevention and/or reducing the generation of waste, improving the quality of waste generated, including reduction of hazard and encouraging re-use, recycling and recovery”. This definition relates to efficient use of all inputs in production processes to produce the maximum amount of products alongside minimal waste output (Pratt and Phillips, 2000). Furthermore, definitions of WM can be linked to the way in which waste minimise (e.g. changing processes and activities). The adopted definition of WM for this research is “a systematic approach to the reduction of waste at source, by understanding and changing processes and activities to prevent and reduce waste” (DEFRA, 2006a, p.35).

3.2.2. Waste Quantification

It is difficult to give an exact figure or rate for construction waste produced on a typical site between different countries. For instance, Table 3.1 shows that waste quantities published in different countries are different in terms of unit of quantification. Thus, it enables the comparison difficulties of construction waste figures and rates between different countries.

Table 3.1. Construction waste quantities

(Compiled from literature)

Country	Waste quantification	Reference
Australia	▪ 15% by volume of waste (approximately)	▪ McDonald and Smithers (1998)
Brazil	▪ 20% - 30% of weight of total site building materials	▪ Pinto and Agopyan (1994)
European Union	▪ 25% of all waste (approximately)	▪ Kloek and Blumenthal (2009)
Netherlands	▪ 9% (by weight) of purchased materials (approximately)	▪ Bossink and Brouwers, (1996)
USA	▪ 20% - 30% Kg (waste) /m2 (designed facilities floor area)	▪ Peng et al. (1997)
UK	▪ 120 million tonnes per year (approximately) ▪ 50% of all landfill waste (approximately) ▪ 32% of the total waste (approximately)	▪ WRAP (2007) ▪ Ferguson et al. (1995) ▪ DEFRA (2006b)

Having noted the latter, the figures published in the UK show that construction, demolition, refurbishment and excavation activities produce 120 million tonnes of waste in the UK each year (WRAP, 2007). Furthermore, construction waste accounts for more than 50% of all landfill waste in the UK (Ferguson et al., 1995). In addition, the construction industry consumes a vast amount of materials every year and is responsible for approximately 32% of the total waste generated in the UK, which is little more than three times of household waste (9%) (DEFRA, 2006b). Therefore, this suggests that even within the UK, the comparison of waste figures and rates is difficult as the published data based on different units of measurements.

Skoyles and Skoyles (1987) indicated the allocation of waste on building sites through three different categories as natural waste, direct waste and indirect waste. These three types of waste included under the difference between material quantities delivered to the site and material quantities used for the construction and charged at the final account (Figure 3.1). These examples indicate that research studies have adopted different waste quantification approaches (e.g. percentage of weight, volume, and the cost compared to the initial delivery to site) to quantify waste. Yahya and Boussabaine (2006) noted that waste rates may not be comparable between countries mainly due to differences used in construction techniques, work procedures, and common practices. Moreover, as indicated in Section 3.2.1, different definitions adopted for construction waste may also be account for comparison difficulties of waste rates between countries.

Materials delivered to site	**Natural waste**	**Natural waste**: This waste is sometimes called as unavoidable waste; identified as the acceptable level of waste and allowances for such wastages are included under the 'pricing norms' (normally defined by cost consultants). There is a limit to the waste prevention that can be achieved in the construction process; beyond that, any attempt to prevent it causes greater cost than the value of saving materials.
	Direct	**Direct waste**: Waste, which can be prevented and involves the actual loss or necessary removal and replacement of a material. 'Direct waste' is the only portion of wastage which is unaccounted for under the payments (e.g. *cutting and conventional waste* – when materials cut into various sizes and uneconomical shapes; *stoke pile waste* – loose materials disperse on the site due to poor storage; and *criminal waste* – occurs due to theft and vandalism).
	Indirect	**Indirect waste**: Occurs in cases when materials are used for purposes other than that for which they are ordered. These materials are not lost physically, but cause financial effects: losses to the builder, sub-contractor or to the client. The loss is identified as the difference between the cost of materials, which could have been used and the cost of materials that were actually used (e.g. *substitution of material* – use of high strength concrete instead weak concrete; *production waste* – use of extra plastering to rectify uneven brick work; *negligence waste* – use more materials than specified).
	Material accountable to site	Material used in the construction process charged on the final account at a rate corresponding to the price paid for it.

Figure 3.1. Allocation of construction waste

(Based on Skoyles and Skoyles, 1987)

The above waste figures highlight the fact that construction waste comes to a considerable amount in many countries irrespective of its measure of quantification. However, the figures appear to have a small contribution to the total waste generated as 'Construction and Demolition'. Even if the percentage of contribution of construction waste to the total waste is smaller, the large and growing body of literature has given priority to the investigation and analysis of construction waste due to several reasons (which will be further discussed in section 3.2.3 and section 3.2.4). For example, construction material wastage is given more attention because most of the raw materials used in the construction industry come from non-renewable resources (Ekanayake and Ofori, 2000). The forthcoming section attempts to present a guide to determining the best practicable option to address waste issues.

3.2.3. Waste Hierarchy

The waste hierarchy is a guide to determining the best practicable option to address waste generation related issues. Similarly, the waste hierarchy (Figure 3.2) is a useful framework which sets out the order in which options for waste management should be considered based on environmental impact (DEFRA, 2007b). In addition, the waste hierarchy represents a chain event of priority for waste management, extending from the ideal situation of prevention and reduction to the last resort of disposal.

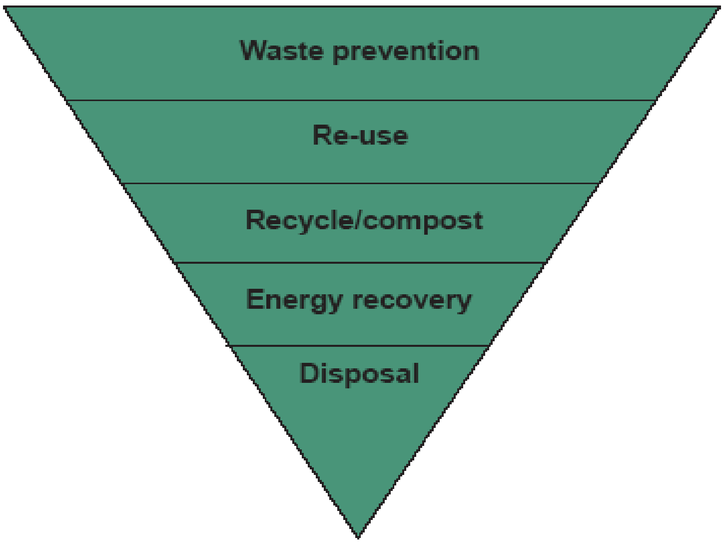

Figure 3.2. Waste hierarchy

(DEFRA, 2007b)

EU policy specifies the waste management hierarchy "waste management strategies must aim primarily to prevent the generation of waste and to reduce its harmfulness. Where this is not possible, waste materials should be reused, recycled or recovered, or used as a source of energy. As a final resort, waste should be disposed of safely" (EU, 2006, p.397). This indicates that primarily it needs to consider options to prevent or reduce waste, since this is likely to be the most effective way to minimise waste generation. Secondary recycling and composting, which are lower in the waste management hierarchy, are possible options to consider and both these options require additional energy and resources to reduce waste levels. However, incineration is to be considered after the opportunities of recycling and composting. Disposal of waste is the last resort, once all other options have been considered and optimised.

Even though waste prevention and WM are placed in top priority position in the waste hierarchy, relatively less attention has been paid to construction WM. Instead, recycling of construction waste has received much research interest in the past decade (Poon, 2007). However, there is a consensus in the literature that reduction is the best and most efficient method for minimising the generation of waste and eliminating many of the waste disposal problems (Peng et al., 1997; Baldwin et al., 1998; Formoso et al., 2002; Esin and Cosgun, 2007; Osmani et al., 2008).

The next section of this chapter will further discuss the extent of the WM option of the waste hierarchy since it could serve as a solution for a number of construction waste related impacts/issues.

3.2.4. Construction Waste Minimisation Drivers

The impact of construction waste can be categorised into two groups: at the project level and problems at the national level (Ekanayake and Ofori, 2000). Construction waste leads to complex environmental issues nationally and globally (e.g. pollution, over consumption of natural recourses, landfill issues). Construction waste related problems at a project level affect contractors' profit, performance, and productivity of the organisation, and finally as an additional cost to the clients' budget (Skoyles and Skoyles, 1987; Ekanayake and Ofori, 2000). Moreover, recent literature has shown that economical, industrial, environmental, government policy and regulatory drivers significantly impact on the industry practices with regard to WM (Osmani et al., 2006, Jaillon et al., 2009). These four thematic drivers also have direct links with issues at project and national levels. Thus, the subsequent section discusses environmental, economic, industry and government policy and regulatory concerns that prevail as the foremost drivers of construction WM.

3.2.4.1 Environmental drivers

Construction waste contributes to environmental pollution such as surface water pollution, attract pests, create fire hazards and detract from the beauty of natural areas (Esin and Cosgun, 2007). Thus, the need for eradicating environment pollution places construction WM as a top priority. Furthermore, construction waste is difficult to recycle due to its high level of contamination and a large degree of heterogeneity (Brooks et al., 1994; Bossink and Brouwers, 1996). Moreover, construction waste is also more difficult to dispose of as it may contain such hazardous matters as asbestos, heavy metals, persistent organic compounds, and more volatile organic compounds than other types of waste (e.g. household waste). Therefore, prevention of construction waste is preferable to recycling of demolition waste “at the end of the pipeline” (Yahya and Boussabaine, 2006).

Furthermore, land is one of the limited resources, which is more damaged due to soil erosion, ground waste contamination, acid rain and other industrial pollutants (Sve, 2009). Limited landfill sites to accommodate the higher volumes of debris from construction sites are becoming a serious problem (Chan and Fong, 2002). Often there is insufficient land space for waste disposal, especially in large cities. Furthermore, in many countries, the large volumes of construction waste strain landfill capacities and leads to environmental concerns. For instance, the landfills in Hong Kong, originally expected to last approximately 40 to 50 years, would be filled up by 2010 (Wong and Tanner, 1997). Besides, a high level of waste creates unnecessary demands on the transportation system in turn accountable for air pollution and high level consumption of natural resources. Construction WM is a major concern because most of the raw materials from which construction inputs are directly originated are from non-renewable resources (Ekanayake and Ofori, 2000), as well as resources that are in danger of depletion, such as timber, sand, and crushed stone (Bossink and Brouwers, 1996). Consequently, high levels of construction waste could result in reducing the future availability of materials and energy. Furthermore, the disposal of waste leads to emissions from landfill sites and incineration. Diverting waste streams away from landfill sites through the collection of recyclables and compostable waste avoids emissions, saves landfill space, and therefore reduces carbon footprint (Wiedmann, 2008). The carbon footprint of an organisation is a measure of the total amount of carbon dioxide emissions that can be attributed exclusively to the full life-cycle impacts of the organisation's activities (Wiedmann and Minx, 2008).

The amount of waste produced emphasises the scope of the environmental problems and the detrimental effect on the environment i.e. higher consumption of natural resources, pollution (hazardous waste), fly tipping, land use (landfill site) and image and responsibility of the construction sector. These can be further related to the UK context as below.

Natural resources consumption: The UK construction sector uses over 420 million tonnes of material resources and converts 6,500 hectares of land from rural to urban use each year (Environment Agency, 2003). Furthermore, approximately 13 million tonnes of construction and demolition waste is material delivered to sites but never used (DEFRA, 2007c). Moreover, 10% of all materials delivered to construction sites in the UK are wasted due to damage, loss and over-ordering (Guthrie et al., 1998).

Pollution (hazardous waste): Construction and demolition waste is the largest component of hazardous waste in England and Wales, constituting 32%, nearly 1.7 million tonnes (DEFRA, 2007a). Waste that has hazardous properties, which may make it harmful to human health or the environment, is known as hazardous waste (NetRegs, 2007). Importantly, the amount of hazardous waste contained in the construction waste shows the extent of danger to the environment, considering the complexity of the problem. For instance, construction materials that have a hazardous risk: adhesives, asbestos, CFC – refrigerants and foam, treated timber, emulsions, solvent-based concrete additives, resins, some scrap electrical and electronic material, bituminous compounds used for roofing, and some packaging associated with hazardous substances (ICE, 2004).

Fly tipping: Construction, Demolition, and Excavation (CDE) waste is a major component of fly-tipped waste. CDE waste formed over 31% (i.e. 21% CDE waste and 10% asbestos) of fly tipping incidents dealt with by the Environment Agency in 2005/06 (Environment Agency, 2007). Moreover, nearly 60,000 incidents involving construction related waste were reported to English local authorities, resulting in significant clean-up costs (DEFRA, 2007a). Thus, both fly tipping and construction related waste cleaning incidents can contribute to environment pollution.

Land use (Landfill sites): The majority of landfill sites contain biodegradable organic matters that are responsible for releasing harmful greenhouse gases such as methane and carbon dioxide, ground water pollution, transportation issues and pollution due to dust, noise and odour. For instance, in 2001, UK landfill sites released 25% of the UK's methane emissions (DEFRA, 2006a). The UK government projected that landfill capacity will be reached by 2017 (Harman and Benjamin, 2003). Moreover, hazardous wastes were banned in the UK from 2004 and there is a legal requirement to treat all hazardous waste prior to its disposal to landfill. Consequently, it is estimated that the number of commercially available landfill sites accepting hazardous waste could have fallen from 240 to 10 -14 (Environment Agency, 2004).

Image and responsibility of the sector: The construction industry as a business is responsible for many issues (e.g. environmental pollution, disposal of waste, health and safety issues) due to higher production of waste. Having said that construction, as an industry has to minimise waste generation in order to reduce potential contribution (i.e. 1/3 of total waste) to total waste generation as well as minimising negative impacts to the environment.

3.2.4.2 Economic drivers

Cost reductions caused by preventing the generation of construction waste is of direct benefit to most of the participants that work on a construction project (Bossink and Brouwers, 1996; Yahya and Boussabaine, 2006). Specifically, because of the construction waste, contractors may be working at a loss due to several reasons: extra overhead costs; delays; extra work on cleaning; and lower productivity (Skoyles and Skoyles, 1987; Ekanayake and Ofori, 2000). Similarly, costs associated with waste disposal (e.g. transportation, Landfill Tax) are also an additional burden for project contractors. Furthermore, Skoyles and Skoyles (1987) pointed out that construction waste has become a burden to clients, as they have to bear the cost of waste in the long run. Similarly, recently it has been demonstrated that clients can gain benefits by tackling construction waste to reduce project costs, typical savings (net of costs) of around 0.2% to 0.7% of construction value (varying by project type) (WRAP, 2010a).

Interestingly, there is a developing perspective driver at project level that construction WM can act as a profit centre (Johnston and Mincks, 1995; Graham and Smithers, 1996; Baldwin et al., 1998) and a means of collaboration between parties. Moreover, Baldwin et al. (1998) noted that minimising waste is arguably the most readily available 'management tool' to save money, and increase profits and can even swing the decision in favour of permitting a particular project. It is reported that WM techniques can typically save businesses between 4% and 5% of their turnover (Netregs, 2007). Moreover, an efficient and effective approach to WM and waste management can typically save up to £110,000 on projects with a floor area of 75,000 Ft^2 (WRAP, 2009). Furthermore, ideally, WM should be 'designed in' for all construction projects. An initial review of where waste is being created can be done before the project operation is on-site, thus generating the first savings before more comprehensive studies. Besides, the minimisation of landfill waste enables savings to be made on transportation and landfill deposit costs, reduces pollution due to transportation, promotes sustainable jobs by encouraging a construction salvage industry, and reduces use of primary natural resources (RICS, 2006).

The construction industry in the UK calculates that its output is worth over £100 billion a year and represents 8% of Gross Domestic Product, and approximately 3 million people in the UK are employed in it (BERR, 2008), with 17% of all employment linked to the industry in some way (RICS, 2008). This indicates the significance of the construction industry to the national economy and its size. Up to 5% of the UK's construction industry turnover is consumed by waste and £200 million spent annually on Landfill Tax (BRE, 2006). The true cost of construction waste includes: the purchase price of materials that are being wasted; the cost of storage, transport and disposal of waste; the cost of the time spent managing and handling the waste; and the loss of income from not salvaging waste materials (CIRIA, 2006). Therefore, this has a wider link to economic effects on material usage. Material waste without any use; 10% all materials delivered to construction sites in the UK are wasted and the true cost of the waste is estimated to be around 20 times the disposal of waste (Inne, 2004). Therefore, this highlights not only the amount of waste generation but also whether or not proper WM practices improve financial benefits for both raw material purchasing and the disposal of waste. Furthermore, Landfill Tax was set to increase by £8 per tonne each April from 2006 up to and including April 2013; when Landfill Tax will have reached £72 per tonne (HM Treasury, 2007). Therefore, the Landfill Tax accelerator will act as an economic incentive to reducing waste at source. In addition, waste handling labour and transportation costs also count in this regard.

3.2.4.3 Government policy and regulatory drivers

Recent literature suggests that there is a growing concern amongst a number of governments to introduce and further reinforce different policies and regulations on WM and management (e.g. Hong Kong, New Zealand, Australia, EU countries, Malaysia). The UK government has also introduced a number of policies and regulations to assist the construction industry to manage and minimise waste. These are at different levels and can be identified into different types including: directives, acts, regulations and good practice guidance. These policies and regulations aim to set up WM and management targets at a strategic level, introducing guidelines with best practice examples, and establishing institutional and legislative requirements for efficient implementation of set targets and guidelines.

Regulations: The UK government established a number of regulations regarding the construction industry WM and management. These include directives such as the Waste Framework Directive (provides overarching legislative framework for the collection, transportation, recovery and disposal of waste) and Landfill Directive (aims to improve standards of landfills such as specific requirements for landfill design operation, and aftercare of them) and acts such as Environmental Protection Act 1990 and Waste Minimisation Act 1998. Moreover, several other regulations are in place urging WM and management in construction such as Aggregates Levy, Hazardous Waste Regulations, Code for Sustainable Homes and Climate Change Levy.

The Landfill Tax and Site Waste Management Plans (SWMP) regulations are widely discussed in terms of their direct impact on WM and management practices. The Landfill Tax aims to encourage waste producers to produce less waste, recover more value from waste (e.g. through recycling or composting), and to use more environmentally friendly methods of waste disposal. Waste Strategy 2007 indicates the Landfill Tax escalator so that the standard rate of tax will increase year by year where as it will give greater financial incentives to businesses to reduce, re-use and recycle waste (DEFRA, 2007a). In addition, the Landfill Directive (European and Landfill Tax for UK) is already bringing about improvements to the way the construction industry manages waste, including setting targets to divert waste away from landfill. Recently, SWMP came into force (in 2008) which made this compulsory for all construction projects in England costing over £300,000 (DEFRA, 2008). This regulation aims to increase the amount of construction waste that is recovered, re-used, and re-cycled and improve materials resource efficacy; and prevent illegal waste activity by requiring that waste is disposed of appropriately, in accordance with the waste duty of care provisions. Thus, a SWMP focuses to record the amount and type of waste produced on a construction site and how it will be reused, recycled or disposed.

Policies: The UK government introduced a number of policies to assist the construction industry to better manage WM and management activities such as Waste Strategy 2007 and Sustainable Construction Strategy 2008. The Waste Strategy 2007 published by DEFRA sets out its vision for waste management. One of the key objectives of the strategy is to decouple waste production growth (in all sectors) from economic growth and put more emphasis on waste prevention and re-use. Waste Strategy 2007 was laid down with the potential objectives of zero net waste (at construction level) by 2015 and zero waste to landfill by 2020 which urges the importance of WM. Further, Waste Strategy 2007 states that the UK government is considering, in conjunction with the construction industry, a target to halve the amount of construction, demolition, and excavation wastes going to landfill by 2012 as a result of waste reduction, re-use and recycling. Specifically, the immediate set target is, by 2012, a 50% reduction of construction, demolition, and excavation waste to landfill compared to 2008. Furthermore, there is the Strategy for Sustainable Construction 2008 which is a joint industry and Government initiative, and is intended to promote leadership and behavioural change, as well as delivering substantial benefits to both the construction industry and the wider economy (BERR, 2008). Among the other sustainable construction targets WM is recognised as one of the overarching target areas, which makes WM into a top priority list in a wider policy context.

Good practice guidance: A number of institutions have been established to support construction industry for WM and Management. Institutions such as Waste & Resources Action Programme (WRAP), Construction Industry Research and Information Association (CIRIA), Environmental Agency, Constructing Excellence, and Envirowise that is linked to WM and management. These institutions offer a number of support avenues: a free help line; free publications; workshops; technical and methodological support; and best practice examples and guidance.

3.2.4.4 Industry drivers

The construction industry stakeholders (i.e. clients, contractors, consultants, manufacturers, material suppliers, and research and development institutions) are becoming more aware about WM and management issues due to various means: fast growing environmental issues; poor economic conditions; and various government initiatives on WM and management such as regulations, policies and good practice guidance. Therefore, the construction industry by itself is asked for more intense WM and management practices.

Increasing client demand for WM and Management: clients are increasing demand for improved environmental performances (Osmani et al., 2006) as their awareness grows about WM and management requirements, applicable legislative requirements and associated benefits. For example, large public clients such as the National Health Service (NHS) have already begun to respond to government legislation on WM and management and aims to cut the costs of waste in NHS construction. As such, guidelines are documented for NHS trusts to address the material use and waste impact of construction projects: business case for NHS Trust to take action on construction waste by deriving improvements through procurement and project teams to measure and report on waste; and model wording to incorporate good practice requirements in procurement documentation (WRAP, 2010a). Thus, as a construction client, the NHS is recommended two main actions: to set clear and actionable requirements for reducing, reusing and recovering construction, demolition and excavation waste in their policies, strategies and procurement documentation; and to ensure that contractors measure and report on performance (WRAP, 2010a).

Institutional pressure and guidance: Institutions linked to WM and management exert pressure and influence on the construction industry by enhancing awareness of sustainable WM and management to abandon their narrow theory of value (i.e. profit making) in favour of broader approach, corporate social responsibilities and seeking stakeholders' engagement (Osmani et al., 2006).

Proactive engagement: There are a number of client and contractor organisations that are leading the way on achieving sustainable WM and management practices. In 2010, over 500 large companies have committed to contribute to halving the amount of construction, demolition and excavation waste going to landfill by 2012 by adopting and implementing standards for good practice in reducing waste, recycling more, and increasing the use of recycled and recovered materials (WRAP, 2010c). Moreover, the major contractors have responsibility for mentoring their supply chain to ensure that the smaller contractors have an understanding of WM and management and how they can improve their working practices.

3.2.5. Origins and Causes of Construction Waste

There are two principal ways through which construction waste can be minimised: through source reduction techniques and improvement of onsite waste management strategies (McDonald and Smithers, 1998). Source reduction is defined as any activity that reduces or eliminates the generation of waste at the source usually within a process (Begum et al., 2007). It is notable that both the terms 'origins' and 'sources' have been synonymously used in the literature. Many studies explored the origins and causes of construction waste. The literature reveals that there are a variety of different approaches to classification of the main origins and causes of waste in construction. These classifications are based on material types (Pinto and Agopayan, 1994; Formoso et al., 2002); different project activities (Gavailan and Bernold, 1994; Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000); project stakeholders (Keys et al., 2002); project life cycle approach (Osmani et al., 2008); and construction sector (Ilozor, 2009). Moreover, several other studies have indicated wide range of factors that construction waste includes delay times, quality, costs, lack of safety, unnecessary transportation, improper choice of management methods or equipments and poor constructability (Koskela, 1992; Serpell et al., 1995; Ishiwata, 1997). Furthermore, Pinch (2005) categorised waste into seven groups: delays due to waiting for upstream activities to finish; over-processing; over-production; maintaining excess inventory; unnecessary transport of materials; and unnecessary movement of people. However, these causes are aimed at reducing waste caused by unpredictable workflow; and are thus applicable not only for construction material waste, but also for labour and machinery waste.

Gavailan and Bernold (1994) identified waste sources in construction as design, procurement, material handling, operation, residual and other. Bossink and Brouwers (1996) also adopted a similar approach to extend the list of sources and respective causes. For the latter, it is important to note that 'procurement' represents 'material procurement' and not a 'contract strategy'. Similarly, Ekanayake and Ofori (2000) categorised construction waste causes under four main categories: design, operational, material handling and procurement (material). Keys et al. (2000) used a different approach and classified waste origins under the headings of manufacture, procurement (material), supplier, designer, logistics, client, contractor and site management. This classification indicates that waste origins are associated not only with project activities but also with project stakeholders.

Ilozor (2009) attempted to ascertain key sources of waste, and whether generation varied with the type and size of the constructors. Although the study has not provided an overly exhaustive review and examination of all aspects that may be relevant to waste management practices or waste causes classification, the study showed that to some extent the construction type and size can influence waste generation and minimisation. Moreover, Tam et al. (2007b) demonstrated that different types of construction projects have different levels of waste generation whereas housing and private commercial projects generated the highest wastage levels when compared with other types of projects. Osmani et al. (2008) adopted a life cycle approach to classifying construction waste origins from inception to completion following RIBA (Royal Institute of British Architects) Plan of Work Stages. Furthermore, this categorisation appears to be comprised mostly from waste sources and courses mentioned in the literature and thus, the classification indicates that although the construction waste (physical) is generated at the construction stage, the causes of waste are linked throughout the project stages.

Design, tendering and contract, and construction can be identified as major processes in a construction project (Cox and Clamp, 2003). For instance, these three processes relate to the key stages of the RIBA Plan of Work: preparation/design stage (Design); pre-construction stage (tendering and contract) and construction stage (construction). Therefore, for the purpose of this study, waste causes mentioned in the literature can be related to three waste origins categories: design, tendering and contract, and construction. Moreover, this categorisation may allow proper understanding of waste causes mentioned in the literature and enhances the simplicity and possibility of integrating into further studies.

As shown in Table 3.2., design changes during the construction period (Gavailan and Bernold, 1994; Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Poon et al., 2004a; Kulathunga et al., 2005; Osmani et al., 2006; 2008), selection of low quality materials and products (unclear specifications) (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Kulathunga et al., 2005; Osmani et al., 2006; 2008) and detailing errors/lack of information and complexity of reading the drawing have frequently been mentioned in previous studies as design related waste causes (Gavailan and Bernold, 1994; Ekanayake and Ofori, 2000; Poon et al., 2004a; Kulathunga et al.,2005; Osmani et al., 2006; 2008). Besides the lack of attentions paid to standard sizes available on the market (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Kulathunga et al., 2005), designers' unfamiliarity with alternative products (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Kulathunga et al., 2005) and lack of attention paid to dimensional coordination (Ekanayake and Ofori, 2000; Kulathunga et al., 2005; Chen et al., 2002; Poon et al., 2004a) have also been identified as design waste causes. Interestingly, few studies indicated waste causes such as last minutes changes due to clients' requirements (Poon et al., 2004a; Osmani et al., 2006; 2008), designers' lack of experience in method and sequence of construction (Ekanayake and Ofori, 2000), and lack of influence of contractors (Bossink and Brouwers, 1996).

Table 3.2. Waste causes: design related

(Compiled from literature)

Waste cause	Source of reference
Design changes (during construction period)	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Poon et al. (2004a,b); Kulathunga et al. (2005); Osmani et al. (2008)
Selection of low quality materials and products (unclear specifications).	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005); Osmani et al. (2006; 2008)
Detailing errors/ lack of information in the drawings/complexity of reading in the drawing	Gavailan and Bernold (1994); Ekanayake and Ofori (2000); Poon et al. (2004a); Kulathunga et al.(2005); Osmani et al. (2006; 2008)
Lack of attention paid to standard sizes available on the market	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005)
Designers' unfamiliarity with alternative products	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005)
Lack of attention paid to design and dimensional coordination and communication	Ekanayake and Ofori (2000); Chen et al. (2002); Kulathunga et al. (2005); Poon et al. (2004a)
Last minute changes due to clients' requirements	Poon et al. (2004a); Osmani et al. (2006; 2008)
Designers lack of experience in method and sequence of construction	Ekanayake and Ofori (2000)
Lack of influence of contractors	Bossink and Brouwers (1996)
Delays due to drawing revision and distribution	Osmani et al. (2006; 2008)
Long project duration	Poon et al. (2004a)
Blue print error	Gavailan and Bernold (1994)

The literature presents limited waste causes that are due to tender and contract. Baldwin et al. (1998) highlighted the issue that contracts could produce waste because of their contractual set-up, in which waste is accepted as lost profit but that the definition of waste may differ for different parties to a contract. As indicated in Table 3.3, errors in contract/tender documents (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000; Osmani et al., 2008) and incomplete contract documents at the commencement of construction (Ekanayake and Ofori, 2000; Kulathunga et al., 2005; Osmani et al., 2008) are recognised in few studies.

Table 3.3. Waste causes: tendering and contract related

(Compiled from literature)

Waste cause	Source of reference
Errors in contract /tender documents	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Osmani et al. (2008)
Contract documents incomplete at commencement of construction	Ekanayake and Ofori (2000); Kulathunga et al.(2005); Osmani et al. (2008)
Contract type (i.e. cost plus- client bears full cost of materials supply to the site)	Skoyles and Skoyles (1987)
Tendering method (allowance being made for waste in the tender)	Skoyles and Skoyles (1987)

Table 3.4 presents waste causes related to the construction stage. This category represents the largest number of waste causes. Therefore, waste causes are further classified into construction activities: material procurement, transportation, on site management and planning, material handling and storage, site operations and residual. Of these, the site operation category appears to have more waste causes than other categories.

Table 3.4. Waste causes: construction related

(Compiled from literature)

Waste cause		Source of reference
Material Procurement	Ordering errors (i.e., ordering items not in compliance with specification)	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005); Osmani et al. (2008)
	Over allowances (i.e. difficulties to order small quantities)	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al.(2005)
	Supplier errors	Gavailan and Bernold (1994); Osmani et al. (2008)
	Shipping errors	Gavailan and Bernold (1994)
Transportation	Damage during transportation	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005); Osmani et al. (2008)
	Insufficient protection during unloading	Bossink and Brouwers (1996); Osmani et al. (2008)
	Inefficient methods of unloading	Bossink and Brouwers (1996); Osmani et al. (2008)
	Difficulties for delivery vehicles accessing construction sites	Osmani et al. (2008)

Cont.

Waste cause		Source of reference
Material storage	Inappropriate site storage space leading to damage or deterioration	Gavailan and Bernold (1994); Enshassi (1996); Ekanayake and Ofori (2000); Kulathunga et al.(2005); Osmani et al. (2006;2008)
	Materials stored far away from point of application	Bossink and Brouwers (1996); Osmani et al. (2008)
	Inadequate storing methods	Osmani et al. (2008)
Material handling	Material supplied in loose form	Kulathunga et al. (2005); Ekanayake and Ofori (2000); Osmani et al. (2008)
	Onsite transportation methods from storage to the point of application	Enshassi (1996); Ekanayake and Ofori (2000): Osmani et al. (2008)
	Inadequate material handling	Enshassi (1996); Gavailan and Bernold (1994); Osmani et al. (2008)
	Unpacked supply	Bossink and Brouwers (1996)
On-site management and planning	Inadequate planning for required quantities	Bossink and Brouwers (1996); Ekanayake and Ofori (2000);Kulathunga et al. (2005); Osmani et al. (2008)
	Delays in passing information on types and sizes of materials and components to be used	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Osmani et al. (2006; 2008)
	Lack of on-site material control	Kulathunga et al. (2005); Osmani et al. (2008)
	Lack of on-site waste management plans	Bossink and Brouwers (1996); Osmani et al. (2008)
	Lack of supervision	Enshassi (1996); Osmani et al. (2008)
	Inadequate project information when work has commenced	Enshassi (1996)
Site operation	Accidents due to negligence	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005);
	Equipment malfunction	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005); Osmani et al. (2008)
	Poor craftsmanship	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Kulathunga et al. (2005); Osmani et al. (2008)
	Use of wrong materials resulting in their disposal	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al.(2005); Osmani et al. (2008)
	Poor work ethic (unfriendly attitudes of project team and labours)	Ekanayake and Ofori (2000); Kulathunga et al.(2005); Osmani et al. (2008)

Cont.

	Waste cause	Source of reference
Site Operation	Poor communication between designer and builder or within organisations	Ekanayake and Ofori (2000); Kulathunga et al. (2005)
	Damage to work done caused by succeeding trades	Bossink and Brouwers (1996); Ekanayake and Ofori (2000); Kulathunga et al. (2005)
	Unused materials and products	Osmani et al. (2006; 2008)
	Time pressure	Osmani et al. (2008)
Residual	Waste from application process (i.e., over preparation of mortar)	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Kulathunga et al. (2005); Osmani et al. (2006; 2008)
	Off -cuts from cutting materials to length	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Osmani et al. (2008)
	Waste from cutting uneconomical shapes (conversion waste)	Bossink and Brouwers (1996); Enshassi (1996); Osmani et al. (2006; 2008)
	Inadequate or incorrect packaging	Enshassi (1996); Bossink and Brouwers (1996); Osmani et al. (2008)

As discussed earlier, a large number of waste causes are related to design, tender and contract, and construction. The impact of each cause to total waste generated is yet unknown and possibly difficult to determine accurately. Moreover, it can be further noticed that some of the waste causes are inter-related and as such could be combined together to make the list of causes manageable for effective WM process.

3.2.6. Waste Minimisation Approaches

The current and on-going research approaches in the field of construction WM and management are diversified into different areas. For instance, Osmani et al. (2008) revealed the current and on-going research in the field of construction WM and management in eleven clusters and so broadened WM and management research studies into twelve clusters. These eleven research approach clusters (i.e. Osmani et al., 2008) appear to have compiled the most up to date (by 2008) research in the field of construction WM and management. Moving further, Table 3.5 shows an updated list (by 2010), twelve research approach clusters in construction WM and management.

Table 3.5. Approaches to WM and management

(Adapted from Osmani et al., 2008)

Research approach clusters	Source of reference (example)
Construction waste quantification and source evaluation	Gavailan and Bernold (1994); Bossink and Brouwers (1996); Faniran and Caban (1998); Ekanayake and Ofori, (2000); Poon et al. (2004a,b); Kulatunga et al. (2005); Guzman et al. (2009)
On-site construction waste sorting methods and techniques	Poon et al. (2001); Wang et al. (2010)
Development of waste data collection models, including flows of wastes, waste management mapping, to help the handling of on-site waste and eco-costing of construction waste	Treloar et al. (2003); Shen et al. (2004); Yahya and Boussabaine (2006); Hao et al. (2010)
Development of on-site waste auditing and assessment tools	McGrath (2001); Chen et al. (2002)
Impact of legislation on waste management practices	Eikelboom et al. et al. (2001); Tam et al. (2007c); Hao et al. (2008)
Improvements of on-site waste management practices	McDonald and Smithers (1998); Chadrankanthi et. al. (2002); Hao et al. (2008); Tam (2008)
Reuse and recycle in construction	Lawson et al. (2001) ; Emmanuel (2004)
Benefits and factors of WM	Rounce (1998); Coventry et al. (2001); Begum et al. (2007)
WM manuals, including guides for designers	Coventry and Guthrie et al. (1998); Greenwood (2003) ; WRAP (2010d)
Attitudes towards waste	Lingard et al. (2000); Teo and Loosemore, (2001); Sanders and Wynn (2004); Kulatunga et al. (2006); Begum et al. (2009)
Comparative waste management studies	Conventry and Guthrie (1998); Chen et al. (2002); Ilozor (2009)
Construction waste reduction by design	McDonald and Smithers (1996); Keys et al. (2000); Osmani et al. (2006: 2008)

A scrutiny of clusters indicated in Table 3.5 shows that the approaches for construction waste mainly focussed on waste management during the construction stage. For instance, implementing waste management plans during the construction stage (McDonald and Smithers, 1998), waste auditing and assessment (Chen et al., 2002), waste sorting methods and techniques (Poon et al., 2001), and supply chain integration (Dainty and Brooke, 2004).

Very few approaches are evidently related to the design and pre-contract stages, of which a number of studies focussed on WM through design (Keys et al., 2002; Jaques, 2000; Osmani et al., 2006; 2008; Kelly and Hanahoe, 2008; WRAP, 2010d). Several studies attempted to identify design waste causes and recommended solutions: WM manuals, including guides for designers (Coventry and Guthrie et al., 1998; Greenwood, 2003; WRAP, 2010d); standardisation of design (Hylands, 2004; Osmani et al., 2008); appropriate specification for expected lifetime (McDonald and Smithers, 1996; Coventry et al., 2001); and potential of using prefabrication (McDonald and Smithers, 1996; Dainty and Brooke, 2004; Tam et al., 2007a; Silva and Vithana, 2008; Baldwin et al., 2009; Jaillon et al., 2009). OGC (2007a) introduced a sustainable design checklist for waste management and minimisation. Moreover, Keys et al. (2000) noted a broad list for design out waste methodologies: use of prefabrication and off-site construction; standard component/bespoke design; realistic component size, capacity and specification; minimising temporary works; optimising design lives; allowing specification of recycled materials in design; designing for recycling and ease of disassembly; identification of building products that create waste; and poor communication. Recently, WRAP (2010d) introduced a detailed guide for design teams to design out waste from building projects. The guide identifies five key principles: design for reuse and recovery, design for offsite construction, design for material optimisation, design for waste efficient procurement, and design for deconstruction and flexibility.

Even though few attempts were made to identify waste causes with regard to tender and contract, several research studies pointed out that it is critical to introduce special tender/contract clauses at the pre contract stage targeting WM (CRiBE, 1999). Greenwood (2003) recommended a fully integrated WM system at the contractual stage that should be able to identify and communicate the responsibilities for WM between all project stakeholders. Moreover, Greenwood (2003) highlighted that the client has the best opportunity to communicate the requirements and targets of WM to the contractor during the tendering process: by indicating clients WM requirements clearly in the tender invitation; and likely awarding the contract based on the experience in WM activities. This view is mostly applicable for experienced and knowledgeable clients in terms of construction industry. However, there could be a responsibility of client representatives (e.g. consultant designers) to bring client requirements and targets of WM to contractors through tender process. Findings of Tam et al. (2007a) also suggested that contractual requirements are mandatory targeting main contractors for successful implementation of quality, environment and safety management standards within projects. McDonald and Smithers (1996) recommended that for traditional tendering a clear mechanism must be included that should allow designers' WM efforts to be reflected in the final tender price: by identifying in tender information that WM techniques have been adopted in the design; and requesting tenderers to identify allowances made for these techniques in their tender submissions.

Moreover, achieving excellence in construction procurement guide (UK) mentioned that during the procurement process (i.e. procurement stage) the brief should include a requirement for suppliers/contractors to provide waste management plans; and the target should be specified for WM, recycling reuse and how performance will be monitored (OGC, 2007a). Dainty and Brooke (2004) suggested the introduction of contract clauses to penalise poor waste performances. Greenwood (2003) suggested writing down standard tendering conditions and contract clauses in accordance with project WM requirements. Interestingly, Tam et al. (2007a) revealed that current legal commitments (thought it limited) have been mainly allocated to contractors and insufficient commitments and responsibilities are allocated to other project participants such as project clients, designers and consultants. Therefore, they highlighted that there is need for a balanced allocation of responsibilities and commitment among all project stakeholders. Recently, WRAP (2009) introduced a web-based guidance on model procurement requirements (for reducing waste to landfills) wording to client and contractor actions at the key project stages (i.e. policy, preparation and design, pre-construction and construction, handover, post completion and use) to consider all available WM opportunities.

Several studies attempted to evaluate waste sources and causes that were relevant to all project stages (Gavailan and Bernold, 1994; Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000). This highlights the WM efforts need to be enveloping all project stages than at single stage focus. Furthermore, Poon (2007) emphasised that construction waste reduction should be considered at an early stage and by all parties involved in the building process. Baldwin et al. (1998) emphasised the need of partnerships and demonstrating good examples to contractors and clients as a means of reduce waste. Similarly, Dainty and Brooke, (2004) emphasised the need for establishing an integrated WM strategy where project stakeholders must be involved and committed to WM and clients must demand better waste performance from principle contractor(s) and thereafter should communicate it to subcontractors and suppliers whom should take responsibility for implementing trade waste measures suited to their particular package in a way that integrates with other stakeholders' activities. Moreover, Teo and Loosemore (2001) suggested a number of important recommendations for managers wanting to develop waste management policies that engender positive attitudes towards waste at operative level on construction projects: demonstrate commitment to issue of waste; cost benefits of waste reduction appeared and be shared out equitably; provide quality, site specific and practical information about waste management strategies; establish waste management policies to be clearly communicated at project and company level and properly understood by operatives; promote performance requirements to reduce waste and impose equitably at all levels to promote sense of collective responsibility for waste reduction; facilitate the involvement of the work force in waste reduction efforts (avenues for ideas exchange, opinions, feedback); and benefits of waste management should be linked to other project goals. Furthermore, the application of lean principles and concurrent engineering, education, awareness, training programmes, value management techniques, logistics management system, just in time technique (on time and bulk ordering), financial incentives and research are also evident in literature as potential approaches for WM.

Section 3.2.5 has classified waste causes in construction into three categories: design waste causes, tendering and contract waste causes, and construction waste causes. However, arrangement of these three clusters within a CPS is different among different CPS. As such, it can be argued that the effect of waste causes under each cluster on construction waste generation could vary with different CPS. Consequently, the amount of construction waste generated is dependent on selected CPS. Indeed, very few studies have highlighted that CPS could have an influence on generation (section 3.4.1). Thus, the relationship between CPS and waste generation needs to be explored in order to attain WM through CPS. Subsequent sections will discuss CPS in order to pave the way for such relationships.

3.3. Construction Procurement Systems

3.3.1. Definitions

There has not been an internationally accepted definition for construction procurement. However, a series of international standards for construction procurement is currently under development by the ISO. Of which, ISO 10845-1:2010 – part 1 has now been published, with the focus being on construction procurement: Processes, methods and procedures.

The concept of procurement in construction has been identified in different ways. Recently published ISO 10845-1 identified "procurement as the process through which contracts are created, managed and fulfilled. It involves all the steps from the establishment of the project or products to be procured, to soliciting and evaluating tender offers, to awarding and administering contracts and confirming compliance with requirements". Masterman (2002) reported a definition put forward by CIB W92 (1997), procurement process as "a strategy to satisfy clients development and/or operational needs with respect to the provision of constructed facilities for a discrete life cycle." The same source emphasised that the procurement strategy must cover the whole lifespan of a project. Yet, this definition does not refer to 'procurement system'. Instead, it highlights procurement process for a life cycle of constructed facility.

The strategy, which is the most appropriate method of procuring the project, is known as a procurement system (Masterman, 2002). The term procurement system is defined as "the organisation structure adopted by the client for the management of the design and construction of a building project" (Masterman, 1992), and "the organisational structure adopted by the client for the implementation, and at times eventual operation, of a project" (Masterman, 2002, p.27). Both these definitions characterise a procurement system as an organisational structure adopted by the client for the management/implementation of a project, while the former definition covers the management of design and construction of a building project, the latter extends to cover operational period of a project. Similarly, Love et al. (1998, p.222) defined a procurement system as "an organisational structure that arranges specific responsibilities and authorities to participants and defined the relationship of the various elements in the construction projects". This definition expresses some key attributes of a procurement system. Additionally, it gives an insight into how organisational structure should be arranged (i.e. responsibilities, authorities, relationships). However, when compared with the previous stated definitions (i.e. CIB

W92, 1997; Masterman, 1992; 2002) it does not indicate key elements of a project that a procurement system should be covered, or the purpose of the system. Cheung (2001) suggested that the system of procurement includes the organisational arrangement of project participants and project stages to achieve the project objectives, and is critical for determining the overall framework embracing the structure of responsibilities and authority for participants within the building process.

Rolwilson and McDermott (1999) reported that a working definition of procurement was developed by CIB W92 at a meeting in 1999 and it is defined as “the framework within which construction is brought about, acquired or obtained”. Rolwilson and McDermott (1999) noted that this definition served a useful purpose in terms of encouraging a strategic interpretation of procurement and neutral as being applicable for both developed and developing market economies. Furthermore, this definition indicates CPS as a framework, which provides a basis to acquire or obtain construction. However, it is too broad and suggests being customised by incorporating some earlier discussed attributes.

The above review suggests several attributes that need be included in a definition of a CPS:

- characteristics (i.e. an organisational structure that arranges specific relationships and authorities to the participants, and defines the relationship of key elements in the construction project);
- elements (i.e. design, construction and operation of the project); and
- purpose (i.e. acts as a management framework to the client for the management of key elements of the projects).

The following definition, which is put forward by incorporating the above three attributes, will be used in this research;

A procurement system is an organisational structure that arranges specific relationships and authorities to the participants, defines the relationship of key elements in the construction project and acts as a management framework to the client for the management of design, construction and eventually operation of the project.

3.3.1.1 Procurement System or Contract Strategy?

CPS have been a focus on contract management and forms of tendering for construction projects in early 1990s (Walker and Rowlinson, 2008). However, the belief that a CPS is defined by a simple contract strategy is misleading (Rowlinson and McDermott, 1999). Instead, a contract strategy is a key component of a CPS (Figure 3.3) and should be considered within the whole CPS by encompassing the cultural political, social, environmental, and economic factors, which impinge upon any project (Rowlinson and McDermott, 1999; Masterman, 2002; Walker and Rowlinson, 2008).

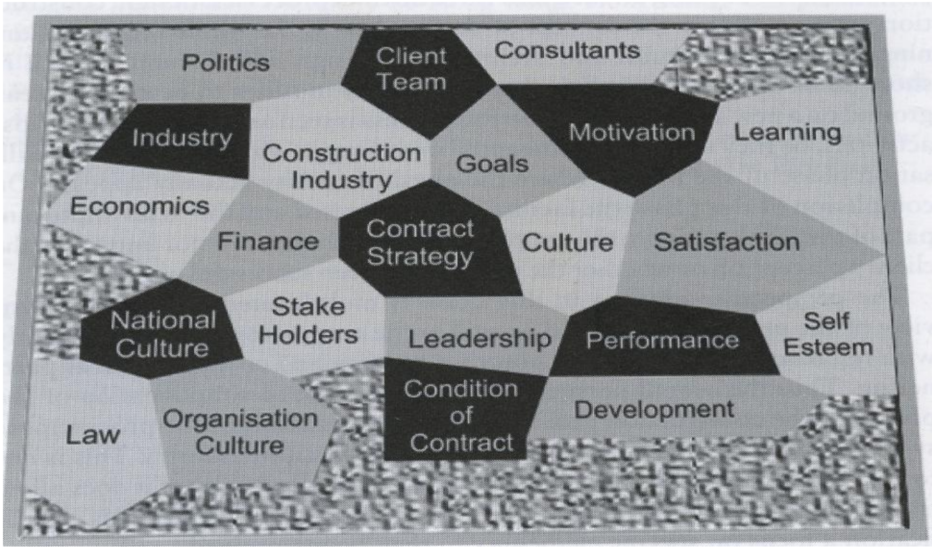

Figure 3.3. A view of CPS

(Rowlinson and McDermott, 1999, p.28)

According to Austen and Neale (1995), 'procurement' is about the acquisition of project resources for the realisation of a constructed facility. Moreover, Austen and Neale (1984) put forward a model (which was highlighted and discussed by Rowlinson and McDermott, 1999) in order to demonstrate the acquisition of resources such as consultants, contractors, sub-contractors, suppliers and clients' own resources that are essential in order to achieve the realisation of a construction project (Figure 3.4).

Therefore, the acquisition of resources or the process of combining necessary resources together is part of the CPS and this could be termed as contract strategy. In order to clearly and adequately define contract strategy, the following variables should be considered: organisational form, payment method, overlap of project phases, selection process, source of project finance, contract documents, leadership and authority, responsibility (Rowlinson and McDermott, 1999), the mechanism for ensuring integration, coordination and active collaboration between project participants (Walker and Rowlinson, 2008).

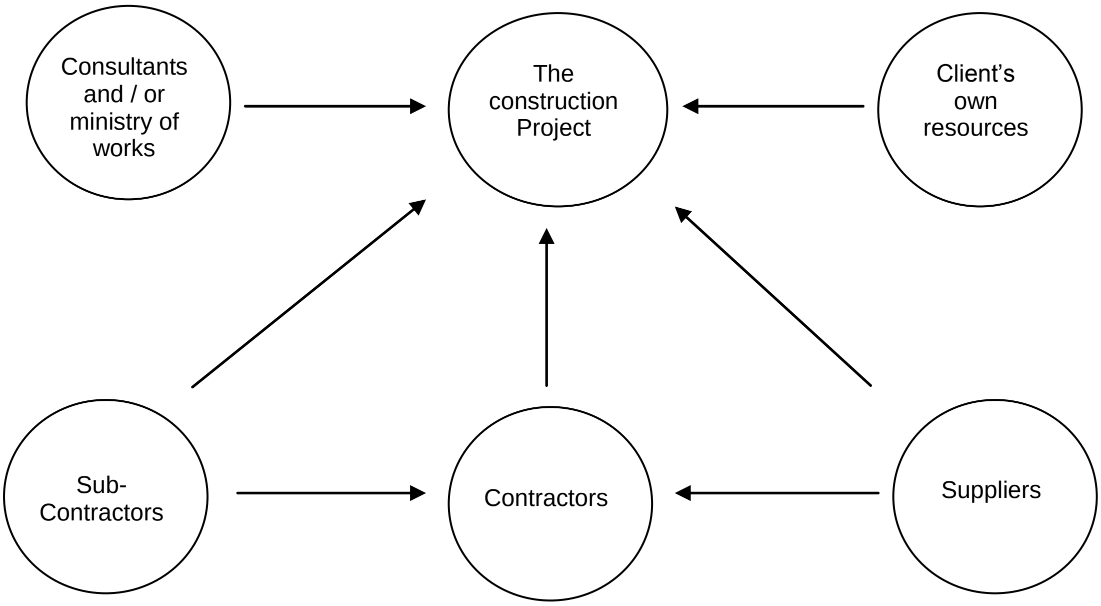

Figure 3.4. Procurement model

(Austen and Neale, 1984, p.34)

3.3.1.2 Relationship between project stages and CPS

Often the term 'procurement' refers to 'procurement stage of a project'. However, as discussed earlier, a CPS envelops a broader spectrum than just a project stage. Project process can be divided into three distinct processes: design, construction and use (Rowlinson and McDermott, 1999). 'Design' process includes: a whole range of planning, funding, structural and architectural design and documentation. The 'construction' process involves all activities: technical, managerial, or strategic which are necessary for the realisation of physical facility. The 'use' process begins with the end of the construction process, which impacts on clients' perceptions of whether the whole process has been successful or not. According to the review of CPS definitions in section 3.3.1, a selected 'CPS' for a project is covered in all of the aforementioned three distinct processes. Moreover, the literature illustrates a detailed organisation between project stages and CPS relating different CPS to all stages of RIBA Plan of Work (Cox and Clamp, 2003; Wilkinson and Gupta, 2005).

Four key elements can be drawn from a project that relates to a CPS i.e. design, tendering & contract, construction and use/operation based on the definition of the procurement system (section 3.3.1) and the purpose of contract strategy (section 3.3.1.2). Figure 3.5 illustrates how a CPS relates to different elements of the construction project process.

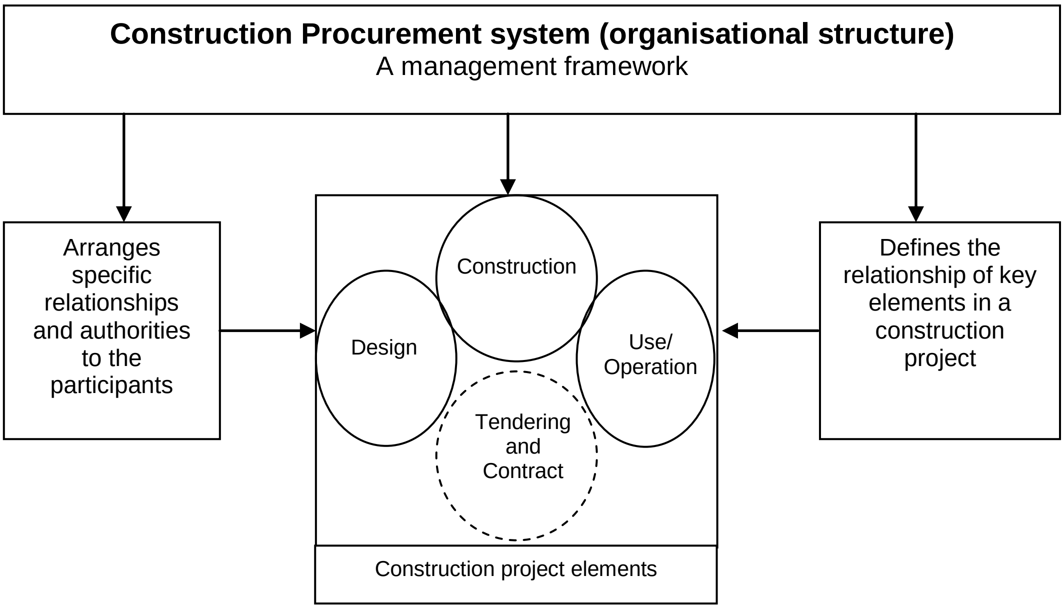

Figure 3.5. Relationship between construction project stages and CPS

3.3.2. Key Stakeholders in Construction Procurement

Stakeholder identification, management, and engagement are recognised as key to project management (Cleland, 1999; Walker and Rowlinson, 2008; Mathur et al., 2008), accordingly for construction procurement. The composition of the project team or the relationship of the parties involved in the procurement process may vary, according to the CPS chosen (Turner, 1997).

The client is the principal party to the procurement process; other parties such as consultants' team, contactor team, project or contact managers, suppliers, subcontractors involved may or may not have a direct contract with the client. The key players in the procurement process can be identified as: client; design team including architect, engineers, technology experts; project manager; cost advisor usually a quantity surveyor; contractor and sub-contractors (i.e. include a professional team such as contract/project manager, engineers, quantity surveyors) and suppliers (Table 3.6).

Table 3.6. Key stakeholders in construction procurement

(Compiled from literature)

Stakeholder	Description
Client	▪ The organisation, or individual, who commissions the activities necessary to implement and complete a project in order to satisfy its/his/her needs and then enters into a contract with commissioned parties ▪ The characteristics of clients influence the implementation of construction project and affect the choice of the most appropriate method of procurement E.g. individuals, groups or partnership of people, corporate bodies; private and public clients; clients who build once or rarely; those who build often; those who build owner occupation; those who build for investment or as developers; those who act as agents or agencies for those who will eventually occupy the building
Designers	▪ Designers often considered as design consultants and key professionals such as architects, engineers (structural and services), surveyors and technology experts ▪ The composition of the design team varies due to several reasons such as project characteristics (type, size, etc.) and adopted CPS ▪ Prepare necessary designs, specifications (e.g. materials, services works; mechanical and electrical), and other relevant documents; supervise the work on the site and retain responsibility for coordinating the work
Project manager	▪ Coordinate and manage the entire project process from inception to completion in order to secure maximum efficiency and enable the client to obtain all information concern the project from one person ▪ Appointment and the role of the project manager may vary according to the CPS adopted ▪ Involves in procurement decision making process
Quantity surveyor	▪ Ensures that the project is kept within the agreed budget and deliver the project to obtain the value of money ▪ Two main distinct roles: to provide cost advice to the design team as an integral part of the design team; and to advise the client generally about cost and value, separate from the design team ▪ Role is diversified into different areas such as procurement selection and management, project management act as commercial managers and procurement managers

Cont.

Stakeholder	Description
Contractor	▪ Undertakes the responsibility of completing a building project in accordance with the contract documents on behalf of the client ▪ Depending on the procurement system selected, contractors undertake design services and construction management services ▪ Holds control of all operations on site, including the work carried out by sub-contractors.
Sub-contractors and suppliers	▪ Sub-contractors carry out defined elements of construction work for the contractor; may design some elements; manufacture and supply the materials or equipment. ▪ Supply materials or equipment; may provide advice or a design services to the design team ▪ Appointment: nomination by client or the principal contractor; depends on the procurement system adopted

Source: Potter (1995); Turner (1997); Seeley (1999); Masterman (2002); Walker and Rowlinson (2008)

Duties, responsibilities, and the relationship between the client and each party vary from one CPS to another depending on the characteristics and organisation of the particular CPS; these differences are discussed in section 3.3.3 and section 3.3.4.

3.3.3. Selection of Procurement Systems

The correct choice of a CPS will ultimately lead to the success of a building project (Chan et al., 2001). If a client or person who is responsible for the selection of a CPS makes a wrong choice, the penalty may be time and cost overrun and a general dissatisfaction. Therefore, the selection of the most suitable CPS is critical for both the client and all other project stakeholders, particularly once the choice has been made and implemented it is unlikely that any remedial action will be possible, because such an attempt of changing the method of design and construction can be costly and will result in delays to the project (Masterman, 2002).

The selection of the CPS involves a systematic assessment of alternatives forms of contract (i.e. alternative CPS) available to the construction industry (Addis and Talbot, 2001). Thus, the basis of CPS selection is the identification of factors that influence the CPS selection process. Traditionally, CPS selection processes result in clients prioritising the basic criteria of cost, quality and time (Seeley, 1997; Addis and Talbot, 2001; Cartlidge, 2004).

The CPS selection has evolved beyond the consideration of traditional factors. For instance, OGC (2007b) indicated the factors that influence the CPS selection should be considered as: project objectives; constraints such as budget and funding, the time-frame in which the facility is to be delivered and the exit strategy; cultural factors such as considerations of the workspace environment that will best support the way people work; risks such as late completion of the facility, innovative use of materials; client's capabilities to manage a project of this type and the length of operational service required from the facility. Moreover, the literature revealed that the selection of a CPS is influenced by client characteristics (Moshini, 1993; Masterman and Gameson, 1994; Molenaar, 1999); client requirements (Latham, 1994; Kumaraswamy, 1994; Chan et al., 2001; Chang and Ive, 2002; Ratnasabapathy et al., 2006; Walraven and de Varies, 2009); project characteristics (Gordon, 1994; Ambrose and Tucker, 1999; Rowlinson, 1999) and external environment (Walker, 1989; Alhazmi and McCaffer, 2000; Kumaraswami and Dissanayake, 2001; Ratnasabapathy et al., 2006). Table 3.7 summarises CPS selection factors, which have been identified from the literature under client requirements, client characteristics, project characteristics, and external environment.

Table 3.7. CPS selection factors in construction

(Compiled from literature)

Client Requirements	Client Characteristics	Project Characteristics	External Environment
▪ Value for money ▪ Speed ▪ Cost Certainty ▪ Quality ▪ Time Certainty ▪ Flexibility ▪ Responsibility ▪ Complexity ▪ Risk allocation/ avoidance ▪ Innovative design/ technology ▪ Price competition ▪ Disputes and arbitration ▪ Public accountability	▪ Public ▪ Private ▪ Experienced ▪ Inexperienced ▪ Primary ▪ Secondary	▪ Project size ▪ project type ▪ Building construction type ▪ Project site location ▪ Site risk factors ▪ Usage of pioneering technology ▪ Payment method ▪ Degree of project complexity ▪ Degree of project flexibility	▪ Political ▪ Economic ▪ Legal ▪ Technological ▪ Sociological

Interestingly, it is apparent that none of the major studies into CPS selection have identified sustainable issues/requirements (e.g. WM, energy conservation) as key criteria for CPS selection. A recent study conducted by Adetunji et al. (2008) revealed that there is still no ‘level playing field’ as procurement practices have largely been focussed on price, whereas the commitment to sustainability issues has been an act of faith rather than a contractual deliverable. Similarly, Varnas et al. (2009) revealed that environmental criteria in tender evaluations are less common and seldom affect the award decisions. Furthermore, Jaillon et al. (2009) revealed that the construction industry paid less attention to WM than other issues such as construction cost, construction time, familiarity with the construction technology, buildability in the local market developer’s requirements and availability of resources. This finding is reaffirmed in other studies that indicate WM was given less attention compared to other issues (Poon et al., 2004a; Osmani et al., 2006).

Conversely, Dainty and Brooke (2004) emphasised that the challenge was how to embed the type of WM schemes from high profile projects such as those investigated to the wider construction environment, where WM may not be given such a priority. Furthermore, the same authors suggested that the main concern should be placed on overcoming the perception that waste is inevitable and embedding the importance of WM as a key performance criterion.

Generally, any CPS is not stand clearly or consistently better than another CPS. However, the success of any CPS tends to depend on greater level of client participation in the procurement process (Davenport and Smith, 1995) and clear guidance from the client who is responsible for playing a key role during the pre-design stages of a construction project, effective management of the project and good understanding and sharing of environmental goals among the design and construction team (Walker, 1995; Addis and Talbot, 2001). Experience with similar projects and a variety of CPS still count for a great deal (Addis and Talbot, 2001).

The decision making point on a particular CPS for a project is also vital as a procurement selection criterion. According to the RIBA Plan of Work 2007, the decision making process needs to be spanned between stage B (Design Brief) and C (Concept) (Table 3.8). However, if the timing of the decision on procurement selection is delayed through RIBA stages, the opportunity of considering a wide range of CPS is minimised. For instance, if the procurement decision is held back until stage E (Technical Design), it eliminates the opportunity for considering alternative CPS such as D & B system and management oriented systems.

Table 3.8. Timing of procurement decisions

(According to RIBA Plan of Work Stages 2007)

Stage		Description of key tasks (relevant to procurement system selection)
B	Design brief	▪ Identification procurement method, procedures, organisational structure, and range of consultants and others to be engaged for the project.
C	Concept	▪ Review of procurement route

Masterman (2002) noted that many clients do not appear to recognise the necessity of making an early decision on CPS selection or even occasionally realise that such choice is required. Further, the same review indicated the need for selecting a CPS before appointing any individual or organisation, other than principal advisor. This allows sufficiently early time in the procurement process so as to enable the consideration of a wide range of available CPS to be chosen and enable an unbiased choice in terms of CPS (if designers are appointed before the procurement decision, the decision on procurement system may be influenced).

Literature that investigates the timing of the choice of CPS is limited. However, Masterman (2002) revealed that the timing of the choice of CPS among 62 clients surveyed show that clients choose procurement system in Inception (53.23%), Feasibility (24.19%), Outline design (17.74%) and Detailed design (4.84%) respectively RICS Plan of Work Stages (before Philips, 2006). This suggests that clients select the CPS in stages where it allows them to consider a wide range of CPS and enables an unbiased choice of procurement decision making. However, this may vary depending on the characteristics of the client.

3.3.4. Procurement Systems in Construction

Categorisation of CPS becomes necessary due to the emergence of different CPS; for example, Sharif and Morledge (1994) who have drawn attention to the inadequacy of the common classification criteria for CPS in enabling useful global comparisons. In a review of procurement and contractual agreements in the UK, Latham (1994, p.5) noted the difficulty of drawing conclusions from existing studies, and stated that “some international comparisons reflect differences of culture or of legislative structures which cannot easily be transplanted to the UK”. On the other hand, CPS have become increasingly flexible (Love et al., 1998). Fellows (1993) suggested that the interchange that exists between such systems has made it essential to distinguish the CPS from the formal subsystem and the subsystem may be used interchangeably in order to enable the procurement system to be tuned to the client, circumstances, and requirements.

Categorisation of CPS is based on several factors. For instance, CPS are based on the range of organisational variants for project management, design and construction (Turner, 1997). Furthermore, categorisation can be based on the way in which responsibility is allocated by the client (i.e. multipoint systems and single point systems) and the way an organisation is responsible to the client for construction payments (i.e. Lump sum, management fee) (Potter, 1995). Similarly, Masterman (2002) explained four possible ways of categorising CPS.

- By the amount of risk taken by the participating parties; the most negative aspect of this categorisation has difficulty in identifying the fundamental differences between the various systems.
- By the level of information available or required at the time that construction contracts are let; this basis is focussed on the amount of overlap required between completion of design and commencement of construction. However, this criterion is likely to be one dimensional and misleading to decision makers.
- The case when a contractor is reimbursed; is considered to be an invalid categorisation as many CPS allow reimbursement method to be made in the same way and would not assist in identifying the individual systems.
- By the way in which the interaction between the design and construction and sometimes funding and operation, of the project is managed; this method enables fundamental issues of the relationship between the main elements of the project to be identified and the approach is considered to be most appropriate means of classification in assisting selection of CPS. Masterman (2002) adopted a fourfold categorisation of CPS: Separated (the conventional system), Integrated (D & B, variants of D & B), Management oriented (Management contracting, Construction management, Design and manage) and Discretionary (British property federation system, Partnering).

Frequently, integrated, management oriented and discretionary systems are referred to in literature as non-traditional CPS or alternative CPS and these systems have been advocated as methods for overcoming some problems inherent in separated (conventional) methods (Turner, 1997; Masterman, 2002). The distinct feature of such recognition of non-traditional methods is early contractor involvement during the design (and development) process. Early contractor involvement allows buildability or constructability advice to the development of design solutions that maintain value in terms of the quality of product as well as providing solutions to construction stage issues (Francis and Sidwel, 1996; McGeorge and Palmer, 1997; Greenwood et al., 2008).

The subsequent sections introduce the basic forms of CPS, which are being used in construction, in line with the fourfold categorisation of Masterman (2002) and further attempt to outline the process that runs through each CPS.

3.3.4.1 Separated procurement system

The unique characteristic of the separated system is the rigid separation of the design and construction process. At least in theory design and construction are seen as separate elements (Cox and Clamp, 2003; Walker and Rowlinson, 2008). Often this category is referred to as the traditional system, conventional system or Design Bid Build (DBB) and has been used by the majority of clients of the industry for at least the past 150 years (Masterman, 2002). This system remains in use mainly because most contractors and clients are aware about the system and thereafter it became a default approach for the procurement of construction projects (Walker and Rowlinson, 2008).

In traditional procurement methods, the client accepts that consultants are appointed for design, cost control and contract administration. The contractor is usually selected after competitive tendering (open tendering) or on a closed or prequalified tendering basis (Walker and Rowlinson, 2008). A study conducted by Love (2002) noted that single stage tendering was predominately used in conjunction with traditional methods, whereas the negotiated type tended to be used more with non-traditional methods. Conversely, the most popular methods of tendering have been found in the UK in order of popularity selective tendering, negotiation and two stage and open tendering (Wong et al., 2000). However, in most of the instances the appointed contractor is responsible for carrying out the works including all workmanship by sub-contractors and the delivery of materials by suppliers.

Masterman (2002, p.50) attempted to define the traditional system as “client appointment consultants, on a fee basis, who fully design the project and prepare tender documents upon which competitive bids, often on a lump sum basis, are obtained from main contractors. The successful tenderer enters into a direct contract with the client and carries out the work under the supervision of the original design consultants”. Figure 3.6 illustrates the traditional procurement system in simplified form including contractual, functional and alternative relationships between key stakeholders.

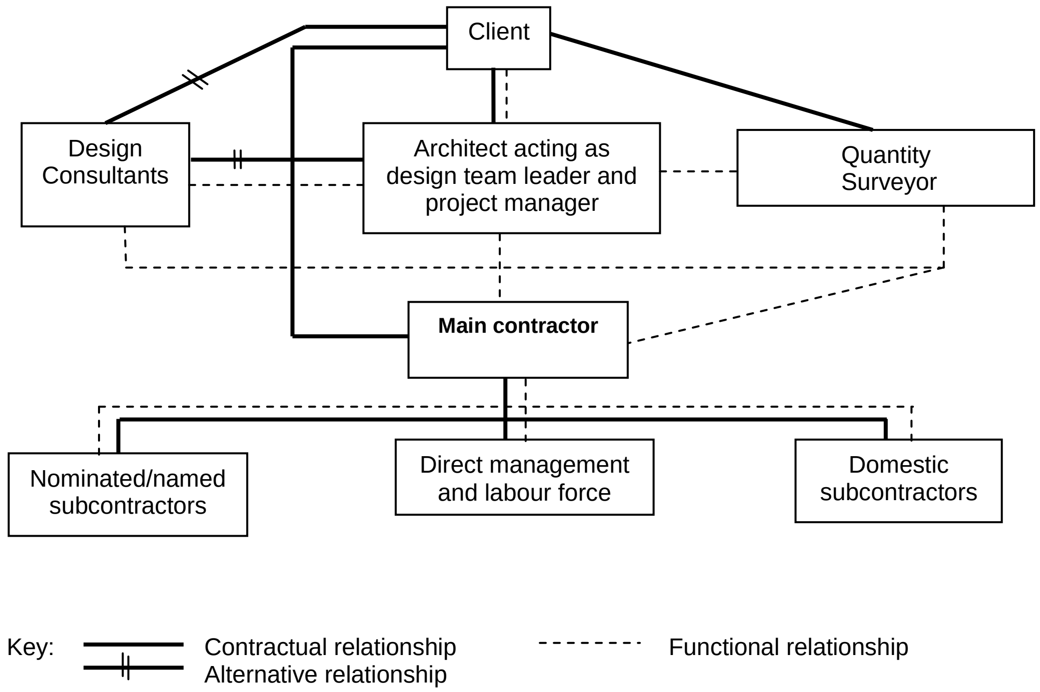

Figure 3.6. Contractual and functional relationship, traditional procurement system

(Masterman, 2002, p.50)

3.3.4.2 Integrated procurement system

The key feature of integrated CPS is the rigid integration of design and construction processes. This category of CPS incorporates all of those methods of managing the design and construction of a project where these two basic elements are integrated and become the responsibility of one organisation, usually a contractor (Masterman, 2002). The main system in this category is the traditional (pure) D & B system (or design and construct) and remaining systems in this category are variants of the D & B system.

Traditional (pure) D & B procurement system

The traditional (or pure) D & B procurement system allows a client to contract D & B organisation to manage both the design and construction process as a single point of contract (Akintoye, 1994; Walker and Rowlinson, 2008). Moreover, the contractor is responsible for the construction and full design, embracing the production of the aesthetic and working drawings together through obtaining statutory approvals (Harris and McCaffer, 2001). Masterman (2002, p.66) defined D & B system as "an arrangement whereby one on contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project". These characteristics, especially the sole responsibility of one organisation for both design and construction facilitate the functional and contractual relationship between client and contactor when compared to other procurement options.

Many research studies advocate that the D & B procurement system can result in a reduction of an overall project duration, because of the increased client involvement in the construction process, the early involvement of the D & B contractor, and the overlap of the design and construction processes (Griffith, 1989; Akintoye, 1994; Ndekugiri and Turner, 1997; Chan, 2000; Moore and Dainty, 2001). Moreover, as shown in Figure 3.7, the functional and contractual relationships of traditional D & B procurement systems are simple. Furthermore, the single channel in communication and coordination enhance the simplicity of the procurement process. The main steps of the D & B procurement process involved: preparation of client's requirements; obtaining tenders; evaluation of tenders (based on the basis of design, specification and price); acceptance of the most appropriate tender and implementation and completion of the project (Masterman, 2002; Cox and Clamp, 2003).

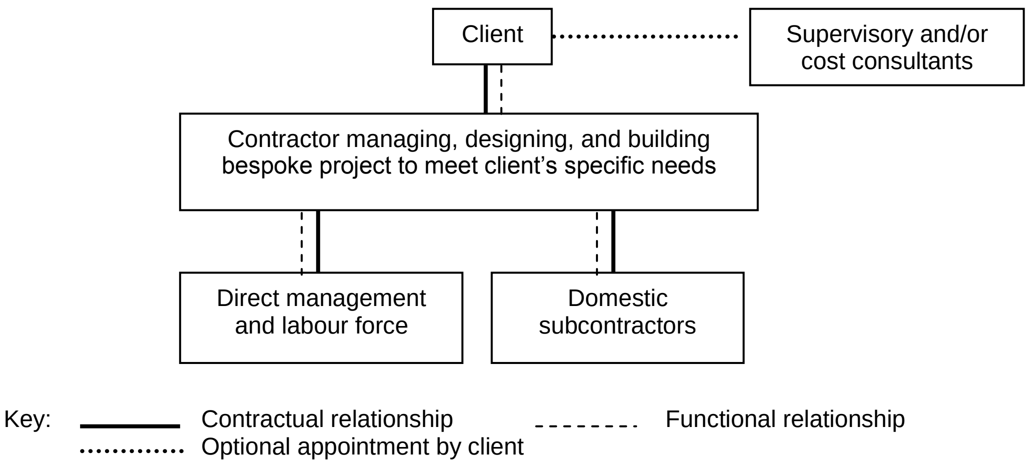

Figure 3.7. Contractual and functional relationships, D & B system

(Masterman, 2002, p.70)

Variants of D & B procurement system

The literature shows that variants of the D & B system emerge as a popular option for procurement (Bound and Morrison, 1993; Ndekugiri and Turner, 1994; Akintoye, 1994;

Chan, 2000; Doloi, 2008). Three major variants of D & B can be identified from the literature: Enhanced D & B (i.e. novated D & B, develop and construct); package deal; and the turnkey method.

Enhanced D & B

'Develop and construct' and 'novated D & B' together can be termed as enhanced D & B. The salient feature of enhanced D & B is that the clients would develop design by employing their own team of consultants to a point where the significant planning issues are clarified and then require tenderers to submit a conforming bid based on the developed design (Anumba and Evbuomwan, 1997; Deakin, 1999). Therefore, the main difference between traditional (pure) D & B and enhanced D & B is the extent to which the design of the project has been developed by the client before inviting tenders (Masterman, 2002).

Novated D & B: The client appoints consultants to prepare conceptual design and prepare D & B tender documentation for the project. Once the contractor has been appointed the novated design team acts as contractor's consultants to carry out detailed design. The contractor is responsible for the design development, working details and supervising the sub-contractors with assignment (i.e. novation) of design consultants from client (Cartlidge, 2004). As such, Ng and Skitmore (2002) argued that novation is a mutual agreement which substitutes an old obligation for a new one, where the process of novation encompasses a contract in its entirety, the new contract replaces the original one completely and may result in one or more of the original parties being substituted. This kind of set up enables the design to proceed more smoothly from the pre-contract to post-contract stage (Masterman, 2002). However, novated consultants will not be available to advice clients from the detailed design stage onwards. This is because the clients' design team contractually become the contractor's consultants for detailed design preparation.

The basic principles of traditional D & B are applicable within the enhanced D & B. For instance, Doloi (2008) noted that the contractor, by accepting the contract, instigates the process of novation and is bound by the contractual obligation of design responsibility, and therefore the basic principles of the D & B are applicable within the novated D & B procurement approach. However, the client has a greater degree of control over design and quality in novated D & B as the contractor is appointed after the initial design. The system is also suitable when the time for completing the project is 'of the essence'; the budget for the project is fixed and extra resources of funding are very limited; and the project involves special design and technical requirements (Chan, 1994; 1998). Doloi (2008) revealed eight factors that have an impact on the success of the novated D & B approach: impact on initial design upon successful implementation of the novated system contracts; clear demarcations of clients' involvement in the post-novation stage; the process of the design team selection; clarity and understanding of the contractor's obligations; the effect of post-novation morale on project outcomes; design team working experience; the working relationship between design team and contractor; and specific novated experience of the design team. Ng and Skitmore (2002) revealed benefits of the novated D & B system to contractors:

- it is less costly at the bidding stage than the traditional D & B system;
- the design has been outlined by the client;
- contractors do not have to go through various design layouts of a building as they do for the traditional D & B system;
- contractors can save time and effort identifying the client's needs;
- contractors should have more knowledge of the project as they have been involved with it since the conceptual stage; and
- the project delivery time can be saved in the time leading up to the start of construction, as well as during the construction, if the contractor was involved early on in the design stage to have an input into the buildability of the project.

Moreover, Ng and Skimore (2002) identified four major risks, mainly to contractors, associated with novated D & B:

- novated consultants' (design team) ability to perform: unsuitability of design team, poor performance of design team; inferior initial design; inheritance of design error made by a design team unfamiliar with local statutory requirements;
- lack of the design team's fee for the post-novation phase: inadequate fee left for completing the design; poor quality of work due to lack of fee; poor morale of design team due to tight budget;
- working relationship with design team: loyalty of design team to client, poor previous working experience and lack of previous knowledge of the design team; and
- timing of novation: alternatives not carefully explored and examined, poor relationship with client.

<u>Develop & Construct</u>: Design consultants are appointed to design the building to a certain stage (may be up to RIBA stage D: detailed design) and then the contractors complete and guarantee the design and competition using the contractors' own

designers in terms of detailing taking into account of the construction technique to be adopted for the project (Akintoye, 1994; Seeley, 1997; Cartlidge, 2004). In brief, the D & B organisation's contribution to the design process is primarily in developing the construction information from the client's concept design (Potter, 1995).

The literature reveals several pertinent issues associated with the enhanced D & B. These are:

- the lack of clients' engagement over the currency of a project undermines the overall performance and success in projects (Akintoye, 1994; Molenaar and Songer, 1998);
- the lack of adequate clients' brief (client requirements are not being adequately defined) reported to have adverse impacts on a contractor's ability to add value in the projects (Siddiqui,1996) and late design changes, cost quality and performance requirements (Anumba and Evbuomwan, 1997);
- difficulties faced by the design team as a consequence of novation and its change in employer; pre-novation working for the client, post-novation working for the contractor (Chappell, 1994; Speed, 1995);
- lack of sufficient pre-novation time to produce good design solutions is a major theme of dissatisfaction of the design team (Akintoye and Fitgerald, 1995) and the successful contractor also has to spend time clarifying client requirements and liaising with the initial consultants and time spent sourcing and seeking approval for alternative materials and design changes (Anumba and Evbuomwan, 1997);
- inadequate time spent by the design team with the contractor at the end of the tender period for detailed checking of errors and omissions and in assisting with risk assessments remained problematic in the transition process (Chan, 1998);
- the outline design, which form as the basis of tenders, inhibits the ingenuity and creativity of the tendering consortia by limiting them to the initial consultants' vision of the desired facility. Thus expertise of the consortia is not fully exploited at the most influential stage of the design process (conceptual/preliminary design) (Anumba and Evbuomwan, 1997);
- there is a significant amount of rework and duplication inherent in existing procedures, particularly where the initial consultants are not novated to the successful contractor i.e. develop and construct (Anumba and Evbuomwan, 1997); and

- the client's influence on the design team's course of action over the post-novation phase exerts adverse impacts (Swindall, 1993).

Package deal

'Package deal' is a special type of D & B variant where the client chooses a suitable building from a catalogue (Ashworth, 1996). The contractor provides standard buildings or system buildings and in some cases there is a possibility to adapt to suit requirements such as space and functional requirements (Cartlidge, 2004). Clients would be able to purchase a total package, virtually off the shelf, to satisfy their building needs at an economical price. The client is often able to view similar types of buildings that have been completed elsewhere (e.g., industrial buildings - timber or precast concrete that needs to be erected very quickly; the client provides the site, relevant design information, performance specs etc.). In practice the fact that package dealers provide an adopted standard product means that they are unable to satisfy the full needs and criteria of the majority of clients (Masterman, 2002).

Turn key

In a turn key arrangement, the contractor provides the total resources required, including the finance as well as the design, construction and fitting out (Aqua Group, 1990). The responsibility of the contractor often extends to include the installation and commissioning of the client process or other equipment and sometimes the identification and purchase of the site, recruitment and training of management and operatives, the arrangement of funding for the project and latterly, under the Private Finance Initiative (PFI) the operation of the project (Masterman, 2002).

The PFI is an alternative method of procuring services for the public sector (Owen and Merna, 1997). Roe and Craig (2004) stated that PFI involves sub-contracting the design, building and operation of public services (particularly capital assets and related activities, such as maintenance, used in those services) to private sector companies in such a way that the operational risk is transferred from the public sector to the private sector. Additionally, the same authors attempted to differentiate the misguidance between PPP (Private Public Partnerships) and PFI by drawing explanations. While PPP serves as an alliance between public bodies, local authorities or central government, and private companies, PFI schemes generally provide the capital assets and services relating to that asset as well as the public sector specifying a level of service in return for a unitary charge. Furthermore, PFI transfer operating risks to the private sector, which PPP do not involve transferring risk to the private sector. PFI arrangements are generally called as concession contracts and the major variants are as follows:

- BOT - Build, Operate, Transfer
- BOO - Build, Operate, Own
- BOOT- Build, Operate, Own, Transfer
- DBFO- Design, Build, Finance, Operate

The fundamental advantage of this method is that the client has an opportunity to take over an operational facility or increase of PFI schemes by reducing the public sector's capital expenditure in the short term while establishing commercial viable developments in the long term.

3.3.4.3 Management oriented procurement system

The basic feature of a management oriented procurement system is the separation of management function from the design and construction. The emergence of this system is due to the demand not only for the earlier commencement and completion times but also to get more control over project costs, higher stands of functionality and quality by the clients, especially in the commercial sector (Masterman, 2002). However, there needs to be considerable involvement and collaboration between the consultants and the managing contractor throughout, as parallel working continues and abortive work can easily occur (Cox and Clamp, 2003). The common variants of this system are: management contracting, construction management, and design and manage.

Management contracting procurement system

The contractor is appointed on a professional fee basis (i.e. lump sum or percentage fee for management services plus the prime cost of construction) well before work starts on the site in order to assist and advise the design team; and the contractor is also responsible for the work carried out by separate work contractors or package work contractors who are employed, coordinated and administered by the management contractor (Potter, 1995; Masterman, 2002; Walker and Rowlinson, 2008).

The process of management contracting can be identified as specific to three periods: before the appointment of the management contractor; pre-construction period and construction (Masterman, 2002). During the period before the appointment of the management contractor, the client appoints a design team including a contract administrator, an architect and a quantity surveyor; prepares brief drawings, specifications that describe in general terms, the scope of the project by the design team; and invites tenders, selection and appointment of the management contractor. Subsequently, the appointed management contractor has to provide certain services to the client design team during the pre-construction period; particularly project programming, advising on design developments, site planning and common services, breakdown of project packages, assisting package contractor selection by preparing tender lists, and relevant procurement documentation. During the construction period the management contractor assists and recommends the selection of tenders and sets out, manages, organises and supervises the implementation and completion of the project using the services of trade/works contractors. Figure 3.8 illustrates the functional and contractual relationships of the management contracting system. The client enters into a direct contract with the management contractor while construction contractors only have direct contracts with the management contractor.

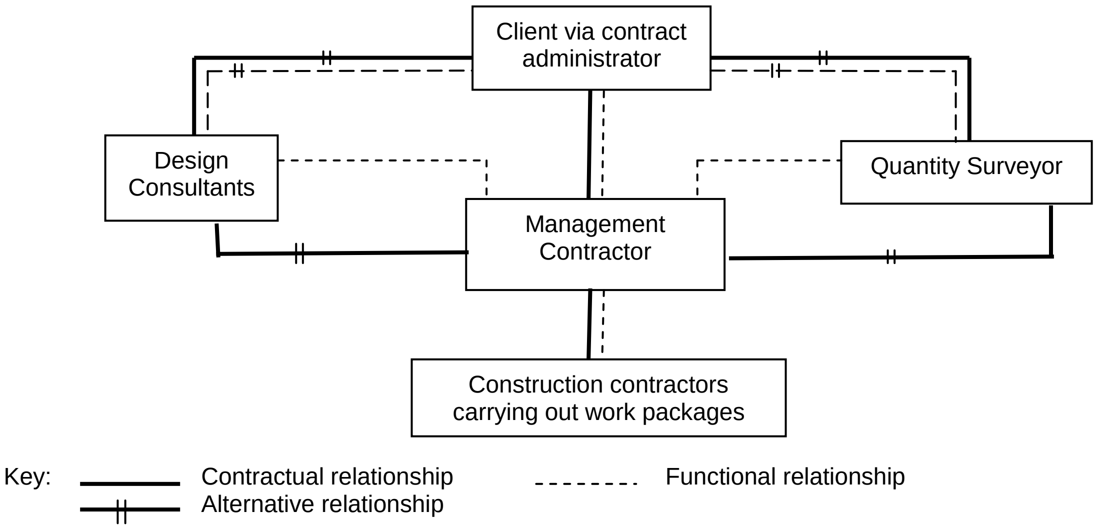

Figure 3.8. Contractual and functional relationships, management-contracting system

(Masterman, 2002, p.96)

<u>Construction management procurement system</u>

The Construction management system is the procurement method whereby the management service is provided by a fee-based consultant, a specialist construction manager or a contractor and where all construction contracts are directly agreed upon between the client and the trade (package) contractors (Masterman, 2002). Thus, the client enters into a contract with the individual works contractors, which highlights the fundamental difference between the construction management system and management contracting. The construction manager should be appointed as early as possible and the process of construction management Masterman (2002). Figure 3.9

illustrates the functional and contractual relationships of the construction management system.

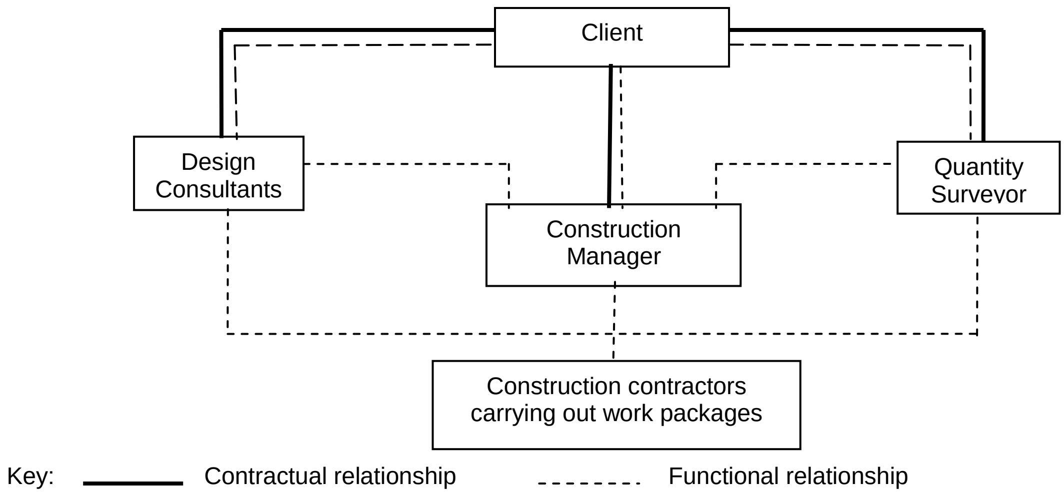

Figure 3.9. Contractual and functional relationships, construction management system
(Masterman, 2002, p.109)

<u>Design and manage procurement system</u>

The key feature of design and manage is that a single organisation manages the whole of the design and construction process for a fee, with both design and construction on site being undertaken by others (Potter, 1995). Usually construction operations are carried out by using package contractors. Hence, this variant combines some of the features of management approaches with some of those of D & B.

3.3.4.4 Discretionary procurement system

A discretionary system is an administrative and cultural framework in to which any procurement system can be incorporated, thus allowing the client to carry out the project by imposing a very specific management style, or company culture, while at the same time enabling the client to use the most suitable of the available CPS (Masterman, 2002). Recent developments relate to procurement saw the emergence of a number of systems that are based on the concepts of relationship management and the development of collaborative and co-operative working relationships (Walker and Hampson, 2003). Thus, this modern view of the procurement system is based on issues of trust, collaboration and ethical behaviour rather than the traditional view of structure and legal frameworks (Walker and Rowlinson, 2008). Moreover, this modern view of CPS underpins systems such as partnering, alliancing and joint venturing. The idea of partnering in the UK builds up with the reports by Latham (1994) and Egan

(1998), where they emphasised the importance of collaboration and integrated working, which results in the emergence of new CPS, especially in public sector procurement (e.g. National Health Service ProCure 21). Since then, there has been a wide range of academic work on the topic of partnering (Smyth, 1999; Walker and Hampson, 2003; Wood and Ellis, 2005).

Partnering is a technique that attempts to create an effective project management process between two or more organizations. Moreover, partnering is a structured management approach for facilitating team working across contractual boundaries. Its fundamental components are mutual objectives, agreed problem resolution methods and an active search for continuous measurable improvements (Cartlidge, 2004). Thus, a partnering relationship involves the essential elements of mutual objectivity, problem-solving and continual measured improvements (Bower, 2003; Hackett et al., 2007). There are two main types of partnering: project partnering, where the relationship is put in place on one specific project and terminated once the project is completed; and strategic partnering, where a long term relationship is established that is related to a series of future projects, often unspecified at the time that the contract is made (Cartlidge, 2004). The process is formally established in the workshop session between partnering members so that everyone has a clear understanding of what the process is and agrees to use it. Several essential stages of project partnering can be identified; for example, the design stage which requires the establishment of working practices and the implementation of partnering practices. Figure 3.10 illustrates the project partnering process.

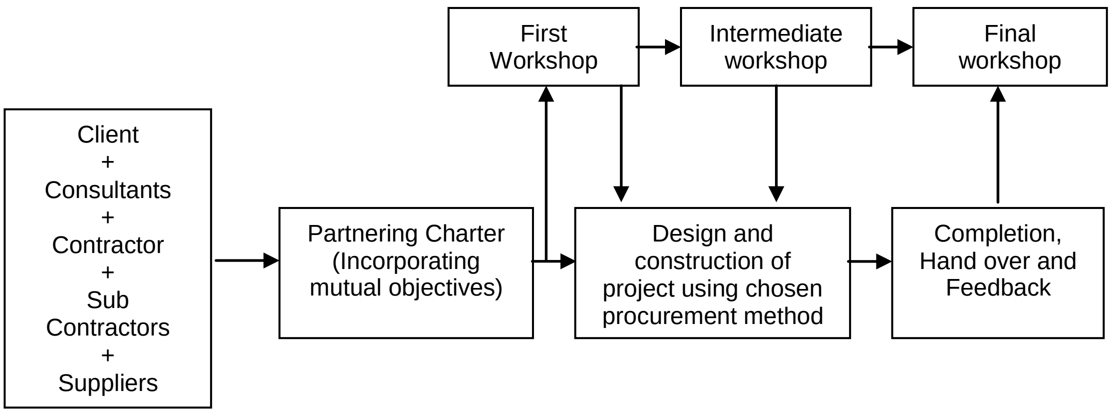

Figure 3.10. Project partnering process

(Masterman, 2002, p.139)

3.3.4.5 Advantages and disadvantages of CPS

Characteristics and organisation of a particular CPS create different advantages and disadvantages. Hence, identification of key advantages and disadvantages of different CPS largely helps in precise procurement decision-making and eventually success of the project. There have been many studies, which have focussed on exploring key advantages and disadvantages of different CPS. Tables 3.9 & 3.10 provide key advantages and disadvantages (compiled from various sources of the literature) with regard to four CPS that are discussed in the previous sections. The various attempts in the literature tend to pool advantages and disadvantages of CPS based on several criteria such as risk, parties' involvement and responsibilities, time/duration, quality of work, cost, communication and coordination, tendering and contracts and documentation. It is noteworthy that advantages and disadvantages identified could be different or slightly altered depending on the variants of each system and the context of the project.

Table 3.9. Advantages of CPS (Compiled from literature)

	Separated (Conventional)	Integrated	Management oriented	Discretionary
Advantages	▪ Fair sharing of risk is possible ▪ A combination of the best design and construction skills is possible ▪ Flexibility for design changes in the construction stage ▪ High quality of functional standards are possible ▪ Enable higher degree of cost certainty and able to know at the start of the construction (lump sum, target cost - higher certainty; measure and pay and cost reimbursable – lesser certainty ▪ BOQs make for easy of valuation of variations and high level of cost control and monitoring ▪ Clear lines of accountability and responsibility ▪ Independent advice is available on most aspects of the process ▪ Allows contractor to plan and programme works properly ▪ Competitive/open tendering is possible with detailed documentation – well tested system low price	▪ Clients' financial risk is minimal ▪ Design becomes a competitive element ▪ Reduced variations and destruction to the original design ▪ Achieves a high level of buildability ▪ Fixed prices bids are used; Financial commitment is known by client early in the process (Usually lump sum) ▪ Process duration: offers shorter overall time: parallel working is possible ▪ Direct communication and coordination between the client and contractor enables the contractor to respond to clients' needs promptly. ▪ Clear line of responsibilities: single point responsibility for both design and construction ▪ Less documentation compared to separated system	▪ Employed a construction manager to manage construction aspects: incorporate contractors experience to design that results higher buildability ▪ Strong management layer allows parties to deal with complex and difficult projects ▪ Process duration: do not need complete drawings (out line drawings); early start and parallel working is possible; total project time become lesser; Less idling time (due to subcontractors adaptation) ▪ Competitive tendering is possible ▪ Payment method: lump sum or percentage fee for management services plus the prime cost – contractors force to minimise their unnecessary costs ▪ Very flexible for client; and changes ▪ Sub-contracted all the work related to project under main management contract: opportunities to deal with specialized sub-contractors ▪ Value management and value engineering are possible to gain additional key knowledge for the process	▪ Low risk of cost and time overruns ▪ Better quality products ▪ Quicker start and improved efficiency of human and other resources ▪ Greater efficiency and productivity ▪ Communication between parties are improved ▪ Collaborative working environment (early involvement of all parties): reduced exposure to conflicts and litigations ▪ Innovative thinking (e.g. value management), research and development opportunities

Table 3.10. Disadvantages of CPS (Compiled from literature)

	Separated (Conventional)	Integrated	Management oriented	Discretionary
Disadvantages	▪ The clients' liability and risk is significant, where the client is inexperienced; client involvement is very high and tend to more design changes (Variations) ▪ Decision processes (i.e. design and construction) are slow and convoluted ▪ The exclusion of the contractor (less coordination) from the design phase eliminates the scope to improve buildability ▪ Process duration: the total project time is the longest of all options and no parallel working is possible ▪ The sequential, fragmented and confrontational nature results leads to reduced team spirit and tends to cause poor communication and coordination ▪ No clear layer of project management (lack of supervision/management in construction stage for quality of materials and workmanship) ▪ Higher numbers of parties' involvement, possibility of arising disputes ▪ Due to time pressure in the pre-contract stage pressure on consultant on initial stage: results in the documentation possibly containing errors and cost overruns ▪ Usually nomination of design team is based on the preference of architect; thus, no contractual relationship for their performances ▪ If nominated sub-contractors are involved; contractual responsibility of main contractor will reduced	▪ Higher design risk with contractor ▪ Requires a detailed brief and specifications ▪ The tender process can be expensive to bidders; Chance of receiving high price bids due to accumulation of contractors; higher cost of non-winning bids ▪ Comparison of bids can be complicated (design evaluations) ▪ Lower level of competition at the tender than in other arrangements (often selective and negotiated tendering approaches) ▪ A lack of independent professional advice to the client at the time of tender ▪ Often lacking broad experience or expertise (e.g. true D & B organisations) ▪ Changes can be expensive due to difficulties in valuation of variations ▪ Aesthetically important buildings are not recommended to procure through this method ▪ No clear layer of project management exists (thus lack of supervision/ management in construction stage for quality of materials and workmanship) ▪ Client involvement in the process s minimised; could be difficult to incorporate & monitor client requirements during the process (e.g. WM requirements) ▪ Overlapping of design and construction complicates the management of the design process	▪ Risk is more with client ▪ Price certainty is less or not known at early stage at the time enter into contract; No overall contractual commitment to cost of construction until all the packages are let ▪ Extra layer of management increase costs and may tends to complex communication and coordination ▪ Change of traditional roles might leads to conflicts: conflicts of loyalty ▪ Client involvement is high – risk of changes (Variations)	▪ Higher risk involved and loss of control over dishonesty ▪ Additional costs are for workshops, to train staff and management ▪ Risk of Maintaining confidentiality ▪ Potential lack of accountability ▪ Cultural issues (such as power distance and privilege between project stakeholders)

3.3.5. Procurement Trends in the UK Construction Industry

It is difficult to quantify accurately the past or present level of use of all, or any of currently used CPS, due to a lack of truly comparative figures for the individual methods over a set period of time from a sufficiently wide range of reliable sources. However, Masterman (2002) noted that the RICS (Royal Institution of Charted Surveyors) surveys come nearest to achieving accurate and truly comparative figures as a reliable source. Table 3.11 presents the trend in CPS in the UK (organised according to CPS discussed in earlier sections), which is based on the statistics of RICS surveys: contracts in use from 1985 to 2007 (RICS, 2010). The RICS survey 2007 captured a smaller number of projects than previous years.

Table 3.11. Trends in the methods of procurement: UK

(by value of contracts) (RICS, 2010)

	1985	1987	1989	1991	1993	1995	1998	2001	2004	2007
	Percentage (%)									
Separated (traditional)	**74.9**	**73.2**	**66.1**	**57.8**	**54.0**	**58.3**	**40.1**	**43.3**	**48.4**	**41.0**
Lump Sum - Firm BoQ	59.3	52.1	52.3	48.3	41.6	43.7	28.4	20.3	23.6	13.2
Lump Sum - Spec & drawings	10.2	17.7	10.2	7.0	8.3	12.2	10.0	20.2	10.7	18.2
Target contracts	-	-	-	-	-	-	-	-	11.6	7.6
Re-measurement - App BoQ	5.4	3.4	3.6	2.5	4.1	2.4	1.7	2.8	2.5	2.0
Integrated	**8.0**	**12.2**	**10.9**	**14.8**	**35.7**	**30.1**	**41.4**	**42.7**	**43.2**	**32.6**
Lump Sum - Design & Build	8.0	12.2	10.9	14.8	35.7	30.1	41.4	42.7	43.2	32.6
Management oriented	**17.1**	**14.6**	**23.0**	**27.4**	**10.3**	**11.6**	**18.4**	**12.2**	**1.8**	**10.8**
Prime cost plus fixed fee	2.7	5.2	1.1	0.1	0.2	0.5	0.3	0.3	0.1	0.2
Management contract	14.4	9.4	15.0	7.9	6.2	6.9	10.4	2.3	0.8	1.0
Construction management	-	-	6.9	19.4	3.9	4.2	7.7	9.6	0.9	9.6
Discretionary	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1.7**	**6.6**	**15.6**
Partnering agreements	-	-	-	-	-	-	-	1.7	6.6	15.6

The statistics of the survey presented in Figure 3.11 shows that the level of use of separated systems (including variants) and management-oriented systems has declined over the years. At the same time the popularity of using the integrated system (D & B) and discretionary system (partnering) has increased. However, the use of the separated CPS is still popular in the UK construction industry accounting for approximately 41% by value of contracts. The popularity of D & B is approximately 33% by value of contracts in 2007, which represents the largest percentage as single system in use from 1998 to 2007 whereas second the most single popular procurement method is separated - lump sum firm BoQ, which is over two times less popular compared to lump sum D & B. Moreover, over 50% of contracts (i.e. number of contracts) in the £10k to £50m value bands were procured on a D & B basis (RICS, 2010) and therefore, this further substantiates the demanding popularity of integrated systems. The same trend can be found in many other countries such as China, Denmark, Hong Kong, and United States of America (USA); in the private sector countries like France, Thailand, Norway and Mexico which use D & B systems in more than 50% of their projects; and in the public sector in countries like Greece and France which use the D & B as the main procurement system (International Construction Intelligence, 2004). Even though, the RICS survey does not provide evidence for the use of variants of D & B system, a survey conducted by Akintoye (1994) showed that 21% of private clients in the UK use the D & B system, of which 42% commonly use novated D & B for their projects. The use of D & B system has increased over the years, the reasons are clear: it allows clients an opportunity to integrate from the outset of the design and the construction of the project and enter into a single contract with one company; it allows the contractor the opportunity to design and plan the project in order to ensure the buildability aspects are incorporated into the design; shorter project duration is ensured; and better cost certainty is ensured compared to traditional CPS (Cartlidge, 2004).

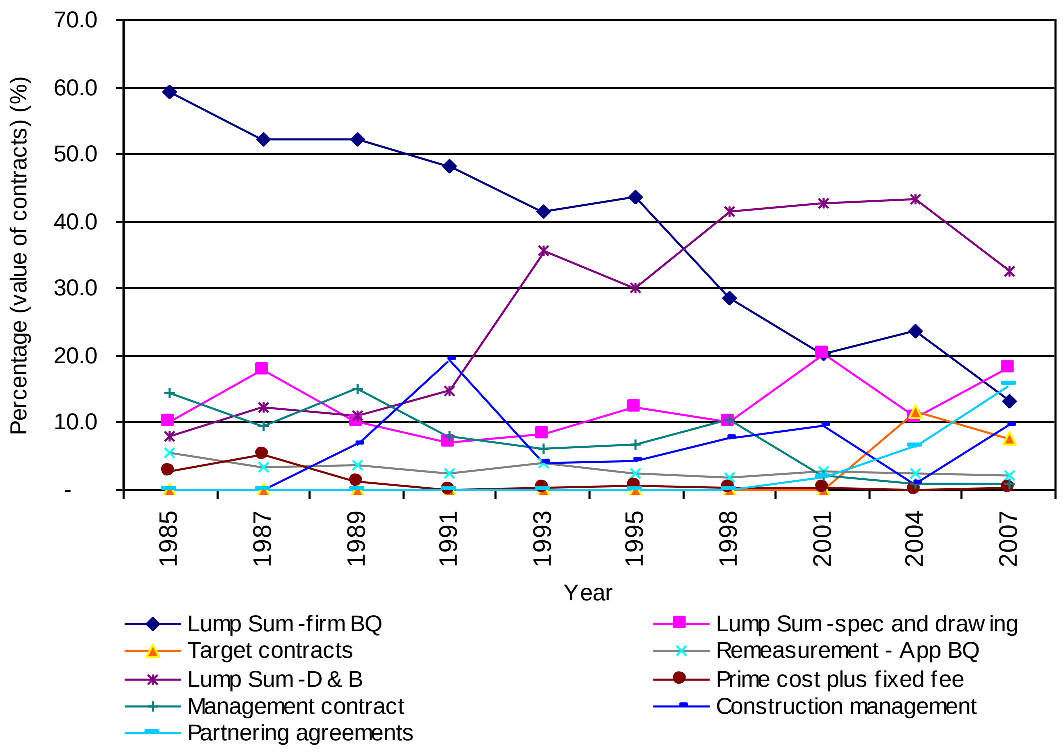

Figure 3.11. Trends in the methods of procurement, UK

There was an emerging trend in the popularity of target contracts and increasing popularity of partnering from 2004 to 2010 (Figure 3.10); however, RICS (2010) indicated that there has been no apparent increase in partnering in terms of number of contracts between the 2004 and 2007 surveys. However, this suggests that the procurement trend in the UK is changing towards new systems from conventional systems. However, the RICS survey statistics analysis covered only up to 2007 and future survey results may change this trend.

It is noteworthy that the same survey indicated that the majority of construction contracts (percentage by value of contracts) use JCT (61.5%), NEC (14%) and prime contract (9.4%) standard contract forms (RICS, 2010). Furthermore, Table 3.12 indicates that JCT D & B contract (or its 1998 predecessor) continues to dominate by far the D & B procurement compared to other forms of contract.

Table 3.12. Use of D & B forms

(RICS, 2010)

	Percentage by Value			
Use of D & B Forms	**1998**	**2001**	**2004**	**2007**
JCT Contractor's Design	27.1	42.7	36.7	26.6
GC/Works Design and Build	0.2	0.0	5.7	2.2
ICE Design and Construct	9.6	0.0	0.0	0.1
Other Design and Build	4.6	0.0	0.8	3.7
Total	**41.4**	**42.7**	**43.2**	**32.6**

3.3.6. UK Government Initiatives to Improve Procurement Process

In the UK, the public sector is a major client of the industry and is responsible for directly procuring about a third of all construction (BERR, 2008). This indicates how the potential that UK government actions impact on UK construction industry trends. Therefore, it is notable that the CPS trend is considerably influenced by the government initiatives (i.e. government is the major client, key regulatory and legislation body). The UK government has recognised that 'procurement' is an important means of delivering better public services that are good value for money and sustainable (HM Treasury, 2007). For example, the joint industry and UK government strategy for Sustainable Construction 2008 states that construction procurement is an overarching target area in achieving sustainable construction (BERR, 2008). Moreover, the UK Government launched the 'Sustainable Procurement Action Plan' in 2007 aiming for the UK to be among the EU leaders in sustainable procurement, in which key targets are:

- a sustainably built and managed central government estate that minimises carbon emissions (e.g. a carbon neutral office estate by 2012 alongside a 30% reduction in carbon emissions by 2020), waste (e.g. recycling 75% of the waste by 2020; reducing waste generated by 25 % by 2020) and water consumption (reducing water consumption by 25% by 2020) and increases energy efficiency (e.g. increasing energy efficiency by 30 % per square metre by 2020);
- sustainably built and managed properties and roads throughout the public sector; and
- government supply-chains and public services that are increasingly low carbon, low waste and water efficient, which respect biodiversity and deliver our wider sustainable development goals.

These targets suggest that the 'Sustainable Procurement Action Plan' has given a high priority for WM in terms of construction and management of government built assets (estate, buildings, roads) and government supply chains and public services.

The Achieving Excellence in Construction (AEC) initiative by the UK government was launched to improve the performance of government as a client of the construction industry and its key initiatives targeted: partnering and the development of long-term relationships; reduction of financial and decision-making approval chains; improved skills development and empowerment; the adoption of performance measurement indicators; and the use of tools for value and risk management and whole life costing (OGC, 2007b). In addition, the government established a set of critical success factors dealing with procurement by focussing the best value for money in the whole life of the service or facility (OGC, 2007c):

- leadership and commitment from the project's Senior Responsible Owner;
- involvement of key stakeholders throughout the project;
- roles and responsibilities clearly understood by everyone involved in the project, with clear communication lines;
- an integrated project team consisting of client, designers, constructors and specialist suppliers, within put from facilities managers/operators;
- an integrated process in which design, construction, operation and maintenance are considered as a whole;
- design that takes account of functionality, appropriate build quality and impact on the environment;

- commitment to excellence in health and safety performance;
- procurement and contract strategies that ensure the provision of an integrated project team;
- risk and value management that involves the entire project team, actively managed throughout the project;
- award of contract on the basis of best value for money over the whole life of the facility, not lowest tender price; and
- a commitment to continuous improvement and best practice in sustainability.

One of the important steps of the UK government initiatives is the introduction of OGC Gateway Process. This Gateway Process is considered by the OGC as a method for scrutinizing the progress of different aspects of projects, in which the biggest area of scrutiny is the assessment of procurement processes. Moreover, this Gateway Process intends to improve: public sector procurement capability; fostering good relations between public sector buyers and suppliers of all sizes; offering solutions for better management of procurement, and the long-term management of what government purchases (OGC, 2007a). In the Gateway Process, there are some important stages (termed as ‘gates’) to be followed. Thus, gate 2 in the Gateway Process is to determine the procurement stage. One of the actions in the procurement stage is the selection of procurement strategy that highlights the importance of the selection of an appropriate CPS in order to accomplish a successful construction project.

Since April 2000, the UK government policy has been geared towards three recommended procurement routes of PFI, Prime Contracting or Design & Build; and traditional approaches that separate design from construction, which should not be used unless they demonstrate better value for money than an integrated route (OGC, 2007b). Furthermore, the primary consideration in the choice of a procurement route is the need to obtain overall value for money in the whole life of the service or facility, and this includes maintenance. Design, construction, and maintenance should not be considered in isolation from one another. The recommended procurement routes promote integrated project team members working together, whether they are involved in the design, construction or service delivery. An integrated approach allows early involvement of all team members to advise on buildability of the design and the on-going maintenance of a facility. Having said that, the UK construction industry is being driven towards integrated CPS as it is recommended in government procurement policy (OGC, 2007b).

The construction procurement trend is being geared towards integrated CPS. Particularly, according to section 3.3.5, the D & B procurement system has shown increasing use in the past two decades consistently while traditional CPS has shown a decline in use. Moreover, this increasing trend of D & B is well reinforced by the UK government procurement policy that recommends an integrated system for public project procurement.

3.4. Sustainable Construction: Waste Minimisation and Construction Procurement

While it is recognised that the key factors in delivering sustainable construction are skills, experience and knowledge of the client and project team (Addis and Talbot, 2001), both construction procurement and WM have an effect on achieving sustainable construction. For instance, the joint industry and the UK government strategy for Sustainable Construction 2008 state that construction procurement and WM are overarching target areas in achieving sustainable construction (BERR, 2008), in which, 'waste' is identified as one of 'ends' while 'procurement' is identified as one of the 'means' for achieving sustainable construction.

In terms of achieving sustainable construction, the topic of prevention of the generation of waste can be considered as an issue that focuses on the danger of depletion of materials used in the construction industry (Bossink and Brouwers, 1996). For instance, a study conducted in Greece ranked energy conservation followed by waste reduction as the main contributions to sustainable construction (Manoliadais et al., 2006). Further, Masterman, (2002) noted the need for practical green building principles such as waste reduction, reduced rework and benefits derived from the application of buildability or constructability principles for the improvement of sustainable construction. Similarly, construction waste is often considered as a 'Key Performance Indicator (KPI)' of sustainable construction (DETR, 2000). There are five standard industry indicators, which relate to construction waste: reduction in tonnage of waste per unit of construction activity; percentage of total waste sent to landfill; percentage of recovery of waste materials for reuse and recycling; percentage reuse materials on site; and waste created per build phase (WRAP, online). These set indicators are also directly relevant to environmental impacts of construction and urge WM.

The growing body of literature demonstrates the importance of procurement for achieving sustainable construction. In broader terms, sustainable procurement is a process whereby organisations meet their needs for goods, services, works, and utilities in a way that achieves value for money on a whole life basis in terms of generating benefits not only to the organisation, but also to society and the economy, whilst minimising damage to the environment (DEFRA, 2006c). Sustainable procurement is necessary in order to give due consideration to the impact of the procurement on the environment, on the community and on the social conditions of those delivering or receiving the product or service (Welsh Assembly Government, 2004). Therefore, sustainable construction procurement is focused on the key social, economic, and environmental factors during the life cycle of a project (OGC, 2007a).

Furthermore, literature emphasises that adopting an appropriate procurement strategy is essential for the delivery of sustainable construction. For instance, the OGC procurement guide indicates that the establishment of an appropriate CPS is a key concern in initiating sustainable construction procurement process, the critical phases of project procurement lifecycle include: business justification; project brief and procurement process; design brief; construction process; operation and management; and disposal and reuse (OGC, 2007d). This highlights important tasks during the phase of 'procurement process': establishing the appropriate procurement route; finalising tender documents including the project brief, the output based specification; and deciding the tender selection process for an integrated supply team.

On the other hand, it is important to identify and realise the distinct opportunities that are associated with different CPS for delivering sustainable construction projects (Addis and Talbot, 2001). Pollington, (1999) pointed out the necessity of alternative CPS to incorporate sustainability issues and the relationship of procurement to the concept of sustainability as fundamental for two reasons: identifying and implementing the process of realising the construction and identifying and implementing the life cycle implications through the specification of performance as stated in the procurement documentation. Furthermore, Rwelamila et al. (2000) noted that incorrect choice and use of CPS have led to neglect of the four pillars (i.e. social, economic, biophysical, and technical) of sustainability and consequently contributed to poor project performance in terms of sustainable construction. These emphasise the need for proper evaluation of sustainability performances that are associated with different CPS.

Ngowi (1998) indicated that the traditional CPS is hardly a basis for sustainable construction. The traditional CPS does not sufficiently make use of the contribution that organisational and individual team members' knowledge make to a project's design, waste and under-utilisation of resources which are inherent within the different stages of design and construction. Rwelamila et al. (2000) revealed that the traditional procurement system does not have appropriate management structures to achieve construction sustainability. In addition, a latter study highlighted the project manager's inability to pull every project stakeholder together where the majority of internal clients and sub-contractors make feel collective towards project sustainability. Hence, the project collective becomes a myth and interdependence is lost among project participants, which blinds the focus to construction sustainability. In brief, this highlights the gap between appropriate CPS and the traditional CPS, which leads to poor sustainability performance.

Varnas et al. (2009) argued that a D & B procurement system gives more opportunity for the contractor to make decisions than other types of contract and therefore, it can be expected that the environmental criteria vary depending on the contractual arrangement. Furthermore, Korkmaz et al. (2010) revealed that green projects delivered by construction management and D & B procurement system outperforms the traditional CPS and they also showed that the level of integration in the delivery process, strong client commitment towards sustainability, early involvement of the constructor, and early inclusion of green strategies are crucial attributes for procurement process that potentially affect final project outcomes, particularly sustainability goals. Although there are several advantages associated with D & B procurement system, it is difficult to assure expertise of the D & B organisation and it may not be able to mitigate environmental impacts (Ngowi, 1998). This is because environmental impacts are not fully explained at the most influential stage of the design process of the D & B project. Similarly, Varnas et al. (2009) revealed that the use of a D & B system might limit the application of environmental requirements due to the fact that the design is carried out after the procurement; it may be impossible or less meaningful to stipulate certain types of requirements in the D & B procurement.

However, as stated in section 3.4, the UK government policy is to use integrated procurement routes: either PFI, prime contracting or D & B; and it further stated that traditional procurement routes should only be used if they demonstrably add value in comparison to the three recommended routes (OGC, 2007d). Addis and Talbot (2001) indicated that Public Private Partnerships (PPP) cover all forms of innovative commercial partnerships between the public and private sectors, including Private Finance Initiatives (PFI), which can offer real scope to promote sustainable construction. Specially, PFI clients specify outputs rather than inputs, whereby the client has the opportunity to specify required sustainability performance; i.e. energy usage per year rather than specifying the use of low energy equipment, which creates a responsibility on contractor to find the most cost-effective way of delivering the performance level required. Moreover, prime-contracting provides contractors with overall responsibility for the management and delivery of a project, including the co-ordination and integration of the activities of a number of sub-contractors to meet the overall specification efficiently, economically and to time. Partnering is in order to encourage organisations to work together to improve performance through agreeing mutual objectives. Essentially, partnering encourages preconditions of achieving sustainable construction by means of supporting to the resolution of disputes, assisting continuous development, promoting performance measurement, leading to share loss or profits, and assisting in the recognition and allocation of risks (Addis and Talbot, 2001).

The literature highlights that there are still ample opportunities available and considerable efforts are necessary in order to develop in procurement process, so that it properly addresses the sustainable construction:

- the need of methods to assist clients for their assessments of procurement, tender evaluation and the evaluation of the environmental impacts of the materials (Sterner, 2002);

- the need for further research to establish and evaluate the links between sustainability and procurement approaches and to model benefits, could provide a useful insight into the perceptions of where sustainability can be best delivered (Carter and Fortune, 2007);

- the need for further research in order to explore the relationships between contractual arrangement and the chances of stipulating and monitoring environmental preferences more thoroughly (Varnas et al., 2009);

- the need for establishing a holistic approach involving the re-integration of the construction disciplines by incorporating concurrent engineering principles, which enable all members to work on a common project model and consider all aspects of project downstream phases concurrently, during the conceptual design phase as a way towards the achievement of sustainable construction (Ngowi, 1998);

- the construction management team must recognise the role of the environmental and specialist consultants as an integral part of the procurement process and emphasise the allocation of full responsibility for considering environmental issues in the selection of a CPS (Pasquire,1999);

- the incorporation of Value Management (VM) can be a fundamental tool for ensuring and maximising value in attaining sustainable construction. The aim of value management is to ensure that clients' objectives are fully articulated and understood and meets these in efficient way. Hence, VM workshop sessions (VM phases: Information, speculation (brainstorming), evaluation, development, and recommendation) can be used to incorporate a client's sustainable requirements and absorb them into the project procurement process (Addis and Talbot, 2001);

- the application of value engineering into the procurement process can help to achieve less waste during the construction and operation stages (Cartlidge, 2004); and

- the adoption of lean principles into the procurement process helps in terms of achieving sustainable construction objectives by eliminating (material) waste (minimising resources depletion and pollution) and adding value to all project stakeholders (Egan, 1998; Common et al., 2000; Bae and Kim, 2007).

The above discussion clearly shows that construction procurement is significant in attaining sustainable construction. It is also shown that numerous avenues are available for improving the procurement process aiming for sustainable procurement. The next section investigates such opportunities and attempts to review the relationship between CPS and construction waste generation.

3.4.1. Relationship between Procurement Systems and Construction Waste Generation

There is a small but growing body of literature that has attempted to explore the effect of CPS on construction waste generation. Several studies on WM and management research have noted the importance of investigating the impact of CPS and construction waste generation. As such, McDonald and Smithers (1998) emphasised the need to minimise the amount of construction waste generated due to the procurement phase of a building contract and suggested that future work should involve assessing the ways in which differing CPS affect the generation of on-site waste as a result of the different interrelationships involved in alternative procurement processes. Moreover, Emmitt and Gorse (1998) concluded that the control of waste should be seen as a continuing process at all stages in the life of a building, but with the focus on a wide variety of participants; all with differing values, goals, and responsibilities. Furthermore, the study noted that it is the social and structural issues that need to be addressed rather than issues of a technical nature, combined with communication between designer and builder. Thus, Emmitt and Gorse (1998) recommended a re-assessment of building procurement to control construction waste focussing on individual responsibility and communication within a 'temporary' procurement team. Another study conducted by Ekanayake and Ofori (2000, p.5) stated that it was necessary to 'promote appropriate clients CPS' where contractors' experience in methods and sequence of construction can help in the decision-making process during the design stage in order to avoid unnecessary extra work during construction, which causes time delays and material wastage. Similarly, Teo and Loosemore (2001) recommended that it is important to explore the impact of procurement and contractual systems upon attitudes towards waste.

Begum et al. (2007) argued that WM should be integrated into the construction process, and planned at the design and tender stages. Similarly, Tam et al. (2007a) proposed to integrate WM at the tender stage and a waste control system as a part of site management functions focussing on mitigating the generation of waste. Thus, these arguments emphasise that WM should be in line with CPS as the design, tendering and construction processes are core elements of a CPS. Similarly, in controlling the on-site waste, Chandler (1978) identified two areas where control can be exercised as design stage and management on site. The same author (1978, p.81) stated that the 'overlap by consultation between design and construction on ways of preventing waste must be encouraged' and furthermore the author noted that the CPS is capable of engaging designer and contractor relationships as negotiated contracts, management fee systems, industrial building systems, and D & B systems. Jorgensen and Emmitt (2009) investigated the integration of design and construction, and their findings highlighted a number of important interdependent factors; of which, appropriate project delivery framework and structuring and planning of the delivery process were also identified as important factors for achieving better integration. Therefore, Chandler (1978), Begum et al. (2007) and Jorgensen and Emmitt (2009) highlight the basic issue that the requirement of using CPS involves the contribution of contractor in the design stage in order to restrain material waste.

A small number of studies have attempted to inquire about the relationship between CPS and construction waste generation, although the main focus and context of such studies were not directly to investigate the relationship between CPS and construction waste generation (Table 3.13). These studies show a disparity of findings in terms of the relationship between CPS and construction waste generation; while some of the studies suggest CPS have little impact on construction waste generation other studies suggest CPS has an impact on construction waste generation. Hence, this presents difficulties in comparing the findings of such studies and establishing strong conclusions. Also, some of the studies failed to indicate possible reasons for particular results and recommended further an in-depth analysis of the relationship between CPS and construction waste generation.

In response, a survey study conducted by Jaques (2000) in New Zealand focusing on contractor, architecture and quantity surveying practices concluded that alternative procurement routes did not have any significant advantages over the traditional route in terms of WM. A similar survey administered by McDonald and Smithers (1996) in Australia focusing on architectural, quantity surveying and sub-contracting practices concluded that the procurement route was not seen by the industry’s participants to be important in waste reduction (Table 3.13). However, this study noted that the findings proposed were more reflective of the experience and interests of the respondents, than that of waste control issue itself. Moreover, the same authors admitted that the study has attempted to provide a basic analysis of the alternative procurement routes with regard to WM and recommended a detailed analysis of incentives and motivations affecting waste control in the alterative CPS with regard to WM.

In contrast, several studies showed (Table 3.13) that CPS has an impact on construction waste generation. A survey study conducted by Johansen and Walter (2007) revealed that large amounts of waste are still inherent in the German construction industry owing to traditional contracting and certain planning methods. Similarly, Tam et al. (2007a) who investigated the implementation of prefabrication in the context of different CPS used in Hong Kong, showed that the D & B procurement method has a considerable effect (high important level) on reducing construction waste, and the other CPS surveyed have been given a ‘medium’ important level in reducing construction waste. Tam et al. (2007a) confirmed that the involvement of contractor at the early design stage of the project has great potential to improve constructability which leads to a minimising of waste production. Jaques (1998) and McDonald and Smithers (1996) also acknowledged that D & B system offered more opportunities in WM highlighting that creating a buildable design that allows for a logical sequence in construction, providing accurate and integrated project information, making waste efforts financially beneficial to the client, and the involvement of the contractor at the design stage, were all important in terms of WM initiatives.

Table 3.13. Key studies on the relationship between CPS and construction waste generation

Study	Country	CPS	Context and Focus
McDonald and Smithers (1996)	Australia	▪ Traditional ▪ Negotiated ▪ D & B ▪ Construction management ▪ Novated	Minimising construction waste: Strategies for the design and procurement processes of building projects
Jaques (2000)	New Zealand	▪ D & B ▪ Negotiated ▪ Fixed or lump sum contract ▪ Project Management ▪ Reimbursable contracts ▪ Novation	Construction site waste generation – The influence of design and construction
Tam et al. (2007a)	Hong Kong	▪ Traditional ▪ D & B ▪ Management contracting, ▪ Management contracting with nominated prefabricator ▪ Strategic partnering	Implementation of prefabrication in the context of different project types and procurement methods
Johansen and Walter (2007)	Germany	▪ Traditional contracts (e.g. General contracts or sub contracts) ▪ D & B ▪ Management contracting, ▪ PFI ▪ Partnering	Lean construction: Prospects for the German construction industry
WRAP (2009)	United Kingdom	▪ Traditional ▪ D & B ▪ Partnering	Procurement requirements for reducing waste to landfill: Model procurement wording for construction clients and principal contractors to deliver improved resource efficiency on construction projects

WRAP (2009) developed a guide that focuses on procurement requirements for reducing waste to landfill. Specifically, this guide recognises that in order to fully benefit from WM, good practice must be adopted at the earliest possible stage and therefore, cutting out waste in construction is essential and mandatory through the procurement process. Therefore, this guide provides advice to clients on how to write procurement requirements for design teams and contractors for the construction and maintenance of building and civil engineering/infrastructure projects; and sets out guidance to contractors on how to apply requirements when appointing your supply chain. However, this guide mentioned that waste to landfill actions are set by the project stage rather than the procurement route. This means that irrespective of those adopted for CPS, the actions and model wording are ordered according to the project stage. Moreover, the guide did not consider the potential impact of different CPS on construction waste generation.

The above review indicates a potential relationship between CPS and construction waste generation. Also, the review emphasises a need for investigation into the impact of CPS and waste generation due to contradictory findings from empirical evidence based research in the literature. One reason for such contractions as shown in Table 3.13 lies in the fact that the literature findings are based on different CPS which are founded upon different definitions, cultural and legislative structures. The other reason could be that the most of the research studies were related to different contexts and lack direct focus and in-depth analysis of the relationship between CPS and WM. Consequently, this background paves the way for the need to explore the relationship between CPS and construction waste generation.

3.4.2. Procurement Waste Origins

A number of WM and management studies focus on either the design stage or the construction stage (section 3.2.5 & section 3.2.6). However, primarily the organisation of design and construction processes depend on the adopted CPS which influences many aspects of the design and construction process due to the diversity of differences such as level of responsibilities, authorities, participants and other relationships of the various sub elements of a project (section 3.3.1). Ultimately, the adopted CPS could have a unique influence on waste origins and causes compared to other CPS. Moreover, from a procurement perspective, most research evaluating CPS has concentrated on research areas such as comparisons of procedures (i.e. procurement processes; advantages and disadvantages), CPS selection, allocation of responsibilities and liabilities, and the distribution of risks. Hence, in order to explore the relationship between CPS and construction waste, the following sections attempt to review major categories of CPS in relation to waste origins. This study defines Procurement Waste Origins (PWO) as potential waste generating characteristics over different CPS.

3.4.2.1 Separated procurement system

The separated (traditional) CPS has been criticised for its sequential approach to project delivery, as they have contributed to the so called ‘procurement gap’ whereby the design and construction process are separated from one another (Love et al., 1998). Therefore, the potential source of waste generation would be the separation of the design processes from the construction processes as this schism restricts the adoption of a holistic approach to waste reduction that encompasses the complete building procurement duration i.e. both design and construction periods (McDonald and Smithers, 1996; Johansen and Walter, 2007). Moreover, this leads to a lengthy design and construction process, poor communication, undermined relationships and finally resulted in problems of buildability, which leads to waste production. Further, Johansen and Walter (2007) stressed that the frequent utilisation of traditional planning and control techniques of traditional CPS are responsible for large amounts of waste in construction.

The other main burdens of using traditional CPS are a lack of contractor involvement in the design stage and a lack of coordination between design (i.e. contractor has no input into building design) and construction phases that largely affects project constructability and is subsequently more wasteful (Tam et al., 2007a; Skoyles and Skoyles, 1987). Furthermore, according to previous sections, traditional CPS to the delivery of built assets tend to result in price uncertainty; little opportunity for innovation; lack of client focus; difficulties in phasing and sequencing of functions; lack of coordination between participants and trades; adversarial contract conditions; and unsatisfactory competitive tendering. Hence, the separated method does not sufficiently make use of the contribution that organisational and individual team members’ knowledge can make to a project’s design, waste reduction, and under-utilisation of resources are inherent within the different stages of design and construction.

Similarly, Tam et al. (2007a) note that the traditional CPS lacks coordination between design and construction phases of the project because individual parties are mainly concerned with their own self-interest. Therefore, traditional CPS has minimal suitability for construction projects which help develop common interests in projects in order to reduce construction waste. Matthews and Howell (2005) reported four major systematic problems that could lead to difficulties through the applying of lean principles with the traditional CPS: good ideas are held back; contracting limits cooperation and innovation; there is an inability to coordinate; and pressure for local optimisation. These could be widely relevant for construction on-site waste generation as well.

There is little incentive to adopt waste reduction strategies in the design stages, as such strategies are not reflected in the tender price due to use of elemental Bills of Quantities (Skoyles and Skoyles, 1987). Wong and Yip (2004) revealed that little interest is taken in the environmental impact of the construction process. They cited two main reasons: clients pay little attention to the environmental impact of the construction process; and the fact that a traditional competitive tendering approach was adopted. The latter has resulted in low profit margins in the face of stiff competition between contractors and thus, contractors have little incentive to address additional requirements such as WM; and reducing cost is the only way of gaining competitive edge. Similarly, the most widely used approach - single stage tendering does not encourage for WM mainly due to three reasons: it does not allow a period of thinking time during which the main contractor can make effective contributions, working with the client and its consultant team; it creates an expensive supply chain only on the basis of enquiries made by main contractor bidders with their own preferred subcontractors/manufacturers prior to submitting main contract bids and, therefore, in the absence of detailed review or discussion of the client's requirements; and it expects main contractors to submit bids based only on their own assumptions as to risk and as to errors or omissions in the client/consultant brief (WRAP, 2010b).

Generally, the traditional CPS relies upon the development of complete design drawings, associated contract documentation and traditional competitive tendering thereby it is expected that the project is to proceed on-site with minimum variations. The increasing demands made by clients for buildings to be completed within a short period of time inevitably lead to constraints of design process duration. Consequently, tenders are obtained on the basis of an incomplete design; restricts the development of design details that minimise waste; and facilitate to respond to late demands for changes, known as variations, which result in costly rework/variations leading to inevitable waste production (McDonald and Smithers, 1996; Masterman, 2002). However, when a design is fully developed and uncertainties are eliminated before tenders are invited, tendering costs are minimised and proper competition is ensured. This allows contractors to provide competitive bid value (by eliminating unnecessary costs) and can be a preset driver for minimising the costs associated with waste production.

3.4.2.2 Integrated procurement system

In integrated CPS, the most important aspect with regard to WM is the convergence of interests of the design and construction processes. Involvement of contractors at the early design stage ensures that the responsibility for both design and construction processes lies with the contractor, which could result in a buildable design (contractor's experience) and improved constructability. Consequently, the latter leads ultimately to a minimising of waste production (McDonald and Smithers, 1996; Tam et al., 2007a). Johansen and Walter (2007) also acknowledged that the adopted CPS should smooth the progress of design and construction in such a way that they can take place concurrently and enable early involvement of downstream players in the upstream process thereby minimising construction waste. In this respect, integrated CPS have been identified as most effective as they allow the downstream players to involved in upstream pre-design and planning activities and concurrent working both design and construction activities. WRAP (2010b) identified the importance of the early involvement of a contractor and they developed a detailed guide document on how to implement early contractor procurement, in which it was noted that "early contractor procurement creates a structured process for involving the main contractor and its subcontractors in the pre-construction phase of a project. This provides the opportunity to maximise the waste and cost savings from designing out waste, since it enables the contractor to inform the design team about technical solutions and advise on buildability, value engineering and programme planning".

Indeed, an integrated system provides the opportunity to adopt a holistic WM approach for both design and construction phases thereby cost savings that may be shared between client and D & B contractor; adoption of logical sequence in construction, provision of accurate and integrated project information, and opportunities to encourage the contractor team to work on waste reduction initiatives (McDonald and Smithers, 1996).

The absence of a bill of quantities makes the valuation of variations extremely difficult and restricts the freedom of clients to make changes to the design of the project during the post-contract period (Masterman, 2002). Design and construction are integrated and simple contractual and functional relationships enhance the communication process and decision-making process, which drives towards WM. Furthermore, McDonald and Smithers (1996) noted that the overlap of the design and construction phases possibly allow for more design development time facilitating WM. Cartlidge (2004) also noted that integrated CPS provides the advantage of concurrent working, re-usable designs and shared experiences and hence, enables contractors to understand client requirements and objectives early, with less time and cost spent on changes, availability of more time for refining the design and innovation.

Overall, integrated systems show that its organisational structure and the arrangement of specific responsibilities and authorities provide the highest opportunities for construction WM. Having noted that, Keys et al. (2000) reported the overlapping of design and construction complicate the management of the design process and moves WM to the bottom of the priority list. Furthermore, enhanced forms of D & B tend to decrease the true opportunities of WM that are linked with traditional D & B. Specifically, the enhanced D & B system is a combination of the separated system (traditional) and traditional D & B system in which the design and construction roles are only partially separated. For instance, several disadvantageous critiques noted in the literature with regard to novated D & B of which several factors could be responsible for construction waste generation: initial design is prepared without the input of the contractor; detailed design preparation continues after a contractor has been appointed; and generally, the building price is agreed on the basis of the initial design drawing and documentation (e.g. specifications). Therefore, once the price has been agreed the only incentive for WM efforts is the contractor's desire to maximise profit (McDonald and Smithers, 1996).

Furthermore, the initial concept design may not have been produced focussing on WM, instead aiming for selection of contractor and getting a price for the project (i.e. method of pricing the preliminary design and contract documents). However, McDonald and Smithers (1996) highlighted that if WM efforts in the initial design can be reflected in the tender price subsequently there is an incentive for design to be resource efficient, hence, minimum waste. The benefits of the enhanced D & B with regard to WM, compared with separated (traditional) CPS, is the involvement of the contractor at least during the detailed design stage. This provides considerable improvements in terms of design details communication to the contractor before completion of detailed designs thereby a reduction of variations.

3.4.2.3 Management oriented system

In management oriented systems, as result of employing a separate management organisation, early start and shorter duration by acquisition of the project is possible. Early stage advice obtained from the contractor enable: design improvements; enhanced buildability; programming for materials and material availability together with general construction expertise (Masterman, 2002). These provide an effective opportunity to minimise variations, hence minimising waste generation. McDonald and Smithers (1996) noted that a construction management system tends to provide the most immediate benefits that could impact on reducing waste including the construction manager from the start of procurement process and direct liaison with the design team that should improve buildabilitiy, communication and limit the number of variations. The system offers a good opportunity to adopt value management in the early stages and to employ specialised trade contractors in the latter stages of the project providing an incentive to minimise waste.

However, McDonald and Smithers (1996) noted that by using a fixed fee for construction management services there is very little financial incentive for waste reduction. Besides, the actual work packages are still tendered for and the prices received may not reflect design efforts at waste reduction. Involvement of the client is highly encouraged by the ‘management oriented’ system. However, this could result in both positive (able to force construction team to adopt WM strategy) and negative (last minute decisions and changes) impacts on waste generation. Furthermore, the use of a higher number of sub-contractors may create not only management difficulties but may also lead to waste generation.

3.4.2.4 Discretionary procurement system

Discretionary procurement system is an administrative and cultural framework in which any procurement system (s) can be incorporated. Therefore, these CPS allow distinct opportunities to incorporate or bring into discussion WM requirements in the early stages of a project. Specifically, discretionary systems allow the client to carry out the project by imposing a very specific management style or company culture, while enabling the use of the most suitable CPS. Hence, discretionary systems enable the client to gain more control and involvement throughout the project, which is a key advantage for WM throughout all the project stages, if the client is experienced, educated, committed for cost control or in need of minimising waste.

For instance, ‘partnering’ allows introducing and planning for WM as client, consultants, contractors and specialists sign in at an early stage of a project and then work towards an agreed maximum price. Also, as discussed in section 3.3.4.4, the use of a ‘partnering’ arrangement enhances the communication between parties and makes for efficient working, greater productivity, allowed innovative thinking, research and development, a shortened construction period and quality of final product. Effective utilisation of personal resources is a key feature of partnering, which enhances flexibility and responsiveness in terms of added skills and resources available from other parties (Bower, 2003) providing a good incentive to minimise waste. Furthermore, partnering allows contractors' early involvement during the design at an early stage and continued partnering relationship for future project developments, which optimises design team time, enhances buildable design, improves opportunities for the adoption of new methods leading to WM strategies. Bower (2003) stated that manufacturers and suppliers stand to gain through partnering in a number of ways: approval of their product recommendation, a voice in the design intent, involvement in the coordination with other projects trades; and the possibly of report business. Thus, this would facilitate a collective action to avert waste generation related for many to material procurement, handling, and buildability.

Discretionary systems do not supersede the process used by the CPS to implement the project, but it acts as a framework within which the selected CPS operates more beneficially (Masterman, 2002). Similarly, Walker and Rowlinson (2008) indicated partnering has been implemented by putting a partnering agreement on top of the traditional contract while alliancing has been implemented, in the main, through a management or cost plus contract. Hence, discretionary systems tend to implement on top of the other three CPS: separated, integrated and management oriented. Also, giving consideration to the share of the current use/trend of CPS in the UK construction industry, these CPS enjoy less popularity (section 3.3.5). Thus, the current study has not given the priority for a discretionary system to further investigate the relationship between discretionary systems and waste generation. Instead, it assumes that discretionary systems provide additional benefits (section 3.3.4.4) to other CPS (separated, integrated and management oriented) when built into each other.

Based on the above review, separated (traditional) systems appear to be the most problematic and having a high potential to generate waste while integrated systems, management oriented and discretionary systems as having the potential to encourage WM. Moreover, several key characteristics over different CPS can be deducted from the potential for waste generation (i.e. PWO). Thus, Table 3.14 summarises the key PWO with regard to different CPS.

Table 3.14. Procurement waste origins

(Compiled from literature)

Waste Origin	Explanation	Supporting References for Deducted PWO
Parties' involvement (Contractor early involvement, client involvement)	Extent to which the organisation of CPS allows clients and contractors' early involvement to the project	Skoyles and Skoyles (1987); McDonalds and Smithers (1996); Ekanayake and Ofori (2000); Bower (2003); Johansen and Walker (2007); Tam et al. (2007a); Korkmaz et al. (2010); WRAP (2010b)
Communication and coordination among parties and trades	Extent to which the organisation of the CPS allows efficient and effective communication and coordination processes	Skoyles and Skoyles (1987); McDonald and Smithers, 1996); Emmitt and Gorse (1998; Ngowi (1998); Matthews and Howells (2005); Masterman (2002); Bower (2003); Tam et al. (2007a)
Allocated responsibilities among parties for decision making	Extent to which the organisation of CPS allows a clear layer of management and defined leadership, authority, and responsibilities for parties in terms of decision making (i.e. design and construction)	Skoyles and Skoyles, (1987); McDonalds and Smithers, (1996); Emmitt and Gorse (1998); Love et al. (1998); Tam et al. (2007a); Masterman (2002); Varnas et al. (2009)
Type and form of contract	Extent to which the type and form of contract adopted within the CPS influences WM opportunities (e.g. payment method i.e. cost reimbursable, measure & pay, lump sum, target cost; and inclusion of waste conditions)	Skoyles and Skoyles (1987); McDonald and Smithers (1996); Baldwin et al. (1998); Ngowi (1998); Masterman (2002)
Procurement system process duration	Extent to which the organisation of the CPS has an influence on total process durations (e.g. design and construction duration, overlap of design and construction processes)	McDonald and Smithers (1996); Ngowi (1998); Keys et al. (2000); Johansen and Walker (2007)
Method of tendering	Extent of influence of adopted tendering type within the CPS i.e. open, selected, negotiated	Skoyles and Skoyles (1987); McDonald and Smithers (1996); Ngowi (1998); Wong and Yip (2004); Masterman (2002);
Documentation	Extent to which the organisation of CPS influences the arrangement of different documentation (e.g. detailing, complete information and types of documents used i.e. client brief, specification, tender documents, contract documents)	Gavilian and Bernold (1994); McDonalds and Smithers (1996) Ekanayake and Ofori (2000); Masterman (2002); Poon et al. (2004a); Varnas et al. (2009)
Other	▪ Innovative thinking opportunities: extent to which the CPS allows innovating thinking opportunities (e.g. VM, advanced construction technologies) ▪ Relationships between parties: extent to which the CPS engenders team spirit, collaboration, accountability & transparency of works, and disputes	McDonalds and Smithers (1996); Bower (2003); Cartlidge (2004); Matthews and Howells (2005); Johansen and Walker (2007); Tam et al. (2007a)

3.5. Summary

This chapter has aimed to examine the relationship between CPS and waste generation in construction. It has given an account of construction waste, CPS and the impact of construction procurement on construction generation.

Environmental, economic, industry and government policy & regulatory concerns prevail as the foremost drivers of construction WM. The review also showed that the origins and waste causes in construction are based on different classifications. The study attempted to classify and discuss waste causes and WM approaches under three headings: design; tendering and contract and construction stage. Furthermore, the findings showed that none of the major studies in the field of construction WM have investigated how waste causes are influenced by different CPS or approaches to WM in the context of CPS. However, the same studies emphasised the importance of examining the correlation between CPS and waste production.

Different forms of CPS used in construction were discussed under four headings: separated (conventional/traditional), integrated, management oriented and discretionary systems. Each of these main categories includes major CPS and their variants. The review also showed that separated systems are still popular in the UK, but have shown a continued decreasing trend over the past two decades. The most popular single procurement system in practice is D & B from 1998, which has shown an increasing trend in use. The literature also revealed that the appropriateness of any procurement system for a project depends on the client’s requirements and objectives, project characteristics and external environment factors. Interestingly, the literature review showed that none of the major studies into procurement selection have identified WM requirements as key procurement selection criteria. However, the importance of adopting the appropriate procurement strategy to deliver sustainable construction was clearly indicated. Separated (traditional) CPS appeared to be the most problematic in this regard while integrated and discretionary CPS were considered to be appropriate.

One of the most significant findings from the literature review was the emergent debate on the relationship between CPS and waste generation in construction. However, the literature review suggested that integrated (i.e. D & B); management oriented; and discretionary are the most effective CPS in terms of WM whereas separated (traditional) systems appeared to be the most problematic by their potential to generate more waste. The chapter also identified potential PWO. These are: parities involvement (contractor early involvement, client involvement); communication and coordination among parties and trades; allocated responsibilities among parties for decision making; type and form of contract; procurement system process duration; method of tendering; and documentation. The next chapter presents the findings of the questionnaire survey.

4. Questionnaire Survey Results

4.1. Introduction

This chapter presents the results of postal questionnaire administered to the UK's top 100 contractor practices and top 100 quantity surveyor practices. The survey aimed to explore the relationship between Construction Procurement Systems (CPS) and construction waste generation.

The first section presents results of the questionnaire survey administration and response rate; this is followed by insights into background information about the companies involved in the survey. The results of current CPS practices, the relationship between CPS and waste generation, and future trends and improvements are presented in subsequent sections. While the results of categorical and rating questions are presented as descriptive statistics summaries (quantitative), the results of open-ended questions are presented as narratives and quotations (qualitative).

4.2. Questionnaire Survey Administration and Response Rate

4.2.1. Questionnaire Survey Administration

A total of 258 questionnaires were distributed to procurement managers and sustainability managers, of which 82 were selected from the UK's top 100 contracting companies and quantity surveyors, of which 94 were selected from the UK's top 100 quantity surveying practices. All questionnaires were posted on the same day and telephone and email follow-ups were processed for all non-respondents on weekly intervals over a seven-week period. As shown in Figure 4.1, 30 questionnaires were received after two weeks from the initial mailing. The second and third follow-up rounds increased the total up to 47 completed questionnaires.

The first three follow up rounds revealed that:

- a number of targeted respondents were out of the office for their vacation;
- some respondents did not receive the questionnaire; and

- some respondents did not want to respond to the questionnaire.

Therefore, it was decided to extend the duration of the questionnaire survey in order to achieve a satisfactory response rate. Additional telephone follow-ups were conducted to contact non-respondents targeting, those who came back from vacation and those who promised to complete the questionnaire during the early follow-up rounds. This led to a total of 57 and 63 questionnaires respectively received at the end of week five and six of the follow up period. The questionnaire survey administration concluded at the end of the seventh week of the survey with 65 total questionnaires.

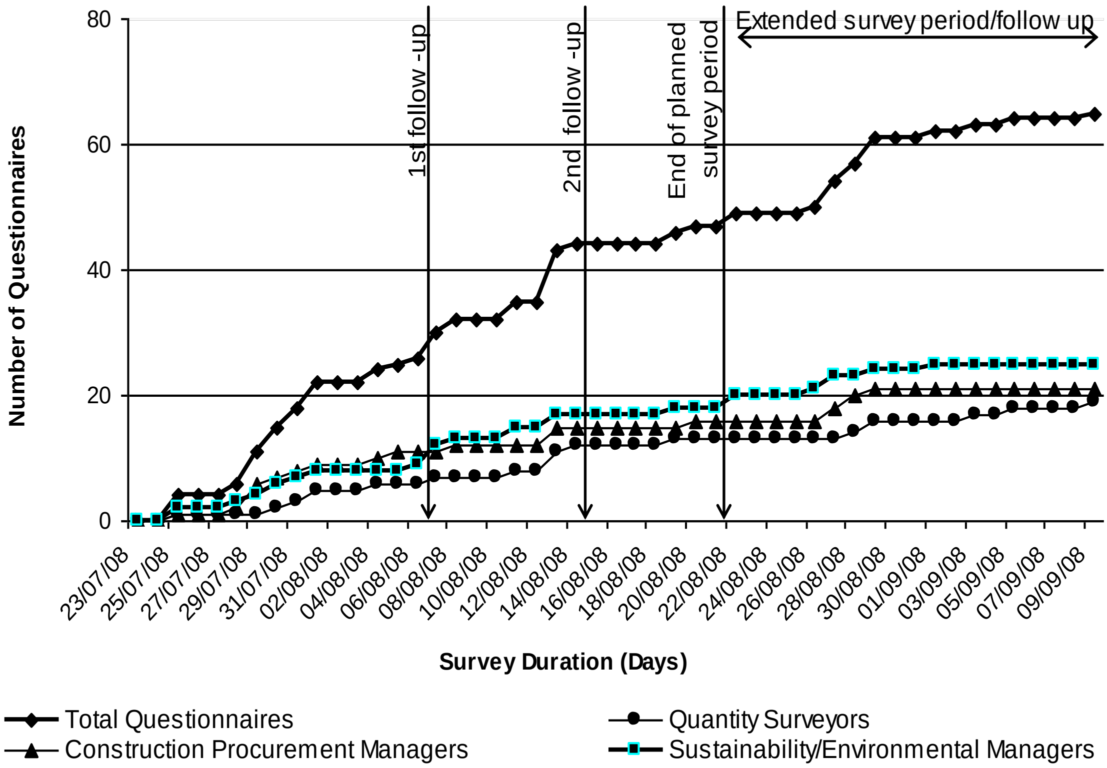

Figure 4.1. Questionnaire survey administration

4.2.2. Response Rate

Table 4.1 indicates the active response rate (discussed in section 2.7.5.2) based on the total number of companies involved in the survey. A net total of 150 companies were eligible for calculation of the active response rate, of which 55 companies responded to the survey. This gave an active response rate of 36.7%. In comparison, the active response rate from contracting companies (49.3%) was higher than the quantity surveying companies (24.7%). This may be an indication that contracting companies as having greater interest on WM and management issues if compared to quantity surveying companies.

Table 4.1. Response rate: by total number of companies

	Quantity Surveying companies	Contracting companies	Total
Number of companies involved	94	82	176
Rejection	17	9	26
Active sample size	77	73	150
No of questionnaires received	19	46	55(65)
Active response rate (%)	24.7%	49.3%	36.7%

As shown in Table 4.2, 65 questionnaires were received from three respondent categories: procurement managers, sustainability managers and quantity surveyors. Hence, the individual active response rate for the survey was recorded as 30.4% based on the number of respondents. The highest active response rate was recorded from sustainability managers (37.3%) whilst the lowest response rate was from quantity surveyors (24.7%).

Table 4.2. Response rate: by total number of respondents

	Quantity Surveyors	Contractors		Total
		Procurement Managers	Sustainability Managers	
Questionnaires distributed	94	82	82	258
Rejection	17	12	15	44
Active sample size	77	70	67	214
No of questionnaires received	19	21	25	65
Active Response Rate (%)	24.7%	30.0%	37.3%	30.4%

4.2.3. Missing Value Analysis

Missing value analysis was conducted for each question as it helps to address several concerns caused by incomplete data. The results of the missing value analysis (shown in Appendix 2.4) indicate that the missing data for all questions were less than 10% except question 4.1.2. Therefore, statistical analysis results can be presented based on the scores of non-missing values while the number of total questionnaire respondents remains at 65. The data obtained from question 4.1.2 was closely observed and treated appropriately in order to nullify possible influence caused from question 4.1.1 (further details are elicited in Appendix 2.4). The missing value analysis suggested that such influence might be due either to the use of a tabular format to present two questions (i.e. 4.1.1 and 4.1.2) or a lack of clarity in the instructions provided.

4.2.4. Kruskal-Wallis H test

Kruskal-Wallis H test (discussed in section 2.9.1.4) was conducted in order to ascertain whether there are any differences of views between the respondents' groups: procurement managers, sustainability managers and quantity surveyors. The results of the Kruskal-Wallis H test are shown in Appendix 4.1. The value of the asymptotic significance level for the majority of items for all questions was greater than 0.05 (except for question 2.2; section 4.3.3). This indicates that there was no difference between respondents' views on the same issues and provided a solid basis to analyse data considering all participants as one sample. However, only question 2.2 data was analysed separately by respondents groups as there was a difference of views between the respondents' groups (i.e. asymptotic significance level was lesser than 0.05) and the results are presented in section 4.3.3.

4.3. Background Information

4.3.1. Current Participating Companies' Workload

Respondents were asked to provide information on their respective companies' workload in terms of operating sectors, project types, nature of work, and building types. The results shown in Figure 4.2 indicate that the majority of companies (84%) operate in both the private and public sectors. Over 80% of companies undertake both new construction and refurbishment, repair and renovation (Figure 4.3).

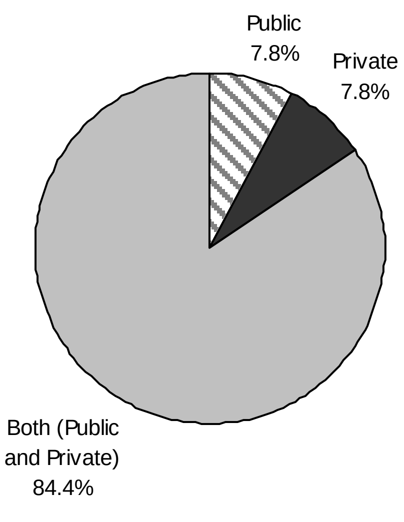

Figure 4.2. Participating companies' workload by project sector

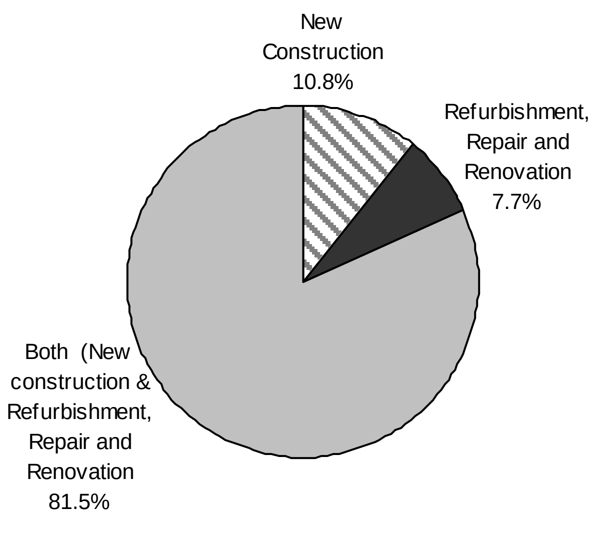

Figure 4.3. Participating companies' workload by nature of work

As shown in Figure 4.4, over half of the companies' workload (56%) relates to building projects only. However, over one-third of companies (34%) undertake both building and civil engineering projects. Figure 4.5 shows that participating companies concentrate on commercial (89%), industrial (86%) and leisure (84%) projects. Similarly, more than two-thirds of companies carry out residential (67%) and social (67%) building work. These results indicate that the participating companies and individuals have a diversified workload covering different areas by operating sectors, nature of work, type of projects, and type of buildings.

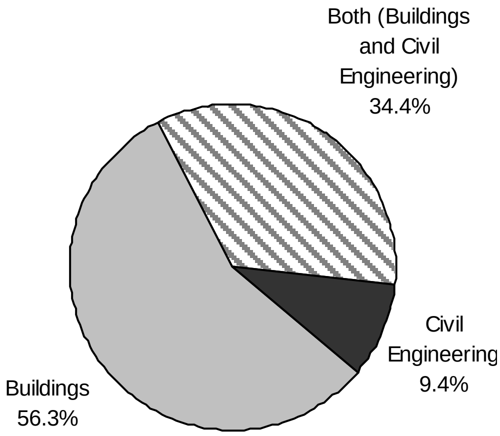

Figure 4.4. Participating companies' workload by construction types

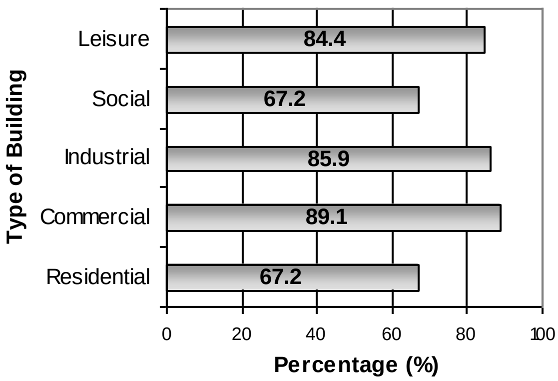

Figure 4.5. Participating companies' activity by building types

4.3.2. Current Sustainable Construction Practices in Company Policy Level

Respondents were asked to indicate whether their respective companies have a sustainability policy, a sustainable construction procurement policy, and sustainable waste management policy in place. As shown in Figure 4.6, over three-quarters of the respondents (78%) reported that their companies have a sustainability policy in place. About two-thirds of the companies (63%) reported that they have a sustainable waste management policy in place, whilst 20% were in the process of establishing such a policy. Approximately one-third (34%) of respondents stated that their companies have developed a sustainable construction procurement policy. Further, over 70% of the companies either already have or are in the progress of establishing all three policies. Additionally, a number of respondents reported that their companies have a separate Environment, Health and Safety Policy in place.

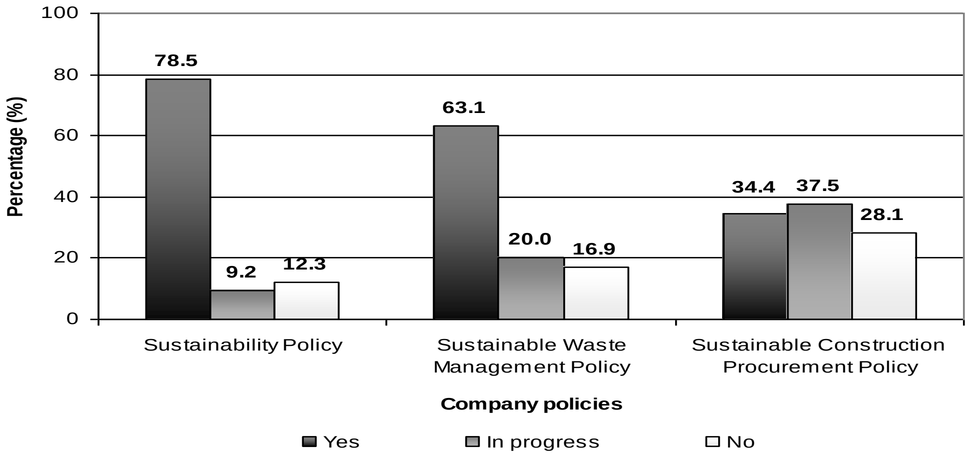

Figure 4.6. Sustainability policies: Company policy level

4.3.3. Impact of Government Policies and Legislation on Current Waste Management Practices

Respondents were asked to rate on a scale from 1 (No impact) to 5 (Major impact) the impact of the key waste management policies and legislation on their current waste management practices. As mentioned in section 4.2.4 (and Appendix 4.1), the Kruskal-Wallis H test indicated that there is a difference of views across the three responding groups in relation to question 2.2.

Therefore, contractors and quantity surveyors' data was separately analysed. As shown in Figure 4.7, approximately three-quarters of responding contractors reported that both the Landfill Tax (74%) and Site Waste Management Plans (76%) have a significant to major impact on their current waste management practices.

Approximately two-third of respondents reported that both Sustainable Construction Strategy 2008 (59%) and Sustainable Procurement Action Plan 2007 (58%) have impact on current waste management practices. As shown in Figure 4.7, approximately one-third of respondents from quantity surveying practices reported that both Landfill Tax (35%) and Site Waste Management Plans (29%) have a significant to major impact on current waste management practices. Furthermore, the majority of quantity surveyors viewed both policies and legislation as having no significant impact on their current waste management practices.

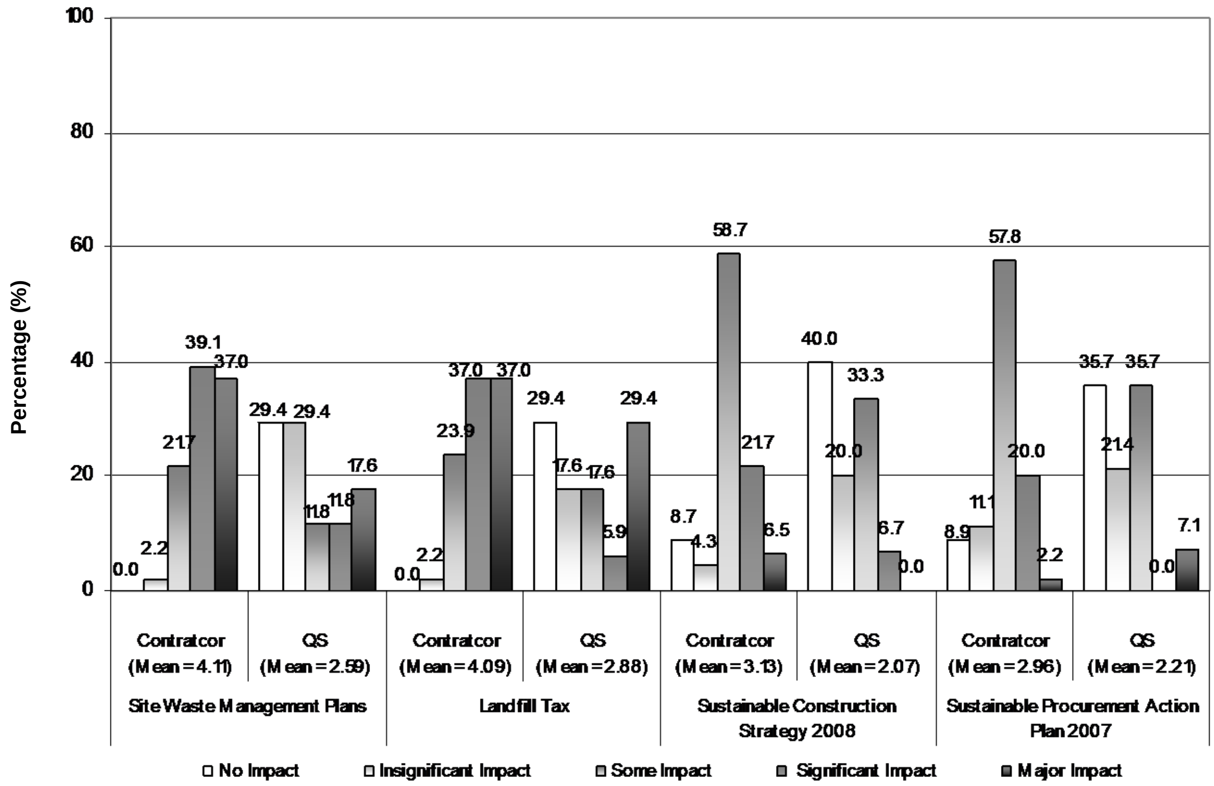

Figure 4.7. Impact of policies and legislation on current waste management practices

4.3.4. Current Waste Management Strategies

Respondents were asked to rate on a scale from 1 (Not used) to 5 (Used in all projects) the extent of use of given strategies to manage construction waste in their projects. It is apparent from Figure 4.8 that all four listed strategies were not being frequently used in all projects. However, over two-thirds of respondents reported that these have been used in some or most projects, of which 'on time delivery and bulk ordering' (65%) was the most commonly used strategy.

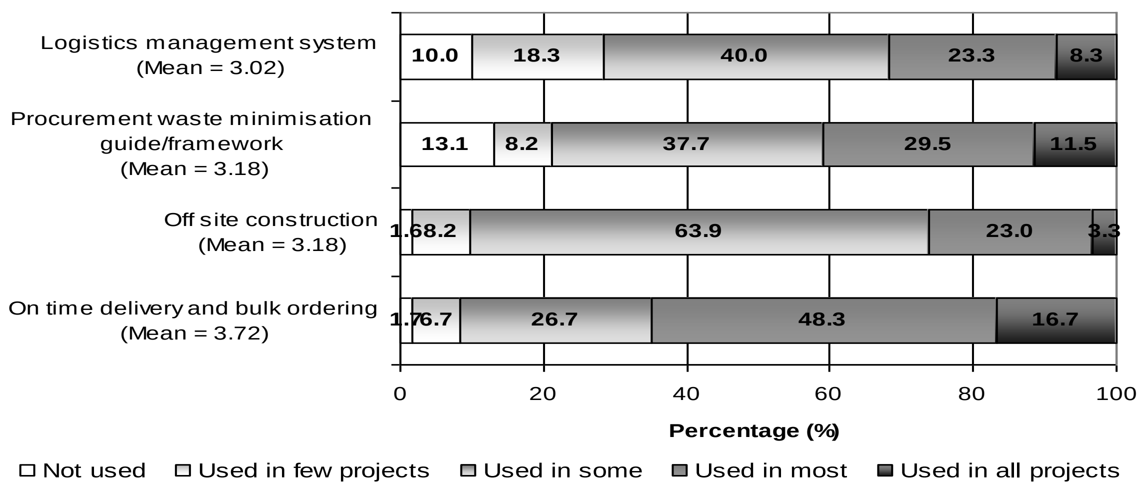

Figure 4.8. Current waste management strategies

4.4. Current Construction Procurement Practices

4.4.1. Responsibility for Procurement System Selection and Implementation

Respondents were given five professional categories (i.e. procurement manager, commercial manager, design manager, project manager, and quantity surveyor) and asked to indicate who may have the responsibility in terms of decision making for the selection and implementation of CPS in their respective companies. It is apparent from Figure 4.9 that procurement managers (28%), project managers (16%), quantity surveyors (9%) and commercial managers (5%) reported as individual professional categories for procurement selection and implementation within the participating companies.

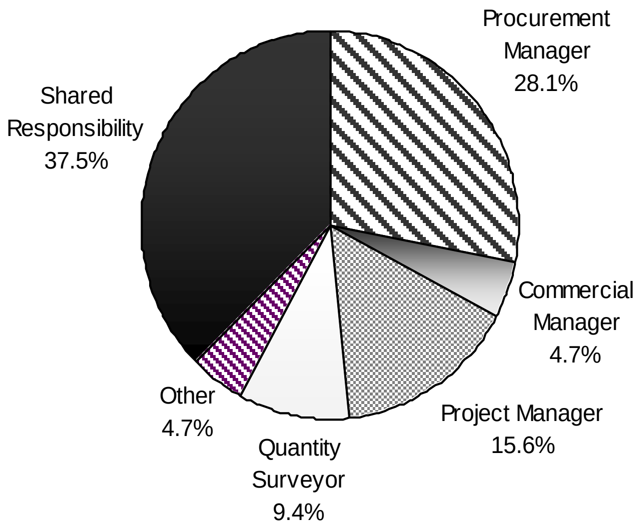

Figure 4.9. Responsibility for procurement system selection and implementation

4.4.2. Procurement Systems Selection Criteria

Respondents were asked to rate on a five-point scale from 1 (Not important) to 5 (Highly important) the importance of five given procurement criteria when selecting a CPS. It can be seen from Figure 4.10 that 97% and 78% of respondents respectively rated significant or highly important client requirements and project characteristics as key procurement selection criteria. Additionally, approximately 58% stated that they considered sustainability requirements and client characteristics (59%) as equally significant or highly important criteria in procurement selection. The results also show that respondents hardly rated external factors as important when selecting a CPS.

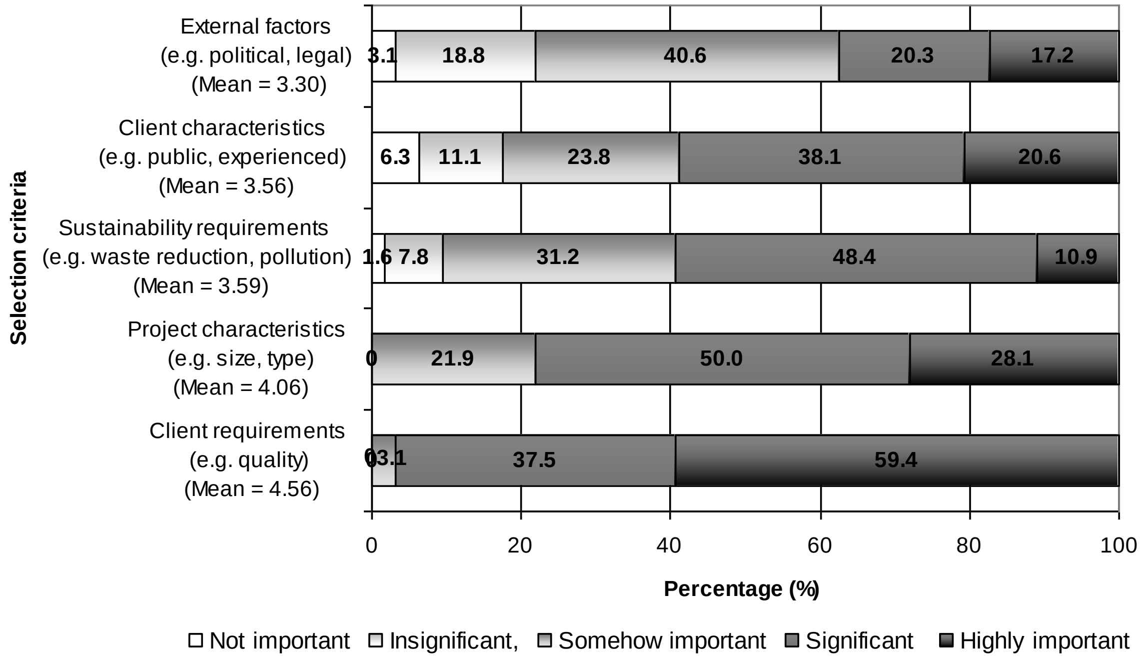

Figure 4.10. Importance of procurement section criteria

4.4.3. Current Procurement System Practices

Respondents were asked to rate on a scale 1 (Not used) to 5 (Used in all projects) the extent to which different CPS are being used in their current projects. Figure 4.11 reveals that approximately two-thirds of the respondents (62%) reported 'lump sum' are being used in most or all current projects, if compared with only 13% and 6% respectively for 're-measurement' and 'cost reimbursable' procurement systems.

Furthermore, 58% of respondents stated that 'design and build' system was selected in most or all current projects. On the other hand, about half of the respondents reported that 'develop and construct', 'package deal', and 'PFI' were rarely used while 55% noted that 'turn key' was not used in their current projects. Similarly, very few respondents stated that 'management-oriented' is routinely applied to most or all their projects, while, approximately one-third of respondents reported that these systems had never been used. Overall, the results indicate the popularity of 'design and build' and 'lump sum' while other CPS were not commonly used.

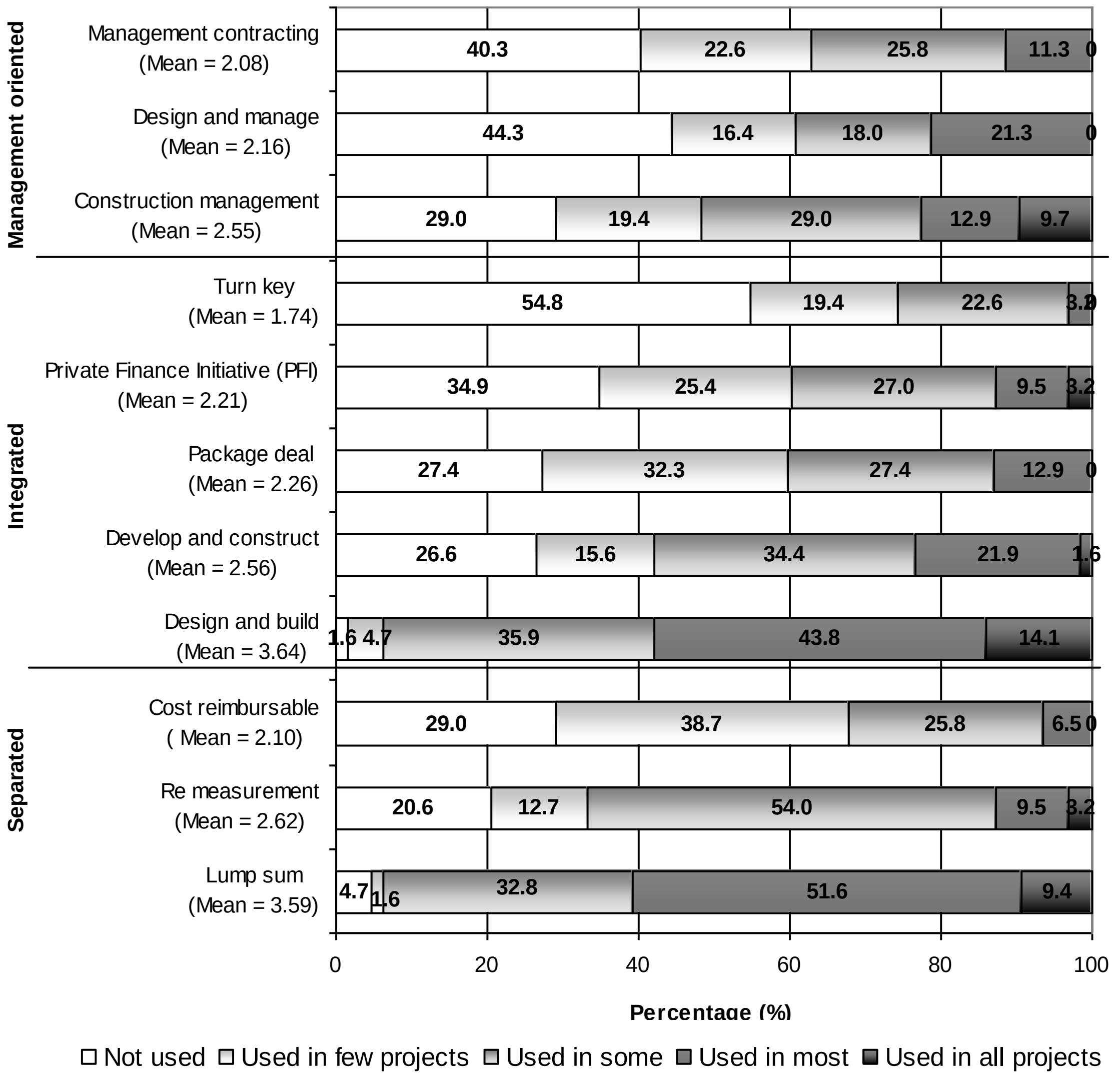

Figure 4.11. Current use of CPS

4.5. Relationship between Construction Procurement Systems and Waste Generation

4.5.1. Waste Minimisation Implementation Responsibility

Respondents were asked to rate on a scale of 1 (No responsibility) to 5 (Full responsibility) project stakeholders' responsibility for implementing WM strategies in their current projects. Respondents were also given a choice to indicate if none of the given stakeholders are responsible for implementing WM strategies in their current projects. The results showed that none of the respondents selected the given choice (i.e.), which strongly confirmed that at least one given stakeholder was responsible for implementing WM strategies. As shown in Figure 4.12, approximately 89% of respondents stated that contractors have full or significant responsibility for implementing WM strategies in their current projects; followed by designers (52%), clients/client representatives (43%), government and regulatory bodies (48%), and material manufacturers (45%). Only one third of the respondents (29%) reported that client/client representatives have full or significant responsibility for implementing WM strategies in their current projects.

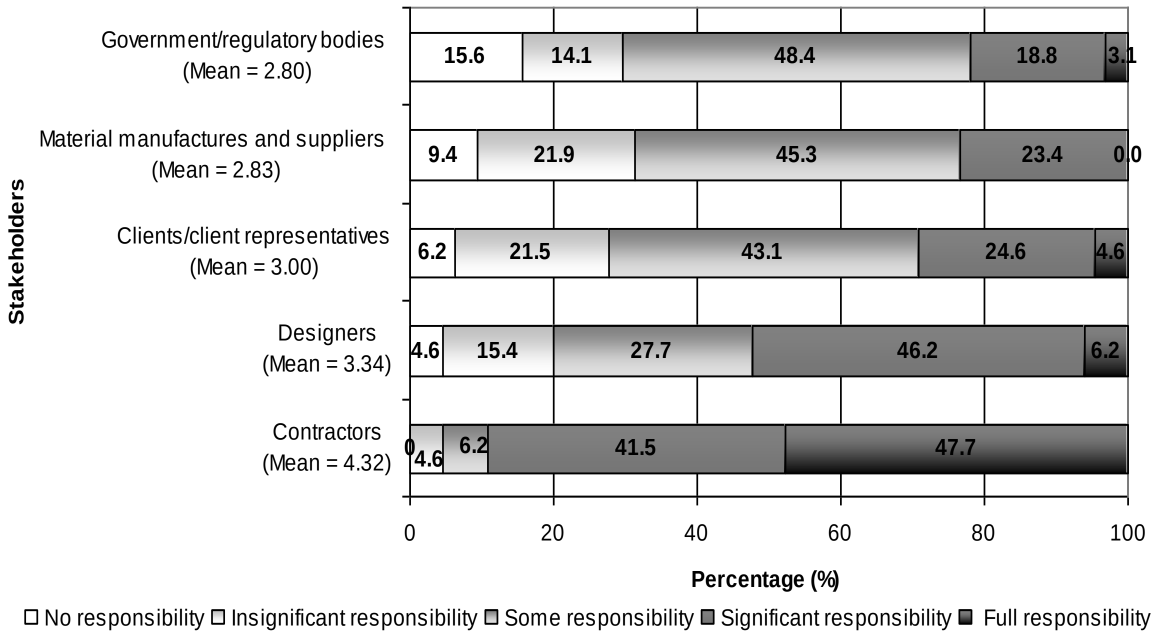

Figure 4.12. Project stakeholders' responsibility for implementing WM strategies

4.5.2. Impact of Procurement System Selection Stages on Construction Waste Generation

Respondents were asked to rate on a scale 1 (No impact) to 5 (High impact) the impact of procurement selection stages on construction waste generation. As shown in Figure 4.13, approximately two-thirds of respondents reported that 'Technical Design' and 'Production Information' stages have a significant or high impact on construction waste generation. Additionally, none of the respondents rated the latter two stages as having 'no impact' on waste generation. The majority of respondents reported that CPS selection at the 'Appraisal' stage has a minimum impact on waste generation compared to the other stages. However, the respondents' views suggested that the CPS selection at the 'Design Brief' stage has a greater impact than at the Concept stage.

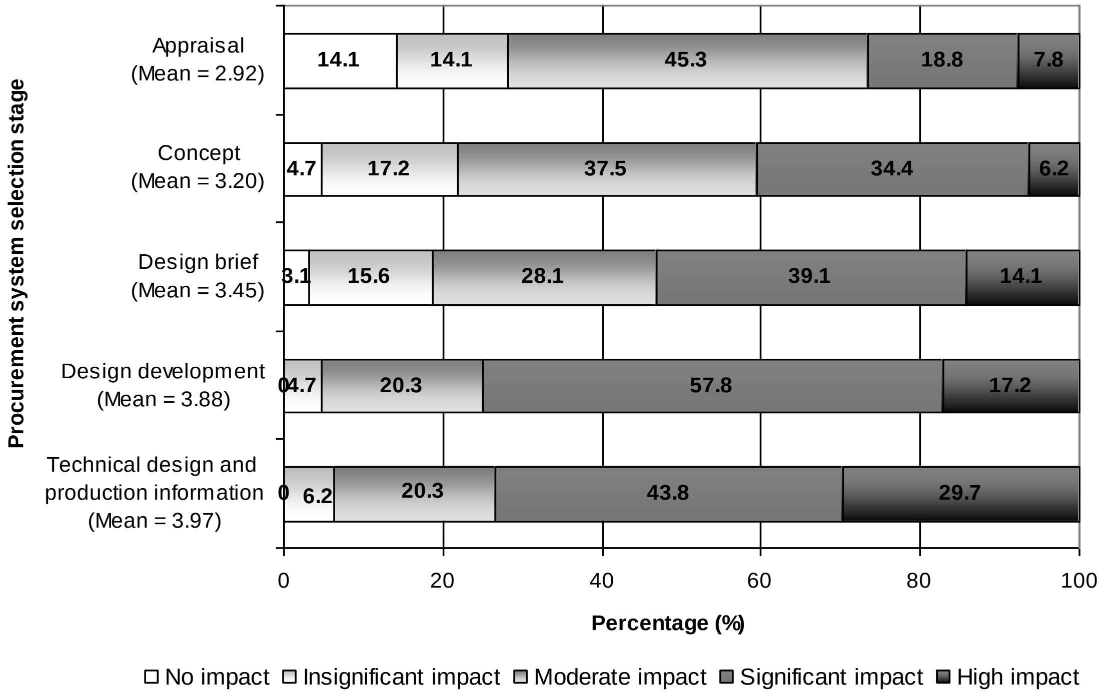

Figure 4.13. Impact of procurement selection stage on construction waste generation

4.5.3. Impact of Procurement Systems on Waste Generation

Respondents were asked to rate on a scale 1 (No impact) to 5 (High impact) typically the impact of the key procurement systems on construction waste generation. As shown in Figure 4.14, less than 10% of respondents reported that there was ‘no impact’ of procurement systems on construction waste generation. Between 45% and 65% of respondents reported that all CPS except ‘cost reimbursable’ and ‘design and build’ had a moderate impact on construction waste generation. Moreover 49% and 43% respectively reported that the ‘cost reimbursable’ and ‘design and build’ systems have a significant to high impact on construction waste generation. Additionally, about one-third of the respondents (28%) reported that ‘re-measurement’, ‘develop and construct’ (31%), and ‘construction management’ (27%) also have a considerable impact on construction waste generation.

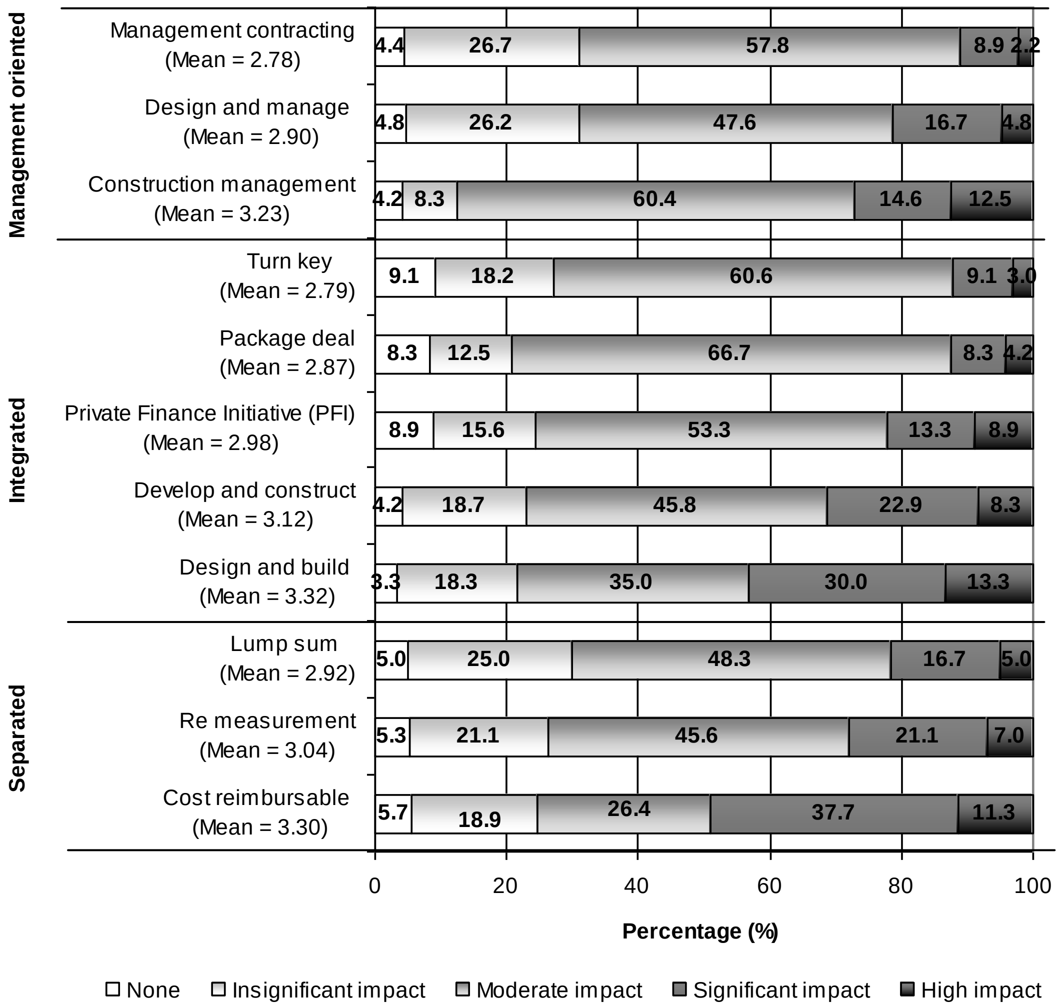

Figure 4.14. Impact of CPS on construction waste generation

More than half of the respondents provided additional qualitative comments. They collectively acknowledged that there was a strong correlation between CPS and waste generation in construction. For instance, one respondent stated that *'a procurement system has a significant effect on the waste generated'* (SM21). Moreover, several respondents believed that integrated systems, particularly 'design and build', produced less waste as they *'tend to promote innovative waste management to reduced cost'* (PM6), as one respondent put it. Furthermore, several respondents highlighted that WM planning and decisions should be made in the early stages of the project by encouraging *'procurement arrangements that facilitate early involvement and good communication within all parties in the project will lead WM'* (PM17). For example, 'trade parties and contractors' early interaction and input '*will improve WM as it also impacts contractors' bottom line (i.e. construction activities and interaction with supply chain)'* (PM3). Hence, these views suggest that design and build system possibly produce less waste as it allows contractors to be involved during the early planning and design stages. Some of the respondents highlighted the effectiveness of integrated systems in terms of waste reduction if compared with separated (traditional) systems:

- *'traditional systems place emphasis on the client and his/her team to manage waste generation - not always good at this. With design and build the emphasis lies with contractor'* (PM2);
- *'contractors are not involved in the earliest stages of design (typically pre-contract stage) under traditional procurement route and certain design and build options too. Waste management must then often control the waste generated from decisions made which are out of contractors' control'* (SM22);
- *'integrated systems work better than separated systems as they allow for design decisions to be made easily in the process. This should help to provide an effective construction process and hence minimise waste'* (PM6); and
- *'by taking part in the design process, contractors can have some influence on reducing construction waste because they can bring more practical lean design solutions and strategies to design such as a more practical design with less changes or variations'* (QS18).

Two additional themes were strongly conveyed by the respondents' qualitative feedback.

Stakeholders' WM responsibilities: Respondents associated the impact of CPS on waste generation with a lack of clarity and guidance in terms of stakeholders' responsibilities. One respondent mentioned that the '*impact of CPS on waste production largely depends on who takes responsibility for WM'* (QS13). Respondents were of the view that each project stakeholder needs to bear a certain responsibility for WM. For instance, one respondent attempted a way forward by suggesting that '*clients [need] to make waste reduction a requirement in their project brief, designers to design out waste, and contractors to minimise and recycle on site waste*' (PM14).

Several respondents stressed that clients are not usually aware of WM issues during the early project stages. One respondent went further by claiming that *'clients appreciate the severity of waste at the site preparation stage'* (SM22). Further respondents' views in this regard are as follows:

- *'clients' objectives on waste need be reflected whatever the system of procurement'* (QS9)*;* and

- *'clients need to set up targets on waste management and minimisation (e.g. BREEAM* (Building Research Establishment Environmental Assessment Method) *target, SWMPs)'* (QS13).

Contractual agreements and cost implications: Several respondents argued that financial incentives play a significant role in WM. Therefore, they commented that CPS and contractual agreements could be effective in incorporating such incentives by quoting:

- *'WM has to be cost driven and incentivised and measured'* (SM19)*;*
- *'if contractors reduce waste they can increase profit, but there has to be encouragement from project procurement route or contractual agreement; in this regard lump sum and target cost arrangements have [more] potential to encourage WM than cost reimbursable and re measurement'* (PM2)*;* and
- *'contract/procurement arrangements and commercial drivers are the key issues in any project. i.e. what financial incentives are there for designers, contractors and engineers to reduce waste?'* (SM11).

4.5.4. Effects of Procurement Waste Origins on Waste Generation

Respondents were asked to rate on a scale 1 (No effect) to 5 (Major effect) the effect of procurement related waste origins on construction waste generation. As shown in Figure 4.15, approximately 82%, 72% and 65% of respondents respectively reported that 'early contractor's involvement', 'ineffective communication and coordination among parties and trades', and 'unclear allocated responsibility for decision making' have a significant or major effect on waste generation. The 'method of tendering' (37%) and 'procurement system process duration' (40%) was reported as having a moderate effect on waste generation.

Respondents were asked to provide additional comments on procurement waste origins. Listed below are procurement related waste origins noted by a few respondents.

- Collaborative procurement approach: *'collaborative contracts allow all stakeholders to have a common objective from the early stages of a project. As such, it helps to reduce waste'* (PM6). Moreover*, 'collaborative working restricts variations and allows reviewing and optimising design related issues at the* *early stages of a project (e.g. value management workshops, life cycle costing)'* (QS18).

- Sub-contractor early involvement and their relationships: *'procurement is the key along with good sub-contractor relationships. Undermined relationships between sub-contractors and other stakeholders lead to waste generation'* (SM1).
- Procurement duration: *'fast track CPS tend to generate high waste due to the fixed time scale. Similarly, long product acceptance procedures can also lead for waste generation'* (QS18).
- Contract process: *'the extent to which the procurement system allows for the completeness and comprehensiveness of the pre-contract process (i.e. completeness of design, tender and contract documents) has an impact on waste generation as it has a direct link with variations'* (QS8).

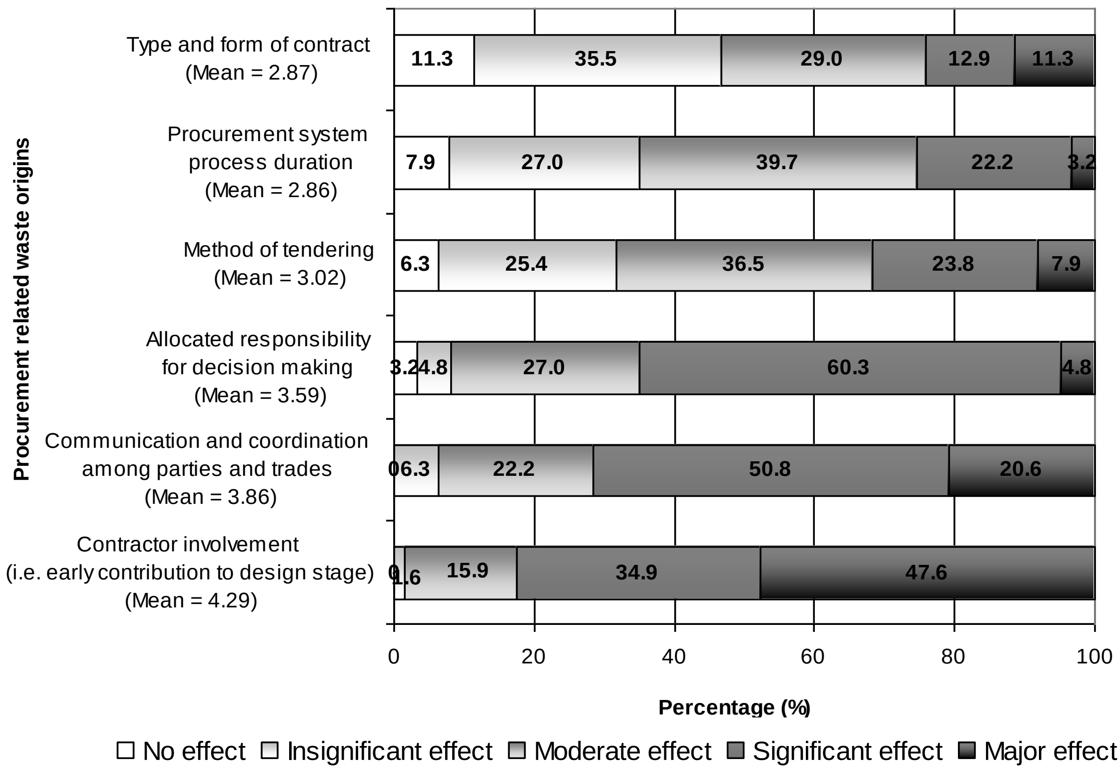

Figure 4.15. Effect of procurement waste origins on construction waste generation

4.6. Future Trends and Improvements

4.6.1. Construction Procurement Trend

A procurement related government policy (i.e. government is the major client, key regulatory and legislation body) was used as a baseline to assess any significant changes that might have occurred in the construction procurement trend in recent years. Respondents were introduced to the UK government recommended procurement policy [since April 2000, projects to be procured by using one of the three integrated procurement routes as PFI, prime contracting or design and build (OGC, 2007d)] and were asked to rate from 1 to 5 (no change, insignificant change, moderate change, significant change, major change) its effect on their current CPS selection practice. As shown in Figure 4.16, around half of the respondents stated that the government recommended policy has caused a moderate change to the selection of CPS generally. However, about one-third of the respondents (35%) thought that the policy caused a significant change to the selection of CPS. A minority of participants (14%) indicated no or insignificant change.

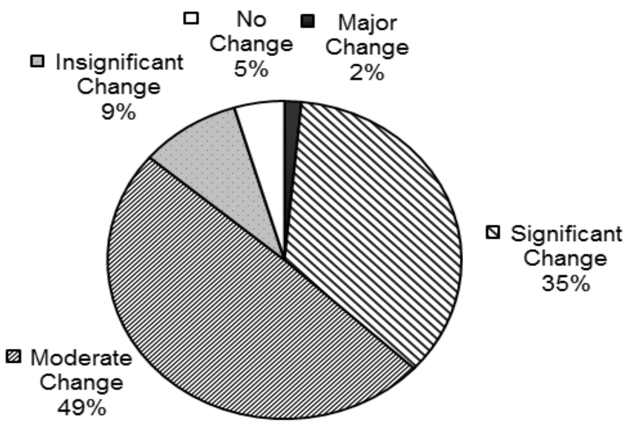

Figure 4.16. Procurement trend after the UK government recommended construction procurement policy 2000

There were 17 (of 65) additional qualitative comments on the current procurement trend; out of which the majority of respondents stated that the design and build procurement system is becoming popular. For example, one respondent mentioned '*design and build has been the preferred route for risk-averse employers for many years'* (QS16) and another stated that '*from our perspective design and build is still prevalent procurement system'* (PM17). Few respondents mentioned that choice of procurement system is driven by client's requirements, desires, and attitudes, which suggested that the procurement selection is independent of the implemented policy.

4.6.2. Potential Procurement Systems to Integrate Waste Minimisation Strategies

Respondents were asked to rate from 1 (No potential) to 5 (Major potential) the most fitting procurement systems that have the potential to embed WM strategies. Figure 4.17 indicates that respondents believed that all CPS have some potential to integrate WM strategies, as none of the CPS was rated as having ‘no potential’. However, approximately three-quarters of respondents (75%) viewed that integrated systems have a significant or major potential to integrate WM strategies followed by management-oriented systems (52%). Conversely, the worst potential systems in which to integrate WM strategies were reported as separated (traditional) systems.

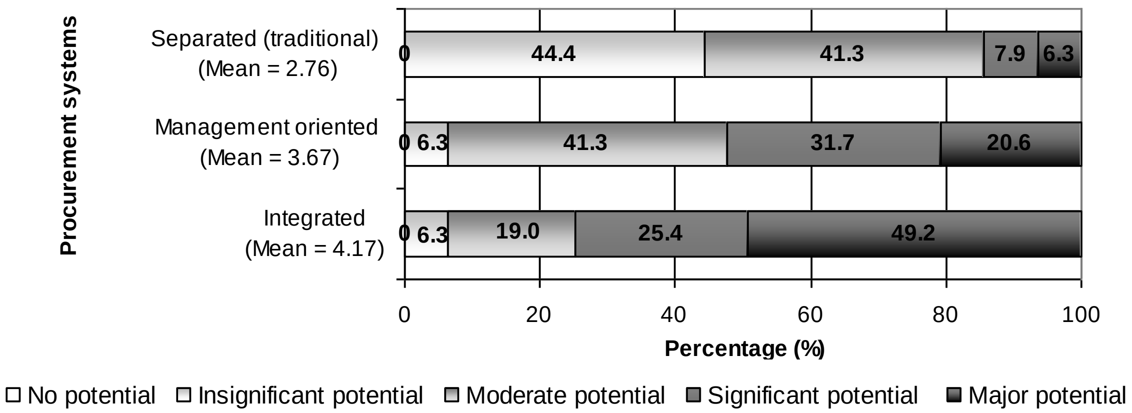

Figure 4.17. Potential of CPS to integrate WM strategies

4.7. Validity and Reliability

As discussed in section 2.7.6, measures were taken to ensure validity and reliability of the survey data. Content validity of the question data was ensured through a thorough literature review and a pilot questionnaire survey. However, construct validity was considered less as it needs more exploration and may not applicable (i.e. predictions). In terms of the reliability, test-retest and alternative forms were not adopted in the survey due to the practical difficulties discussed in section 2.7.6.

Attempts were made to ensure data reliability related to data sources by a careful selection of respondents for the survey. From the survey data shown in Figure 4.18, it is evident that respondents were adequately experienced professionals in the field. Moreover, almost all the respondents provided their background details (i.e. name, designation, experience, email address). Additionally, the diversity of respondents’ representative companies in terms of areas by operating sectors, project types, nature of work and building types (section 4.3.1) provide a solid evidence of reliability related to data sources.

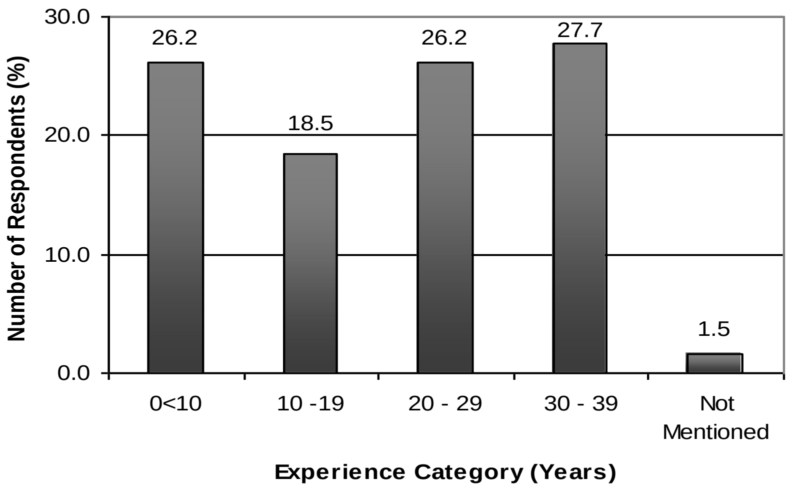

Figure 4.18. Respondents' experience

Respondents' data for items of each question (i.e. that are supposed to measure characteristics, attitudes or qualities) were separately analysed and checked for internal reliability. As shown in Table 4.3, Cronbach's Alpha (α) is greater than 0.5 (mentioned in section 2.9.1.5) for the majority of questions, which indicates an acceptable level of internal reliability (detailed results are presented in Appendix 4.2).

Table 4.3. Internal reliability

Question	Indented to measure	Cronbach's Alpha (α)	Number of items	Reliability
2.2	Impact of government policies and legislation on current waste management practices (section 4.3.3)	0.786	4	Reliable
2.3	Current use of waste management strategies (section 4.3.4)	0.686	4	Reliable
3.2	Responsibility for procurement system selection and implementation (section 4.4.1)	0.237	5	* Low in reliability
3.3	WM implementation responsibility (section 4.5.1)	0.253	5	* Low in reliability
4.1	Impact of procurement selection stages on waste generation (section 4.5.2)	0.704	5	Reliable
4.2.1	Current procurement system practices (section 4.4.3)	0.674	11	Reliable
4.2.2	Impact of procurement systems on waste generation (section 4.5.3)	0.883	11	Reliable
4.4	Effects of procurement waste origins on waste generation (section 4.5.4)	0.777	6	Reliable
5.3	Potential procurement systems to integrate WM strategies (section 4.6.2)	0.460	3	Reliable

There was other positive evidence that the survey has acceptable validity and reliability: low missing values (section 4.2.3), over half of respondents (42) responded to the majority of open ended questions; about one-quarter of respondents (17) gave consent for follow up interviews; and nearly half of the respondents (27) were interested in receiving a summary of the survey findings.

4.8. Summary

This chapter aimed to present the findings of the questionnaire survey that sought to explore issues pertinent to the relationship between CPS and waste generation. The chapter presented key results related to impact of sustainability related policies and legislation; current construction procurement practices; the relationship between CPS and waste generation; and future CPS trends and improvements.

While there was a positive indication that current practices consider sustainability issues at company policy level, it was revealed that there is a need for further attention on improving internal polices related to construction procurement and waste management. On the other hand, the respondents' views suggested that environmental legislation has had a more significant impact on current waste management practices than associated government policies.

The survey responses further reported that design and build system has a trend in increasing popularity as a single procurement system in the UK construction industry. In terms of the procurement selection, priority was given to client requirements and project characteristics while sustainability requirements were reported having a considerably low priority. Similarly, survey results reported that stakeholders who are responsible for procurement system selection should be committed to effectively capturing clients' requirements. Moreover, results revealed that the procurement selection process and implementation responsibility are shared among several professionals at organisational and project levels.

Results of this survey reported that a selected procurement system in later project stages may have a significant to high impact on construction waste generation. Moreover, results emphasised that there is a possibility to investigate how WM requirements and strategies could be embedded into CPS at the procurement selection stage. In terms of the WM responsibilities, the survey responses highlighted that all key stakeholders; namely client, designers, and contractors, possibly have a considerable role to play across all project life cycle stages. It is also evident from the survey results that design and build and cost reimbursable systems are reported as having an impact to generate more waste if compared with other CPS. The results suggested that integrated CPS and design and build system have a high potential to integrate WM strategies. Moreover, the study identified four PWO: lack of stakeholders' involvement in the early design stage and procurement selection stage; poor communication and coordination among parties and trades; a lack of allocated responsibilities for decision-making; and incomplete or insufficient procurement documentation.

The next chapter presents the results of the follow-up semi-structured interviews that sought to investigate the issues raised from the questionnaire survey, design and build related waste origins and potential WM strategies that could be integrated into the design and build system.

5. Interview Results

5.1. Introduction

This chapter presents the results of the semi-structured exploratory interviews conducted with procurement managers, sustainability managers and quantity surveyors selected from the UK top 100 contracting and quantity surveying companies respectively.

The semi-structured interviews were based on the results which emanated from the questionnaire survey and literature review. Consequently, a particular focus was given to the investigation of Design and Build (D & B) procurement approach related waste origins and potential strategies to enhance Waste Minimisation (WM) practices. The themes emerged from the study (i.e. Constant Comparison Method described in section 2.9.2) are presented using narratives and quotations.

Interviewees' profiles and backgrounds are presented first followed by WM and management strategies that are being used in their current projects. D & B procurement practice is discussed with regard to its frequency of use, reasons behind such trends, and contribution to sustainable construction. Subsequently, interviewees' views on how D & B procurement system impacts on construction waste is reported. The next section presents D & B related waste origins. Particularly, the main section gives an account on the impact of uncoordinated early involvement of project stakeholders, ineffective project communication and coordination, unclear allocation of responsibilities and inconsistent procurement documentation on waste generation. The final section shows interviewees' views on ways to address D & B waste origins and reasons and suggestions for a potential incorporation of WM strategies within integrated CPS.

5.2. Respondents Profile

Table 5.1 displays the interviewees' profile comprising 17 questionnaire respondents who expressed their willingness to participate in follow up interviews. The interviewees were selected from different companies and sampling frame comprised five

Procurement Managers (PM), six Sustainability Managers (SM), and six Quantity Surveyors (QS).

Table 5.1. Interviewee profile

	Contractors		Consultants	Total
Profession	Procurement Managers	Sustainability Managers	Quantity Surveyors	
Sample size	5	6	6	17

The respondents were asked to describe their work experience, and the extent of their involvement in procurement and WM and management activities. The majority of respondents held senior managerial positions within their organisations and were involved in a variety of building projects that were procured through different Construction Procurement Systems (CPS).

All PM (5) had over 25 years of experience in the construction industry and performed diverse roles in their professional careers. As indicated in Appendix 5.1, while all PM had direct involvement with different procurement activities throughout their careers, involvement in WM and management were limited to three areas: contribution to company's environmental policies; procurement documentation; and working with supply chains. The majority of SM (4) had over 15 years of experience in the construction industry with diverse experience across different areas such as environmental, procurement and quality management. Moreover, there was clear evidence of direct involvement in WM and management activities both at company policy level (i.e. management and advisory) and on-site operations. Similarly, the majority of QS (5) had more than 20 years experience in the construction industry. As shown in Appendix 5.1, QS careers were mainly limited to some aspects of the quantity surveying profession; however, all of them have had direct involvement with procurement activities during their professional careers. The QS's engagement with WM and management issues were mainly limited to procurement documentation.

5.3. Current Waste Minimisation and Management Practices

Respondents were asked to list and describe the key WM strategies that were being used in their current projects. This was aimed to indentify if current WM and management strategies consider procurement WM. Table 5.2 summarises interviewees' responses which are categorised into pre-waste and post-waste generation. These are arranged according to the interviewees' responses in terms of importance and frequency of use.

Table 5.2. Reported current WM and management strategies

Pre – waste generation	Post – waste generation
▪ Setting waste targets to supply chain ▪ Site waste management planning (waste estimation, waste stream analysis and actions, material reconciliation) ▪ Just in time delivery and bulk ordering ▪ Offsite prefabrication ▪ Set up waste management as one work tender package ▪ Design out waste (use of standard design templates; standardisation modular sizes) ▪ Suitable selection of materials	▪ Reuse ▪ Recycle ▪ Strategic ways to minimise number of skips (i.e. balance between cut and fill of excavated materials; squeeze card boards and scrap timber) ▪ Effective waste storage (onsite waste storage – provide and maintain skips; allocate appropriate space; proper storage practices) ▪ Waste transfer (waste sorting/segregation, encourage sub-contractors to take away waste from the site, employ waste disposal companies, maintaining waste transfer stations) ▪ Waste studies ▪ Supervision and monitoring

The interviewees were also asked to list WM strategies that were currently not used in their projects but could potentially reduce onsite waste. There is a clear consensus among interviewees that three aspects needed addressing.

Identifying waste inherent in the design: Most of the interviewees strongly emphasised very little up-front consideration of WM at the early stages of projects and stressed the need for identifying waste inherent in the design stages. They collectively argued that the whole design for manufacturing to design out waste must be at the start rather than looking to design for recycling once waste is generated. Moreover, specifications should need to be written focussing on being fit for their purpose by ensuring the correct choice of materials at the construction stage.

Assess sub-contractors' waste reduction performance: By and large, participants were of the view that although the bulk of the current D & B work is undertaken by sub-contractors, little attention is given towards challenging of their waste production. The interviewees suggested that current WM practices should be focussed on the following:

- assessing sub-contractors/ sub-traders works and their waste streams;

- identifying responsibility for sub-contractors own waste; and
- investigating suitable strategies to minimise sub-contractors' waste streams.

Improving procurement and planning stages activities: Nearly every interviewee stressed that rigorous attention was needed to improve procurement and planning stage activities in terms of WM. Listed below are some key actions suggested for improving WM at the procurement and planning stages.

- Incorporate WM requirements into contract as percentages of waste levels.
- Specify WM and management strategies for the project to be formally written down and communicated (i.e. client brief, tender document, contract document) to the contractor at the procurement stage. Furthermore, it is suggested that the procurement of the waste management package should be an open book.
- Few participants suggested that introducing legislation targeted at pre-contract stages and aimed predominantly at architects and clients could allow the achievement of WM effectively during the design, procurement and planning stages.

5.4. Design and Build Procurement Practice

5.4.1. Design and Build Trend

The interviewees were asked to comment on the questionnaire survey results on CPS trends. The survey suggested that Design and Build (D & B) is dominant and has an increasing trend in use. Therefore, respondents were asked if they thought the same trend would continue in the immediate future. Almost all of the interviewees (16 out of 17) strongly agreed that the D & B would be the dominant procurement system. For instance, one PM interviewee noted that '*at least 50% of future projects will be procured through D & B'* (PM9). On a similar note, a QS interviewee commented that *'if you went back 25 to 30 years, the dominant practice was traditional procurement system where D & B share was 15%. Currently, it is around 60% and potentially higher in the near future*' (QS3).

Interviewees were asked to explain the reasons behind their views on the widespread use of the D & B procurement system; their responses are illustrated in Figure 5.1 and discussed in the following four sections.

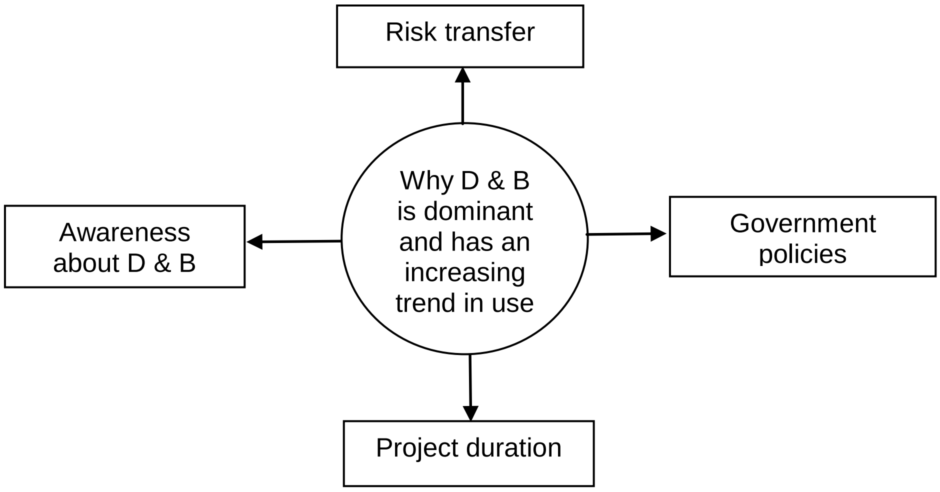

Figure 5.1. Key reasons for dominance of D & B procurement system

5.4.1.1 Risk transfer

The vast majority of interviewees (15 out of 17) took the view that the main reason for the dominance of D & B procurement system was due to clients preference to transfer risks to contractors. Moreover, interviewees argued that the latter was usually based on client representatives' advice to pass design risk to contractors; as one interviewee noted: *'as long as the client is risk-averse which they tend to be, the client's team or the employer's agent would always advice the client to go down the D & B route'* (PM13).

Several interviewees said that the main aim of transferring design risks to the contractor would allow cost certainty of the project which is driven by the current market situation. One interviewee explained: '*particularly with this economic market the client will like to pass the risk on to the contractor, which was not the case 10-15 years ago where clients were quite willing to dictate to the contractor their requirements through the traditional procurement route. Clients were therefore taking risks, avoiding project cost certainty. At present, the process is completely reversed in D & B by passing the risk on to the contractor to achieve cost certainty'* (QS3). However, although risk transfer exercise tends to achieve project cost certainty, there is always a risk in higher project costs. One QS interviewee described this by comparing D & B with the traditional system: '*from a client or developer's point of view, the risk is the cost risk. D & B pushes the cost risk very much more than it does in a traditional route. In D & B, contractors have to iron out their own problems and therefore absorb the cost of those problems to the final project cost that leads to higher project costs'* (QS10). Another PM interviewee pointed out that there is a high possibility of including contingency sums particularly when *'there is not enough time to fully analyse the risk,* *the contractor puts more contingency sums against unforeseen risks that is not good on either side, because that effectively means that the client might be paying more for something unnecessary. Even the lowest contractor puts contingency to twice the real cost*' (PM13). However, the same interviewee noted that contractors also cannot over-inflate the project cost as they take a risk of losing the project at the bidding stage. Few interviewees said that even though risk transfer drives to increase project costs, there is always an advantage to gain value for money for the extra cost as D & B entitles it to gain the construction expertise of contractors and their supply chain at the design stage. For example, one SM interviewee recognised that '*clients can use expertise of contractors and their supply chain which is a key driver behind such trends as it adds value to additional costs due to risks'* (SM22). Moreover, several interviewees noted that if D & B is selected merely as a risk minimisation exercise for the client, there are still some disadvantageous risks to the client such as poor architectural quality building, extensions of project duration, and project cost escalation (variations due to lack of information).

5.4.1.2 Government policies

Over half of interviewees (11 out of 17) believed that government policies have encouraged the use of D & B. Several interviewees said that most government projects had been undertaken under PFI which is within a D & B procurement structure. This was echoed by a PM interviewee stating that *'D & B is probably the way that most government contracts are going at the moment given the current economic situation. Thus, I don't really see that changing too much and some of the other management routes that are being used by the government that have probably been a little tortuous can matter much'* (PM4). Furthermore, a QS interviewee explained how government procurement practices impact on the whole procurement trend: '*the PFI form of procurement which is used now probably has a much higher level of government procurement. Therefore, relatively the goalposts have moved in the way people think about how they are going to deliver these projects; and the 'Egan' 'Latham' reports helped to concentrate people's minds on the procurement'* (QS3).

5.4.1.3 Project duration

Over half of the respondents (9 out of 17) stated that most clients prefer D & B as it allows short project duration compared to other CPS. In particular they reported that D & B allows parallel working (i.e. design and construction) which reduces project duration. In this regard, one QS interviewee said, '*running construction and design in* *parallel can lead to an integrated approach of construction management rather than having the opportunity to do the design alone and construct it later. This can reduce the time tremendously compared to that of the traditional procurement*' (QS13). Moreover, interviewees concurred that D & B has less tendency for disputes compared to other CPS. For instance, one QS interviewee explained how the latter stated helps for short project duration: '*disputes were always the norm rather than the exception, whereas now, with D & B, it is the other way around with less disputes, which ultimately lead to faster construction'* (QS3).

5.4.1.4 Clients' awareness about the D & B system

Nearly half of interviewees (7 out of 17) reported that clients were well aware of the D & B system which is frequently used in their projects. Reasons for clients' preference for D & B were put across by a SM interviewee who stated that '*clients are used to selecting D & B for procuring their projects, as it gives them a certain amount of flexibility and allows the main contractors to bring their expertise in throughout the project stages'* (SM22).

5.4.2. Traditional D & B Versus Enhanced D & B

The interviewees were asked about their current procurement practices in relation to traditional and enhanced D & B system. The overwhelming majority of interviewees (15 out of 17) reported that current practice is more towards enhanced D & B than traditional D & B. One QS interviewee said, *'recently, there has been a good level of design before going ahead to tender; and as such the procurement system should be called 'develop and construct' rather than D & B'* (QS13). A PM interviewee explained the issue further by stating that '*contractors, who are typically in a competition with several other builders, are often given a design that has been completed to RIBA stages D and E. The client provides concept designs and a base specification or output specification to the contractor and requests 'to develop all the design interfaces'* (PM4). Additionally, 14 out of 17 interviewees stated that clients tend to novate 'concept design'' to contractors; as one SM interviewee put it: '*about 70% to 80% of D & B contractual forms at the moment are for a scheme to be designed by a client using designers and then novate it to a contractor who subsequently will employ designers and take full responsibility for design and construction from that stage onward'* (SM19). A large number of interviewees took the view that clients would like to use enhanced D & B as it allows them to employ an architect to determine the basic building form in terms of function and aesthetic and also helps to assess budget requirements prior to a

D & B contract. Moreover, some interviewees argued that clients employ enhanced D & B only as a risk transfer exercise to the contractor. For example, one SM interviewee stated that *'clients demand enhanced D & B in most of our D & B projects, with an aim to pass over the risk to contractors, which indicates that contractors cannot influence build-ability or the construction implications of the design at a very early stage'* (SM2).

Interviewees strongly expressed the view that that contractor's involvement at the early design stage is restricted and therefore, have little opportunity to change the concept design when the contractor is involved with D & B system. As such a PM participant stated that '*contractors have very little opportunity to change concept designs'* (PM11). Another SM interviewee attempted to compare traditional D & B with enhanced D & B by maintaining that in the latter *'a lot of the early design has already been done before the D & B is actually created; therefore missed opportunities to take advantage of contractors' early involvement'* (SM19). Similarly, few interviewees mentioned that the enhanced D & B approach if compared with traditional D & B limits the continuity of design responsibilities whereby contractors will not be in a position to change pre-contract design concepts instead of being fully responsible from the conceptual stage right through the delivery.

Moreover, some interviewees argued that enhanced D & B practice could lead to the increase of cost, if necessary time is not allowed at the tender stage to analyse the risks associated with novated design such as lack of information due to incomplete fundamental design and to develop detailed designs. As such a PM interviewee gave an explanation: *'on average 3-6 months are needed to put tender documents together, then contractors have 6 weeks to process that, put a cost to it, investigate the design possibly develop further designs before contractor can value it. So it moves the risk over, but it is doubtful whether there is ever enough time to fully analyse that risk and therefore the contractor put more contingency sums'* (PM13). The same interviewee went on to state that *'contractors will be obliged to make the most economical assumptions for missing information at the tender otherwise there is a risk of not securing losing the project*' (PM13).

5.4.3. Design and Build Contribution to Sustainable Construction

Interviewees were asked whether D & B stimulates or hinders sustainable construction. None of the interviewees stated that D & B hindered sustainable construction if compared with other CPS in practice. The sections below summarises interviewees' perspectives on D & B contribution to sustainable construction, which can be broadly classified into four aspects.

5.4.3.1 Reduction of materials consumption

All interviewees agreed that the contractor and supply chain involvement at the early design and design development stages confine material wastages and holistically lead to resource efficiency. Moreover, some participants affirmed that a restriction of over design is possible with early involvement of contractor and supply chain. Hence, this drives less material consumption, which is also a starting point of waste and cost reduction. An example was given by a PM interviewee who claimed that: '*employing a steel work sub-contractor to design a frame structure will reduce cost and steel quantity, more than asking a separate structural engineer to design the same frame'* (PM13).

5.4.3.2 Waste reduction

All interviewees mentioned that waste responsibility associated with design and construction is predictably entrusted to the contactor within a D & B system. Eventually it allows a clear line of waste responsibility and therefore, contractors tends to WM from early stages of the project. Further respondents stated that a clear line of waste responsibilities helps for an efficient decision-making process and coordination between design and on-site activities. This was made clearer by a QS interviewee who stressed that: *'contractors, who are involved from the project outset, will have the opportunity to identify waste causes early in the process, enhance buildability; and minimise design changes'* (QS10). Similarly, several interviewees acknowledged that the competitiveness of the design at the tender stage will ensure unnecessary waste through an uninterrupted and integrated design process. One SM participant underlined the importance of considering the cost of waste at the bidding stage of D & B projects by focussing on WM targeting and monitoring.

5.4.3.3 Value for money

Most of the interviewees stated that the D & B process helped to introduce optimum methods at an economical cost for the project as contractors have better control over both design and construction processes; and *'as they can combine design and cost together to achieve the best value'* (PM4), as an interviewee noted. Interviewees' opinions suggested that D & B drives value for money mainly due to contractors needing to produce the best design at a competitive cost in such a way that the design consumes less material and produces less waste.

Several interviewees reported that contractors can attain reduction of cost through the competitiveness from contractors' supply chain as a more competitive design could be produced from the supply chain than from an M & E (Mechanical and Electrical) consultant. Indeed, a PM interviewee elaborated by stating that *'supply chain have better dealing on market rates and can be more economical at any time; which will result in a more competitive price than actually specifying suppliers'* (PM13). Similarly, another stated that D & B contractors have more managerial control over their sub-contractors, thereby leading to better cost control.

5.4.3.4 Whole life sustainable building

There was an agreement among interviewees that D & B provides an opportunity for contractors to understand client requirements at the early stages of the project which eventually leads to a buildable and sustainable whole life building; as argued by a participating QS and PM respectively: *'contractors have the opportunity at the very beginning to set the scene and understand what clients requirements are and to discuss the whole life aspects of the asset when it needs to be constructed'* (QS13); and '*material specification based on whole life cost benefits will ensure minimum onsite waste'* (PM6). Other interviews' views suggested that D & B projects create opportunities to contribute to sustainability by way of engaging with community development activities and continuous improvements through lessons learnt.

Some interviewees claimed that there is a risk of getting poor quality products with D & B approach when clients fail to manage and coordinate the D & B contractor's process of work. Within the same context, most interviewees stressed that clients have a key role to play in clarifying their sustainability requirements to D & B contractors. Several respondents stated that enhanced D & B practices also hinder the ability of contributing to sustainable construction compared to traditional D & B. One of the PM participants emphasised that '*if the design is with a separate party and cost with contractor, then it is very difficult to match the two together. Therefore, traditional D & B helps more towards sustainability than enhanced D & B*' (PM4). In some cases clients who request sustainability input with enhanced D & B may have to incur additional costs because contractors do not usually factor in sustainability aspects at the pricing stage unless they are specifically asked; therefore, this could negatively influence the economic sustainability of the projects. Interestingly, few interviewees pointed out that D & B could hinder economic sustainability in the construction industry in the long run due to the accumulation of design costs of unsuccessful tenders. However, it was suggested that allowing a sensible tender period and selecting few D & B contractors at the bidding stage could minimise the chance of such a drawback.

5.5. Impact of Design and Build Procurement System on Construction Waste

The interviewees were asked for their views on the impact of D & B on construction waste. According to the questionnaire survey results, D & B is reported as the most proven procurement system in terms of the impact on waste generation (after traditional – cost reimbursement). Hence, the respondents were asked whether the D & B is likely to reduce or increase waste production.

Most interviewees (15 out of 17) concurred that D & B procurement system tends to generate less construction waste if compared with other CPS. However, they viewed that traditional D & B tends to reduce more waste than enhanced D & B. Table 5.3 summarises the interviewees' comments with regard to D & B features and their impact on WM. However, all interviewees criticised poor practices of concept architects stating that they do not usually appreciate concept design implications on-site construction; since they are '*consistently trying to solve problems on the site rather than on the drawing board; and by doing so, there is always waste (e.g. materials that don't fit or cuts are damaged and quality always suffer as well)*' (PM6), as a participating PM contended.

Several respondents held the view that enhanced D & B tends to promote issues associated with separated (traditional) CPS which undermine the advantages of D & B concept to minimise waste. For example, one interviewee pointed out issues such as, architects are not being prepared to work closely with contractors, poor communication and coordination, and the undermining of relationships, which are inherent with enhanced D & B. Thus, there is a possibility that enhanced D & B tends to generate more waste than traditional D & B. Another interviewee catalogued a wide range of issues that impact on waste generation due to enhanced D & B, which include lack of attention to '*interfaces between building components or materials; the concept architects do not really care about it (e.g. the architects still want glass and plasterboard to meet in a nice crisp line without putting forward a technical solution);*

the traditional relationships still apply leading a contractor-designer dichotomy because novated concept design team is not the contractor's choice of architects and other designers' (SM19).

Table 5.3. Reported impact of D & B procurement system on construction waste

(Interviewees' views)

D & B Features	Impact on Waste Minimisation
Allows early contractor involvement	▪ Highly improved buildable design ▪ Ensures absolute minimum amount of materials flows to footprint of the building through design process ▪ Allows opportunities to select materials less wasteful and have whole life cost benefits ▪ Price, programme, methods can be built up with the design thereby avoid least information shortages ▪ Allows opportunities for early dialogue with clients thereby always design according to clients requirements that lead to fewer variations ▪ Ensures clear line of waste responsibilities

Design competition at tender stage	▪ Drives for a cost effective design (design risk with contractor):
	  ▪ Reduced material consumption
	  ▪ Design out waste
	  ▪ Innovations

Allows opportunities to work with integrated supply chain from the early stages of the design	▪ Clear understanding of interfaces defined among supply chain and trades which effectively reduces rework and material consumption ▪ Contractor has an opportunity to work closely with designers and sub-contractors. Therefore, it creates a conducive working relationship and an understanding of each others' needs: making it an efficient information flow ▪ Enhanced buildability
Contractors are at a fixed contact sum	▪ Contractors need to work on a tight budget in order to maximise their profits thereby they have to control unnecessary costs (e.g. material wastages)
Minimising design changes: variations could be difficult and expensive	▪ Valuing changes on the D& B project is not straightforward when there are design implications (i.e. in a traditional procurement, there is a BOQ with rates and defined variation process, because design does not make part of it and all the costs are well defined).Therefore, valuing client driven variations could be expensive ▪ Contractors are at a risk to bear the cost of their own driven variations

Listed below are respondents' additional views suggesting that enhanced D & B trends to generate more waste compared to traditional D & B.

- Incomplete fundamental/concept design due to poor concept architect practices that creates interfaces coordination (e.g. lack of information) and supply chain integration issues.

- Very little time to review the whole design, due to the tight tender process at the stage where D & B contractors are involved (RIBA stage D or E). Whereas contractors focus mainly on pricing the existing design and developing detailed designs, rather than their efforts at minimising waste due to backend involvement.

- Problems of communication and ineffective relationships between the concept design team and D & B contractor.

5.6. Design and Build related Waste Origins

This section attempts to shed light on D & B related waste origins based on the findings of the literature and the questionnaire survey, which revealed several waste origins related to procurement and CPS, which were clustered under four themes: lack of early stakeholders' involvement in early design stage and procurement stage; poor communication and coordination among parties and trades; lack of allocated responsibility for decision making (i.e. design and construction); and incomplete or insufficient procurement documentation.

5.6.1. Uncoordinated Early Involvement of Project Stakeholders

All the interviewees agreed that the lack of the key stakeholders' involvement at the early design and procurement selection stages had an influence on waste generation as it leads to problematic issues such as incorrect decisions, poor buildability, misunderstandings, variations, and reworks. One SM interviewee said that there is '*a need to have early involvement of all stakeholders as much as possible, including end users who are not involved in most cases, to reduce design changes'* (SM2). While the majority of participants discussed the lack of early involvement of client-end user(s) and contractor, few interviewees correlated the lack of designers' early involvement with regard to D & B with potential waste generation.

5.6.1.1 Lack of early involvement of client/end-user(s)

Most of the interviewees stated that lack of involvement of client/end-user(s) results in a poor briefing process, and leads to difficulties in identifying what client/end-user(s) requires from the building, which in turn contributes to changes that come in the form of reworks and variations resulting in construction waste. They also held a view that lack of early involvement of client/end-user(s) possibly creates divergence between clients/end-user(s) objectives, concept architects' design, and contractors' site operations. This was further elicited by an interviewee (PM6) by citing the example of a hospital project where concept architects produced a design without consulting clinicians who were discontented with the quality of space, shape of rooms, and provided facilities that automatically led to rework and design changes which generated a considerable amount of on-site waste. Furthermore, he majority of interviewees stated two main barriers for the early involvement of client/end-user(s);

Clients' perception to have minimum involvement at the early stages of the project: Most of the interviewees mentioned that clients/end-users have a perception that they do not need to be extensively involved during the early stages of the project. Furthermore, the interviewees viewed that clients/end-users think that it is the contractor's responsibility to deliver the project and that they do not need to be too specific about their requirements with D & B procurement system. Moreover, participants claimed that this perception could be mainly coupled with uneducated and inexperienced clients/end users. A PM interviewee further exemplified the impact of such a perception on waste generation by arguing that *'most clients believe that they should not need to be too specific in their requirements in D & B projects resulting in a minimum client-contractor communication throughout the project, which in most cases led to client-driven changes during the construction stage'* (PM13).

Clients' perception that WM involves additional costs: Several interviewees mentioned that clients often do not give priority to call for WM at the early stages of the project assuming that it should be considered at the construction stage by the D & B contractor. Importantly, participants felt that the main hindrance of clients' early emphasis on WM is driven by a potential increase of the total project cost and time. Therefore, the early integration of WM requirements to the project does not arise. This was echoed by the comment of a QS interviewee who states that '*most clients do not consider waste reduction as a priority at the early stages; their main objectives are speed of construction, cost and quality*' (QS5).

5.6.1.2 Lack of early contractor's involvement

All the interviewees stated that the lack of contractor involvement during the early project stages has a significant impact on waste generation. Most of them considered that lack of a contractor's involvement hindered their ability to influence design decisions in such a way that improves WM. This was illustrated by a QS participant by acknowledging that '*the absence of a feeding loop consisting of contractor's knowledge and experience of the supply chain to feed into the client brief and all the design team's outputs can be a pitfall'* (QS13) in terms of improving WM performance. Respondents criticised the fragmented nature of enhanced D & B which has a clear impact on construction waste generation (Section 5.5) as the process involves the contractor after the fundamental design is completed. One PM interviewee suggested that '*if the design is fully or partially designed, then it is expected from the D & B contractor and sub-contractors to finish that design off or construct it'* (PM11). The same interviewee cited an example in which partitions' design could be adjusted slightly higher or lower to eliminate wastage on plasterboards; however, if it has already been designed it is inevitably too late to do so, and the only alternative is to change the design which will result in waste of materials such as dry lining.

Similarly, interviews reported that the lack of early involvement of a contractor prevented effective inputs of sub-contractors to the design process. Therefore, the ability to influence design in terms of incorporating buildable design layouts, innovative methods, and sustainable materials into design is minimised. This was reinforced by a SM interviewee who established that '*sub-contractors may know the best way to put certain building's parts better than specified by designers; for example, a masonry sub-contractors could advise on more efficient ways of the dimensional consequences of building a wall'* (SM19).

<u>Clients' reluctance to appoint a contractor at the early stages of a project</u>: Several interviewees opined that clients' reluctance to appoint a contractor at pre-tender design stage is a drawback for an integrated strategic approach towards WM. As discussed in section 5.4.2, the interviewees reported that clients prefer to generate the basic building design required with regard to functionality and aesthetics, and outline the budget required before they employ a D & B contractor. Similarly, several interviewees stated that in terms of involving a D & B contractor early into the project, clients need to develop a comprehensive brief; however, most of the clients do not have experience and knowledge of setting up comprehensive brief requirements.

Therefore, most clients approach a concept designer rather than a contractor to prepare their brief.

<u>Time constraints</u>: Most of the respondents stated that time constraints also largely restrict the contractor's early involvement to a project as there is little opportunity to consider two stage tendering. On the other hand, even if the contractor is involved at the RIBA stage D or E, if the D & B contractors are allowed limited time for the tender process, therefore a comprehensive review about the whole design would not occur as the priority is for pricing and developing detailed designs. Similarly, the interviewees opined that during the post-tender design stage, there is very little time to review completely the pre-tender stage designs and rectify the issues that could generate waste. There was a common view among the interviewees that contractors prefer to involve every supply chain member for each stage of work that they do. However this is a difficult task to achieve because they are all driven by the programme and possibly the client's time scales. Therefore, *'time constraints and the client's needs matter very much*' (PM4), as an interviewee viewed.

5.6.1.3 Lack of early designers' involvement

<u>Discontinuity of the design process</u>: Interviewees were of the view that designers are involved early in the project regardless of the traditional D & B or enhanced D & B. However, the majority of participants pointed out that enhanced D & B restricts the continuity of the design into pre-tender and post-tender, whereas the design process structure is spilt into clusters: concept design and contractor's design teams. As discussed in section 5.4.2, the interviewees views suggest that novated D & B is more appropriate in this regard as the concept design team is novated to contractor at the post-tender stage.

<u>Incomplete and unclear design brief</u>: A number of interviewees stated that designers should be involved early in the project to design out waste. However, several interviewees suggested that design out waste may not possible if the design brief is incomplete and lacks clear design information. Equally, the interviewees recognised that there is a need to increase stakeholders' knowledge (i.e. on the importance of client brief and WM requirements and benefits), whether designers or clients setting out the design brief, it will help designers' early involvement in terms of setting up the concept to maintain the WM agenda.

<u>Lack of designers' proactive engagement</u>: A significant number of interviewees stated that concept designers are not usually proactively engaged with WM during the design stage, which is mainly due to fee concerns. Several interviewees viewed that traditionally, WM is not considered during the design stage and therefore designers may consider WM as an additional task that is not factored in as part of their professional fee; as expressed by an interviewee in alleging that a *'low design fee would never encourage architects to involve beyond the traditional work pattern'* (SM19).

5.6.2. Ineffective Project Communication and Coordination

All of the interviewees agreed that ineffective communication and coordination among project parties impact on construction waste generation; as it leads to design changes, defects, additional work and variations that separately or collectively drive waste production. Additionally, the participants related poor communication and coordination among stakeholders to enhanced D & B practices. One of the PM interviewees compared traditional D & B and enhanced D & B systems with regard to communication and coordination by stating that the former *'leads to good communication as a system, because it links contractor and client directly, compared to other systems. However, an enhanced D & B process may complicate both communication and coordination, and could wipe away the advantage of the traditional D & B that provides the simple link of communication and coordination*' (PM4). Likewise, an interviewee opined that the necessity of early communication and coordination between all parties under current D & B practices by acknowledging that '*in a lot of cases, the D & B doesn't work because the communication and coordination between the client and the architect is not cohesive enough resulting in end-user or client discontent about the proposed building spaces or structures, which subsequently leads to changes and rework that produce waste'* (SM21). The same interviewee recommended that *'there has to be an early discussion among all parties so that the designer, the contractor, and especially sub-contractors, and end-users have to work together, but that doesn't always happen or very rarely happens with D & B in practice*' (SM21).

The next section discusses specific and typical causes for ineffective communication and coordination among stakeholders.

5.6.2.1 Limited communication and coordination between client and designers

<u>Client's inability to express clear requirements</u>: There was a consensus among interviewees that clients' inability to express their requirements clearly in the brief led to poor communication and coordination with concept design teams or the D & B contractor's design team, which they claimed resulted in waste generation. This was further elaborated by a QS participant: *'what the clients have in mind probably was not accurately mapped and expressed in the brief or it was misunderstood. Therefore, what clients end up with is not quite what they had expected or wanted under the design process'* (QS3).

<u>Slow client's response for additional information requests</u>: Most of the interviewees opined that clients are less responsive in providing feedback when asked by the design team to provide additional information, which could result in variations. Furthermore, several interviewees said that when asked for additional information, by and large clients do not communicate what they actually want and are slow in providing feedback. Some participants suggested that clients may not want to divulge that information; take a long time to swiftly and positively respond to request; or rely on contractors to complete the work without the proposed changes rather than actually assisting designers in getting the required data.

5.6.2.2 Limited communication and coordination between internal project sub-teams

<u>Complex client's organisation structure</u>: A number of interviewees reported that different parties of the client organisation, forming a complex structure, could result in conflicting requirements in the briefing process, and make communication and coordination process abstruse. According to several interviewees, the latter situation arises in large public projects, which may have involved different clients, end-users and different design teams. A QS debated the issue by referring to a hospital project where different parties to the client, including the hospital representative and end-users from different departments, and a number were directly or indirectly involved that led to a complex and confused project brief despite the immense effort to talk to the heads of each party in order to capture their respective requirements. The interviewee went on to conclude that *'this situation occurred because of the internal culture of the NHS department and their complex organisation structure'* (QS13).

Traditional parallel working practices between design teams: The results of the interviews revealed that D & B traditional parallel working practices between various design teams have a significant effect on the resulting piecemeal communication and coordination process. The interviewees opined that in traditional parallel working practices, design teams are wholly focussed on their own work without a consistent communication channel with each others, and tend to discuss project issues based on the contractual framework only. Therefore, the interviewees stated that communication and coordination between internal design teams is often marred by lack of information and information delays; interfaces' discrepancies; and divergence of design solutions. One of the PM interviewees highlighted the importance of collaborative working between design teams by stating that *'all parties involved should be made fully aware continually of what the problems are and how they have been resolved, what the plans and the proposals are'* (PM11). All the interviewees agreed that it is important to build up cohesive team working as an approach for parallel working, which eventually limits poor communication and coordination.

5.6.2.3 Limited communication and coordination between designers and contractor

All the interviewees made it clear that poor designers-contractor communication and coordination from the initial pre-contract drawings through to detailed drawings add spills leading to a lot of snagging works and indirectly create diverse on-site waste streams and types. A PM interviewee went further to explaining that *'the biggest creation of waste is communication of drawing details and alterations from designers to D & B contractor, which leads to more breakouts from what has already been built resulting in lots of waste*' (PM4). The interviewees related the ineffectiveness of designers-contractors communication and coordination to wider cultural issues in the construction industry. As several interviewees opined, the latter issues are linked to 'privilege' and 'fragmentation' that create a huge gap between parties' relationships in terms of information flow. The interviewees suggested that the contractor is a less privileged party compared to the concept design team, as one PM participant explained: '*relationships are distant due to traditional set up work, privilege working, which is always a source of misunderstandings, conflict of interests, and lack of team work'* (PM9). He went on to round off his comments to reiterate that the main contractor is only seconded bottom two to sub-contractors and suppliers.

Moreover, as discussed in the section 5.5, interviewees believed that concept designers and clients are not prepared to take on board contractors' suggestions especially in terms of buildability. This was mainly owing to the fact that designers are more interested in the visual appearance and creativity rather than practical outcomes. This was strongly portrayed by a PM interview by claiming that *'designers seem to be quite protective of their design, and they feel that any change the contractor proposes to carry out would degrade their design'* (PM11).

5.6.2.4 Limited communication and coordination between main contractor and sub-contractors

Most of the interviewees stated that D & B system by its organisation structure gets several sub-contractors involved for the design and construction processes. Furthermore, several respondents mentioned that in terms of novated D & B, clients also get involved in appointing a concept design team and in some cases to nominate sub-contractors. Therefore, the interviewees were of a view that the involvement of a large number of sub-contractors and designers contribute to the ambiguity of the project communication and coordination process.

Large number of sub-contractors involvement: According to the interviewees' views, the involvement of large number of sub-contractors leads to lengthy and complex communication and coordination channels between the main contractor and sub-contractors. Moreover, several interviewees stated that in a typical D & B project, contractors generally act as construction managers and employ numerous and different sub-contractors who frequently sublet some of their work to trade contractors. Therefore, the interviewees opined that the latter causes the fragmented nature of the project supply chain which results in difficulties in coordination and management of design interfaces. This was summarised by an SM interviewee who reported that *'coordination is not only the manner in which work should be done, but also in working with different skills, systems, which fit together'* (SM22). All interviewees agreed that wastage will unavoidably be created if there is no proper coordination and communication between the D & B contractor and all sub-contractors'.

However, interviewees argued that contractors face two main challenges due to the diversity of subcontractors' teams in terms of managing design interfaces. According to the interviewees, first issue arises due the way in which design process is managed. Several interviewees reported that the design process initially led by concept designers and the main D & B contractor's designers at a later stage. Therefore, the interviewees stated that it is a challenge for the D & B contractor to correctly communicate and coordinate the concept design information to the large number of sub-contractors for the design development process. The reported second challenging issue by the interviewees is that the difficulty for the D & B contractor to coordinate interfaces between the different design sub-contractors in order to avoid repetitions and missing details. This was illustrated by an interviewee who articulated that '*a separation of mechanical and electrical design interface can end up with both proposing to do the same thing or neither of them proposing to do anything. It is the same with the cladding and steel work'* (PM11). These were seen by all interviewees as typical areas where the interfaces can either be doubled or completely missed and significantly affect on-site waste generation.

Additionally, several respondents went further by highlighting other challenges associated with the involvement of a large number of sub-contractors in D & B projects; these include: damage to another's trade work due to blinkered working practices; and failure to do things in the right order, and sub-contractors' attitudes that waste is unavoidable and assumptions that the main contractor should be responsible for on-site waste management.

Difficulties to work with client nominated sub-contractors: The interviewees took the view that D & B contractors find it difficult to work with client nominated sub-contractors. This is mainly due to the unfamiliarity of work relations and therefore communication and coordination links lack coherence and compatibility between the two parties. Additionally, some interviewees stated that the problems the D & B contractor has with the client are the same, with client nominated sub-contractors who are generally fixated with the design process only without adequate consultation regarding the practical issues and impact of design decisions on waste generation.

5.6.2.5 Limited communication and coordination between stakeholders due to time pressure

There was a consensus among interviewees that many communication and coordination issues arose due to time pressure. They stated that in D & B projects, stakeholders are under a lot of pressure to reduce time spent on design, tendering, and construction processes. Furthermore, several interviewees mentioned that D & B projects are also characterised by parallel working and overlaps of sub-contractors' work schedules, thereby accentuating difficulties in communication and coordination between parties who are all driven by time restrictions. The interviewees' views suggested that limited communication and coordination between parties due to time pressure is a critical cause of information delays and shortages. Thus, interviewees claimed that these have a direct effect on alterations of works that generate waste. As one QS interviewee put it, '*hasty decisions that affect quality or cost, which are the* *consequences of time pressures, create changes and problems that necessitate rectifying at later stages of the project'* (QS10).

The interviewees also referred to the impact of time pressure on the communication and coordination between designers and D & B contractor. They considered that in Enhanced D & B, the contractors have the opportunity to review the design but they are not given enough time for tendering and design development due to the information requested being received too late due to shortage of time. Therefore, a part of the building is not constructed at the design development stage since it was too late to be understood, during the time of construction. Hence, a last minute rush to try and detail something that works. Similarly, an interviewee mentioned that '*sub-contractors try to start their activity before the previous trade has finished; however, there could be programme restrictions or time pressures which might result in a knock on effect'* (SM2).

5.6.2.6 Lack of contractual provisions to encourage communication and coordination

The interviewees claimed that project stakeholders tend to communicate less unless the contractual provisions encourage them to do so. They took the view that a typical contract does not provide provisions for effective communication and coordination. However, they mentioned that this depends on the nature of the contractual provisions that influence how the parties within the contract are reacting with each other. Some of the interviewees expanded on the subject by stating that this can get quite adversarial in terms of project outcome, for instance waste generation, of it is not considered in the contract and was not done on time. A PM interviewee encapsulated the topic by indicating that *'if the contract doesn't call for communication, it is unlikely to happen; hence one of the barriers for communication is lack of contractual provisions'* (PM6).

5.6.2.7 Inadequate communication channels and tools

Some interviewees commented on the impact of inadequate communication channels and tools on communication and coordination. They stated that communication of necessary information is not targeted to people who actually do the work. Hence, the interviewees claimed that this results in poor organisation of work packages in both directions: upstream and downstream. Similarly, most of the interviewees criticised the frequent web-based communication methods (i.e. emails), as they do not allow effective discussions among parties. Instead, most of the interviewees mentioned that face-to-face interaction encourages the communication between project stakeholders.

Additionally, the use of different working methods were seen to make the communication process more intricate and restricts the common working grounds for stakeholders, which could potentially lead to waste generation. A simple example was given by a QS interviewee by arguing that *'the fact that some stakeholders use imperial methods while others use matrix could unknowingly cause bigger misunderstanding among the project team, which in turn could lead to consequential on-site wastages'* (QS8).

5.6.3. Unclear Allocation of Waste Minimisation Responsibilities

All interviewees indicated that a lack of clarity in allocation of different responsibilities has a compelling impact on waste generation. For instance, one PM interviewee said that *'if each stakeholder does not know what his/her responsibilities, then it is going to be gaps and overlaps of works, which create unnecessary wastage'* (PM4). The next section presents specific issues that are accountable for unclear allocation of responsibilities with regard to waste generation.

5.6.3.1 Design overlaps and gaps

The interviewees reported that unclear allocation of design responsibilities creates overlaps and gaps between the concept design and D & B contractor's designers' team thereby it could result in discrepancies and inconsistencies of interface designs and choice of materials selection. Similarly, respondents mentioned that lack of understanding as to where a particular party's responsibility starts and finishes is a major issue. They claimed that this issue results in overlaps and gaps in design responsibilities and it directly influences waste generation. One SM interviewee explained: *'junction detail between frame and facade is a classic example. It is not common knowledge on who is actually responsible for steel framing, secondary steel work, and all connecting details'* (QS10). This was further explained by a number of interviewees who held a consensus that during the construction stage contractors are confronted by unparalleled and uncoordinated design outputs that drive onsite waste production through redesign, alterations, procurement and purchasing.

Furthermore, the interviewees opined that in most D & B projects, the design responsibility is shared between the concept architect and the contractor's designers. This complicates the decision making process and could lead to a complex situation, including waste production. They also viewed to a lack of clarity of design responsibilities within D & B contractor design parties that possibly leads to waste generation. Most of the interviewees shared the view that if any party is not specifically allocated responsibility for the concept design and detailed design tasks, then there will be critical gaps and/or overlaps. They stated that by and large concepts get designed, but it is the lack of detailed design has a propensity to generate a substantial amount of waste; and concurred that the tendency to produce clear and coordinated detail designs if design responsibility is specifically allocated.

5.6.3.2 Unclear waste minimisation responsibilities at project level

The majority of interviews evidenced that WM responsibilities are on the whole unclear and adequately shared between stakeholders for the following reasons.

<u>Perceived WM as a contractor's responsibility</u>: There was a consensus among interviewees that notwithstanding changes made by the client or designers as being major sources of construction waste generation. The interviewees went further commenting that the sole responsibility of onsite waste production lies with the D & B contractor irrespective of who was actually responsible for making design changes (variations) in the first place. As such, the participants endorsed earlier comments to allocate certain WM responsibilities to designers and make design teams accountable for their variations and waste arising due to their works during the construction stage.

<u>Lack of clear WM responsibilities in the project brief</u>: Several respondents mentioned that clients do not provide clear WM responsibilities in the project brief, mainly due to the perception that WM is a contractor's responsibility. For instance a QS interviewee stated that *'WM and management responsibilities are hardly specified by the client or in project brief'* (QS3). They strongly believe that the allocation of WM responsibilities should be client driven which will incentivise stakeholders (i.e. concept architect and D & B contractor) to consider WM throughout the project stages.

<u>Lack of mechanisms for specifying and allocating WM responsibilities</u>: Although it is emphasised that designers and clients are also held responsible for WM, some interviewees believed that there is lack of mechanisms (e.g. innovative WM methods) for specifying and allocation of WM responsibilities. This was echoed by a QS interviewee who reported that '*there is limited proper standard guidance available for clients or designers in terms of WM and what resources should allocate for the project*' (QS12).

<u>Lack of contractor's influence on allocating WM responsibilities during pre-tender design stage</u>: As discussed earlier, the contractor has limited opportunities for early involvement at the pre-tender design stage due to Enhanced D & B practices and thereby has less influence on allocating responsibilities. The interviewees implied that the ownership or the responsibility for the design stage has a significant impact on waste generation.

Undefined sub-contractors MW responsibilities: Several interviewees mentioned that the contractors' failure to define sub-contractors' WM responsibilities and issue related guidance is a major on-site waste origin. They called for precise WM responsibilities and instructions to sub-contractors and suppliers.

Absence of a dedicated onsite WM and management professional: Some interviewees suggested that WM and management tasks should be allocated to a single project team member for each site, ideally a 'waste manager', to be fully responsible for all related activities from planning, liaison and coordination to managing on-site arrangements implementation and monitoring, including day-to-day management of Site Waste Management Plans.

5.6.3.3 Inadequate procurement decision making

Some of the interviewees viewed that poor decisions in procuring both project and sub-contractors; and lack of clarity of procurement selection responsibility or absence of party to be responsible for identifying, allocating and monitoring responsibilities at the procurement stage have a notable impact on waste generation. They indicated that there are major concerns with respect to the robustness and coherence of the contractors' selection process leading to flaws and conflicts between what is visually required and what practically works which sequentially leads to waste. One SM interviewee gave further insight by revealing that '*the approved solution may not be the best architectural or visually but not liable for wastage'* (SM19). However, the interviewees disclosed that conventionally the most economical solution gets chosen and the responsibility for the consequences of 'abrupt' decisions is never clearly defined, as it comes down to the type of project and stakeholders' personalities, particularly the client.

Unclear individual responsibilities at the procurement selection stage: The absence of someone to take responsibility to define and allocate the degree of other parties' responsibilities during the procurement selection stage was cited by many interviewees as an indirect origin of waste. This was mainly related to gaps and overlaps of responsibilities for example in the case of an architect having a role as a lead designer for a specific work package but may be assisted by a sub-contractor.

Therefore, as several interviewees suggested, the latter mentioned situation raises concern over what the degree of responsibility the sub-contractor has on that particular package; hence the overlap of responsibilities resulting, no one makes a decision..

Lack of consideration on construction waste issues at procurement stage decisions: Most of the interviewees endorsed the argument that procurement or project managers do not advise clients about consequences of waste production and the benefits of WM. Moreover, several interviewees mentioned that limited guidance is provided to adopt WM strategies and assess contractors' waste track record at procurement stage. The interviewees emphasised the importance of exploring the options and ways to reduce waste during the early procurement stage and subsequently selected contractors or builders that could actually achieve the selected optimum WM solution.

5.6.4. Inconsistent Procurement Documents

Insufficient procurement documentation leading to gaps or assumptions was portrayed by the interviewees as a key waste generation driver. As such, they disclosed that procurement documents are produced at different stages of a project, and if any one of these is not aligned and not clear or detailed enough, the project can end up with a large amount of waste. However, they acknowledged that the completeness or insufficiency of procurement documents in practice varies according to the circumstances. They also accepted that there are few projects where procurement information is substantially completed when resulting in very little variations in the project. The interviewees referred to consistencies that are common to a number of procurement documents, namely: client brief, drawings and specifications, Pre-Qualification Questionnaire (PQQ), and tender and contract documents.

5.6.4.1 Client brief issues

The interviewees stated unclear or incomplete briefs as having a great deal of influence on the project in terms of general and waste production in particular; as it is the basis for setting up and developing the subsequent project activities and documents that are predominantly associated with design, specification and contractual issues. Additionally, they explained that from a practical perspective, a vague or curtailed brief tends to encourage assumptions on design decisions and requirements, which are always a source of variations, thereby wastages.

<u>WM requirements are not clearly stated in the brief</u>: In line with the raised concerned associated with the client brief and client requirements, the interviewees reported that in most of instances sustainability and WM requirements are not built into the brief. Therefore, brief interpretations and consequent design actions and activities create waste.

<u>Client's unawareness of WM benefits</u>: According to the interviewees' views, the other main reason pertinent to the client brief is the client's unawareness about WM benefits. Therefore, there are no incentives to incorporate WM requirements into the brief.

5.6.4.2 Drawings and specifications issues

<u>Incomplete drawings</u>: All the interviewees opined that one of the major problematic issues with D & B in terms of waste generation is incomplete or 'rushed' drawings due to enhanced D & B practices. This was articulated by the interviewees in association with the other previously discussed concerns over design interfaces, buildability issues, and gaps and overlaps of design responsibilities.

<u>Inadequate specifications</u>: There was a common agreement among all interviewees that written specifications can be unrealistic, unclear or incorrect, frequently leading the D & B team to refer back to the brief to obtain details required to take the design process forward. They reported that most of the specifications are irrelevant and nearly every specification document is similar, as these comprise standard clauses that were used in previous projects with minor alterations and amendments to suit the specificities of the project at hand.

<u>WM requirements are not embedded into specifications</u>: Most of the interviewees stated that WM requirements are not adequately embedded into current specifications. Some of the participants viewed that designers expect that D & B contractors to take overall responsibility for WM aspects of a particular specification. They went further to comment that due to time constraints, it is a common practice for architects to 'assemble' specifications and in some cases specify materials and products that are not even being made or available.

<u>Poorly coordinated pre-tender design outputs and client brief</u>: Several interviewees opined that pre-tender design outputs (i.e. concept designs and specifications) have a direct impact on waste generation if they are not are not properly coordinated with the client brief. For instance a PM interviewee indicated that '*if* *drawings and specifications in a contract do not mirror what the client wants; the contractor prices and programmes against only the drawing and specifications. However, the project variations which arise as a result of conflicts with the client brief and expectations will unavoidably have an impact on project time, resources, cost and waste generation'* (PM4).

5.6.4.3 Prequalification document issues

There was a consensus among interviewees that prequalification documents do not necessarily impact on waste generation. Nevertheless, they took the view that pre-qualification documents can be used for effective WM at strategic level as it helps to qualify parties and make them aware of what WM standards would need to be achieved. One QS interviewee emphasised that a three part prequalification has a robust process and would lead to efficient WM process as it informs '*what needs to be done; when and how it is going to be addressed'* (QS10).

Inadequate provisions for WM in Pre-Qualification Questionnaire (PQQ): Most of the interviewees reported that current PQQ practices do not provide adequate provisions for WM. Therefore, the interview participants pointed out that PQQ does a poor check of WM competence of contractors. For instance a QS interviewee said that '*we use a form of PQQ to contractors to set out health, safety and environment requirements. WM issues are very vague and nothing is generally established as a prescribed form*' (QS3). Also several interviewees stated that the available waste-related prequalification responses and recommendations in PQQ are mainly focussed on D & B contractor's onsite waste management actions rather than early WM requirements.

Lack of project specific PQQ inquiries related to client brief: There was a major concern among interviewees that PQQ is not properly associated with the client brief, particularly in relation to waste or sustainability. Similarly, interviewees opined that qualification inquiries in PQQ are more generic or involve standard questions that do not necessarily deliver project-specific WM requirements. One SM interviewee elaborated on this issue by suggesting that '*clients in general are raising more challenging concerns on environmental and waste issues during the pre-qualification stage; however, the same issues are not considered in the client brief. That said, questions in PQQ are quite often standard, generic and are not project-specific'* (SM2).

5.6.4.4 Tender and contract documents issues

There was a general agreement among interviewees that tendering and contract documents do not necessarily have an influence on waste generation. However, the respondents held the view that these factors had not been effectively used to promote WM. For instance a QS interviewee noted that '*tender and contract documents actually have an impact, but they do not have a negative impact. It is necessary to tie the contractor into the early WM and waste produced in some way*' (QS13). The interviewees reported several shortcomings which are associated with current tender and contract documents for not being used effectively for WM in construction projects.

Lack of tender provisions and contract conditions for WM: The majority of interviewees stated that WM is rarely considered in tender provisions and contract conditions; and if provided, these are not specific or detailed enough and do not usually reflect the requirements intended by the client. Moreover, interviewees opined that WM is not as important as it possibly should be, due the nature of the contract. They went further to recommend that the contractual set-up should encourage all parties to be involved early and hold proactive ownership for project activities, which was seen as a key driver to improve WM provisions in tendering and contractual implementation.

Poorly built onsite measures for implementing and monitoring WM into tender provisions and contract conditions: Most of the interviewees stated that tender and contract documents lack provisions for 'waste target settings', 'performance indicators' and 'measurements'. Thus, they viewed that tender and contract documents should guide and monitor not only D & B contractor's on-site waste management actions but also early WM actions. A QS interviewee emphasised that '*building key performance indicators, including target setting, around contract clauses is an essential requirement. WM performance-related terms can be built into the contract'* (QS10).

Moreover, some interviewees acknowledged that only a few tender and contract provisions are evident for measuring the quantity of waste produced. Furthermore, they noted that if WM process is to be effective, measures should be specified in tender and contract provisions to quantify waste that can be easily implemented and audited. Similarly, a number of participants argued that contractual provisions need to be focussed not only on reducing onsite waste but also waste due to pre-construction activities. For example, a PM gave further insights indicating that '*the amount of waste that goes to landfill is measured from a sustainable point of view, or the amount that leaves the site measure in terms of materials. Measuring waste in terms of man-hours; professional - design hours is probably a bit difficult. However, based on design criteria* *specific to material types, the maximum wastage levels can be specified in contractual clauses, for example 5% of concrete, 2% of plasterboards'* (PM13). However, most of the interviewees pointed out that recording waste produced is becoming a common practice due to Site Waste Management Plans.

Several interviewees stated that D & B tender provisions and contract conditions are short of terms to explore specific processes, organisation, and ways to reduce sub-contractors' and suppliers' waste.

No WM performance incentives and penalties in tender provisions and contract conditions: Several interviewees reported that WM incentives and performance penalties are not adequately incorporated into tender provisions and contract conditions. Interviewees went further by indicating that current tender provisions or contract conditions do not recognise or encourage the importance of WM against cost savings or attempt to incentivise D & B contractors to reduce waste. An SM interviewee explained that '*contractors have got no financial incentives to cut down on the volume of waste generated, because they are paid by the client for the agreed work packages regardless of quantity of waste produced. However, WM enhanced performance could be a major incentive for contractors who are competing at the tender stage'* (SM2). However, several interviewees opined that all the project parties should be incentivised for WM from the project outset. This was echoed by an SM interviewee who stated that '*the correct way for better WM performance is for the client to forward more focused instructions in terms of incentives and penalties within the contracts'* (SM19).

5.7. Achieving 'zero waste'

The interviewees agreed that a concerted effort is needed to address the key D & B waste origins; which were grouped as follows: a lack of stakeholders' involvement in the early design and procurement selection stages; ineffective communication and coordination among parties and trades; inadequate allocation of responsibilities on decision making; and inconsistent procurement documentation. The interviewees were asked their views on the potential attainment of 'zero on-site waste', which was seen as something that most of the interviewees reported as a very difficult and over ambitious target. Nevertheless, they believed that *'zero waste to landfill'* can be an achievable target, at least very close to the zero mark. However, such efforts can be more efficient and effective if it comes as a client requirement. For instance, an SM interviewee echoed the above by stating that *'every project is bound to have some waste one way or other and thus, 'zero onsite waste' is difficult to achieve. Alternately, options are available for waste reuse, recycle or transfer waste to waste management workstations rather than sending it to landfill'* (SM21).

Most of the interviewees stated that achieving a *'zero waste to landfill'* target could also add several challenges such as additional costs, scale of the projects, time constraints and limitations of existing alternative methods for recycling. There was a clear concern over additional costs; as one QS interviewee described: '*the clients need to be aware of the possible additional costs involved and consultants should carefully explore what the brief's requirements are and compare against project budget before accommodating additional cost allocations'* (QS12).

Several interviewees highlighted the limitations associated with current waste recycling facilities. An SM explained that '*there is a downstream facility that can take some of this waste for recycling. However, there is a point where recycling capacities may have excess waste materials that they did not want anymore, and, as such, some of that may have to go to landfill'* (SM21). The latter suggests that efforts should be invested in reducing the production of waste rather than focussing on recycling.

The interviewees mentioned several key measures when they were probed on actions they would like to effectively address D & B waste origins. These are synthesised and discussed in the next section.

5.7.1. Common Improvement Measures

5.7.1.1 Collaborative working

Most of the interviewees stated that an introduction of a collaborative work setting at the beginning of a D & B project improves stakeholders' involvement, enhances effective communication and coordination among clients, D & B contractors' project teams and project sub-teams, resulting in rigorous allocation of responsibilities on decision making and precise procurement documentation. One of the QS interviewees opined that collaborative working '*helps to become more efficient and more profitable and improves overall WM and management as it aims for ways of cutting unnecessary costs, increasing efficiency and increasing profitability'* (QS5). There was a common view among interviewees that collaborative working can be achieved through some of the following ways.

Collaborative meetings and learning sessions: Most of the interviewees opined that collaborative meetings and learning sessions allow an upfront dialogue among all stakeholders. In particular, strategic partnering, collaborative contracts and value management workshops help contractors and clients to initiate early dialogue about the project proceedings. The interviewees went further stating that it is an effective way of identifying client/end users' requirements, objectives upfront of the project process thereby prepare client brief collaboratively and getting an informed design. Furthermore, the respondents reported that collaborative meetings and learning sessions allow sub-contractors' involvement at the planning stage in order to make sure WM requirements are considered, monitored, and communicated throughout the project.

The interviewees also stated that collaborative work meetings and learning sessions allow contractors, consultants, and supply chains to be involved and to define roles and responsibilities specific to all the project stakeholders; as one PM interviewee highlighted: 'e*veryone is aware of the responsibilities of others and then collaboratively prepare project programme to that process to achieve the end-product minimising duplication resources and wastages'* (PM13). Several interviewees emphasised that regular collaborative meetings (i.e. coordination, design, collaborative, progress) need to be conducted at the key stages of the project as these help all stakeholders to understand the project process and to plan their own works.

Collaborative working software and web-based applications: The interviewees implied that project based collaborative working software and web based applications (e.g. IT databases, intranets, 3D & 4D modelling, BIW - Business Information Warehouse) help improving communication and coordination. Particularly, the interviewees were of a view that such applications enhance efficiency and preciseness of information sharing, documentation and effective involvement of stakeholders (i.e. acquiring prompt responses and actions). Additionally, web based and IT collaborative working platforms enhance communication and coordination between internal project sub-teams as *'getting different departments and professions to work together in a project team is always difficult. Therefore, the use of such applications helps document control, sharing information and saves time'* (SM19), one SM interviewee opined. Table 5.4 summarises the interviewees' views on the key advantages and challenges of using collaborative working software and web-based systems with regard to WM.

Table 5.4. Reported advantages and challenges of using collaborative working software and web-based systems with regard to WM

(Interviewees' views)

Advantages	Challenges
▪ Provides real time design and project development process ▪ Accelerates information sharing ▪ Helps more transparent communication chain ▪ Effective information file management system ▪ Helps coordination of design – interfaces and stakeholder ▪ Optimises the project procurement process.	▪ There can be information overload where everything goes to everyone ▪ Need to have discipline and training to use those effectively ▪ Availability of internet and technical infrastructure ▪ System break downs therefore less speed in information flow ▪ Lack of IT literacy (e.g. small sub-contractors)

5.7.1.2 Allowing for contractual provisions

Most of the interviewees agreed that contractual provisions need to be firmly established in order to enhance WM practices. These should be targeted to strengthen stakeholders' early involvement, effective communication and coordination, to define and allocate responsibilities clearly and improve procurement documentation process. For instance, a PM interviewee suggested that '*it is necessary to provide sufficient contractual information to enhance communication and coordination links between parties, otherwise a lack of information in contract leads to failing communication among project parties'* (PM11). While a QS interviewee opined that '*it is important that project stakeholders are aware of their WM responsibilities to improve on what is in the tender and contract provisions. What has been put into the contract allows us to make sure what client and client representatives require from D & B contractors as far as WM is concerned and is also a means of informing responsibilities at the early procurement stage'* (QS13).

<u>Contractual provisions; rewards versus penalties</u>: Interviewees were probed about the viability of contractual conditions with regard to WM, particularly 'rewards versus penalties'. The majority of the interviewees concurred that reward systems rather than penalties would encourage WM efforts. For example, a PM interviewee opined that *'rewards should relate to cost savings from WM'* (PM9); while another SM interviewee stated that *'project stakeholders would like to see a client formulated reward system'* (SM8). Table 5.5 summarises the negative effects of introducing penalties in line with WM performance, as annotated and argued by the interviewees.

Table 5.5. Reported effects of waste contract conditions: penalties
(Interviewees' views)

Negative effects	Explanation: Interviewees' quotations
▪ Financial consequences: risk of inflated contract sum	▪ *'As soon as somebody sees a penalty a dedicated cost percentage will be added to the contract price in order to mitigate the risk'* (QS3) ▪ *'Undoubtedly the client will pay in the end'* (PM6)
▪ Adverse effects on relationships and work progress	▪ *'Tend to have adverse effect on relationships between project parties and the project progress'* (PM11)
▪ Discouraging innovative methods	▪ *'Implementing a penalty is accepting a failure. So, a penalty would not really not be encouraging innovative ways of dealing with WM*' (SM8)
▪ Difficulties in measuring or setting exact targets	▪ *'There is a need for a WM target to be set out; some sort of punitive damage may not improve achieving on the set target'* (PM6) ▪ *'There is no framework or mechanism in a contracting term to objectively impose and point out exactly the waste measures or set targets'* (QS3)

Some interviewees argued that the only way a penalty can be applicable is where measurable target can be set out. Similarly, a number of interviewees emphasised that such a penalty should be considered by all stakeholders. For instance, a PM echoed that *'if the system towards penalising is carried out then all stakeholders, including the client and designers should bear the consequences'* (PM13). However, several interviewees opined that penalising a client should be done with extra effort and care. Such a move ensures that the client, designers, suppliers and sub-contractors will end up having more interest in the project WM. Another interviewee went further stating that *'clients are not used to their obligations on the Site Waste Management Plans Regulations. They are still not penalised for it and maybe that will change in the Regulations in the future*' (SM22). Few interviewees suggested a 'waste target cost approach' to be incorporated as additional waste contractual conditions. For instance, one PM interviewee termed it as a 'pay and gain system' and clarified that *'if the D & B contractor is going to generate more than estimated waste tonnage, then he/she should pay the certain agreed cost perhaps to the client or into a community environmental fee* (PM4).

5.7.1.3 Appointment of experienced & WM specific professionals

The appointment of experienced and WM specific professionals was considered by the interviewees as an important measure to improve stakeholders' engagement, effective communication and coordination, clear allocation of responsibilities, and quality of procurement documentation. Table 5.6 indicates the following professional categories identified by the interviewees for such a role: the project manager, procurement manager, contractor, programme manager/design coordinator, and waste manager.

Table 5.6. Reported extended traditional role of professionals

(Interviewees' views)

Profession	Extended job description requirements
▪ Project manager	▪ Start the whole process and understand holistically the scheme to see the process through and to iron out as much of the waste risks related to design, cost estimates, planning and first or second stage of the tender process. ▪ Extend WM responsibility to project managers' job description or give authority to appoint somebody on-site that has specific role to minimise waste. ▪ Identify and monitor who should have ultimate responsibility for each package: produce a design management plan including the interested parties and what their degree of responsibility is and take responsibility to appoint a programme manager/ design coordinator. ▪ Persuade people to achieve agreed targets.
▪ Procurement manager	▪ Ensure the actual selection of the best D & B contractor in line with WM experience and capabilities to compel services accredited or certified (e.g. ISO), operate a sustainable procurement policy, measure and monitor waste targets.
▪ Contractor as a part of concept design team	▪ The concept design team should employ a builder to advise on measures to reduce waste.
▪ Employ programme manager/ D & B coordinator	▪ A D & B project leader with a strong personality who can make decisions effectively because sometimes each of the sub parties get their own agenda; and pull them together channelling down construction programme effectively. ▪ The D & B coordinator will be able to coordinate aspects related to brief and design; and issue guidelines for carrying out the work.
▪ Waste Manager	▪ Identify roles and responsibilities within a contractor's management team with regard to onsite WM and management.

The interviewees suggested redefining the traditional professional job descriptions in such a way as to effectively address waste origins. They recommended that the project manager should take overall responsibility to manage and monitor all aspects of waste reduction responsibilities across the project life cycle. Furthermore, the interviewees opined that the contractor could be employed as a part of the concept design team to enable a more informed understanding of the construction process and embed WM measures to the early design and planning processes. Moreover, several interviewees viewed that programme managers or design coordinators should need to direct and coordinate project teams with regard to the proposed WM programme, especially the management of design interfaces.

5.7.2. Specific Improvement Measures

Interviewees mentioned several specific improvement measures applicable for large scale D & B projects (i.e. undertaken by UK top 100 contractors and consulted by UK top 100 quantity surveyors); these are presented in Table 5.7.

Table 5.7. Reported specific improvement measures for WM
(Interviewees' views)

Improvement Measures: Early project stakeholder involvement	
▪ Two-stage tendering	▪ Investigate opportunities for two stage tendering: ▪ An effective method to bring contractors early into the project ▪ A good way of selecting experienced D & B contractors ▪ Allow the assessment of WM performance early in the process ▪ Helps enhance client involvement early in the project process
▪ Enhance contractors' ability to be involved early in the project	▪ D & B contractor should advice the clients to get involved at the beginning to incorporate WM measures ▪ Match clients and design team requirements with finalised drawings before the actual start of construction (i.e. use of modelling techniques) ▪ Provide a list of alternative solutions to clients/concept architects ▪ Undergo training on capturing and understanding clients'/stakeholders' requirements
▪ Benchmarking	▪ Establish WM targets for each stakeholder at the beginning of the project
▪ Legislation	▪ Introduce tax, levy, or development acts focussing on early D & B project planning and application stage: essentially encourage early stakeholders' involvement and consent to WM measures at the D & B project planning stage ▪ Introduce a 'waste credit system' aimed at WM efforts of stakeholders
▪ Stakeholder management system	▪ Use management techniques to analyse project stakeholders and their involvement at the beginning of the project

Cont.

Improvement Measures: Better communication and coordination	
▪ Regular meetings/ workshops/training	▪ Direct interaction (i.e. face to face) helps communication and coordination effectively (i.e. reduces information delays and waiting time for decision-making) ▪ Regular meetings (i.e. coordination, design review, progress), ▪ Workshops (i.e. risk, value management, project waste awareness) ▪ Training sessions ▪ Meetings, workshops, and training need to be conducted, specifically targeting WM activities from the beginning of D & B projects
▪ Project specific gateway procedure and sign up	▪ Develop key project gateways as project progressions, which help stakeholders to understand what is required at what stage, which targets, which Key Performance Indicators (KPI) have been set. A sign off is just a recognition that whoever the stakeholders are, they realise that at this stage relevant parties are informed of changes that are due, and about the clients' requirements, and agree on the way a forward
▪ Communication protocol from client to contractor/ designers	▪ Establish a project-specific communication protocol by identifying a clear chain of communication, involving a series of loops ▪ Recognise and allow provisions for communication and coordination between client nominated suppliers and D & B contractor
▪ Interactive working plan and interface management system	▪ Set up an interactive working plan between client nominated sub-contractors and main contractor ▪ Establish a project specific interface management system: Custer similar sub-contractors
▪ Adequate time provisions	▪ Allow enough time to prepare design and tender documents
▪ Other	▪ Introduce suitable legislation to change cultural barriers which limits effective communication and coordination between project parties ▪ Development of common tools to understand difficult scenarios ▪ Building up long-term relationships (if repetitive D & B works are applicable)

Cont.

Improvement Measures: Clear allocation of responsibilities	
▪ Define and allocate WM responsibilities for project stakeholders	▪ Inform the client and design team accountable on the correlation of design changes and associated waste (e.g. maintaining records, signing off key stages) ▪ Define responsibilities of designers between concept and detailed designs of interfaces. Make it evident in tender and contract documents ▪ Classify supply chain into different levels based on responsibilities; Define and disseminate clear sub-contractors WM and management responsibilities
▪ Best practice methods and guidelines on WM	▪ Investigate best practice methods and WM guidance documents (e.g. WRAP Waste Forecasting Tools) to specify and allocate WM responsibilities: clients, contractors, designers and sub-contractors
▪ Novation	▪ Explore opportunities for novation to maintain the same design team at the post-tender design stage
▪ Other	▪ Ensure the selection of experienced D & B contractor, nominated contractors and suppliers
Improvement Measures: Improved procurement documentation	
▪ Client brief	▪ Involve experienced professionals for brief preparation and adopt a collaborative approach throughout the briefing stage by allowing D & B contractors in collaboration with all stakeholders to investigate (as a framework contractor) and come up with detailed solutions. Clients/ representatives to agree the detailed version of the prepared brief ▪ Include a separate section in the brief for WM and management (e.g. targets, responsibilities and KPI) ▪ Brief signing up: Although an early collaborative agreement on the brief content is the best practice in terms of WM as it avoids floating briefing requirements ▪ Set up standard guidelines for clients with regard to project WM requirements (review best practices and prepare WM feasibility studies): a set of clear and detailed guidelines to guide or remind clients or their consultants to set up project-specific WM requirements and targets

Cont.

Improvement Measures: Improved procurement documentation	

▪ Drawings and Specifications	▪ Devise a 'design and management plan'
	▪ Review and finalise pre-tender design information documents (before preparation of post tender drawings)
	▪ Reiterate and reinforce the WM focus on specifications: including WM.
	  ▪ Write down prescriptive specifications
	  ▪ Include (prescribe) sourcing of the materials
	  ▪ Specify standards available in clients brief for specifications
	  ▪ Engage specialist sub-contractors and negotiate for a practical solution for specifications
	  ▪ Prepare supporting documents for WM requirements (i.e. scope documents)

▪ PQQ	▪ Include a separate and comprehensive section for WM and management ▪ Include qualification inquiries that focus on D & B contractors' WM capabilities other than conventional onsite waste management practices ▪ Include project specific inquiries rather than generic or standard procedures ▪ Conform PQQ inquiries with client brief's requirements
▪ Tender and contract documents	▪ Include project-specific WM terms and conditions (e.g. rewards, penalties) ▪ Incorporate waste key performance indicators ▪ Provide D & B terms and conditions to explore processes and organisation of trade contractors and sub-contractors waste and comply with legislation (e.g. SWMPs) ▪ Indicate proactive ownership and responsibility necessary for WM (i.e. concept design, interfaces, WM, procurement of trade/sub-contractors/suppliers) ▪ Establish communication channels and links between parties in tender and contract documents
▪ Other	▪ Allow sufficient time for documentation processes (especially for design development and tender/bidding process) ▪ Incorporate measures to bridge the gap between those who actually prepare tender and contractual documents and information providers (e.g. head office design teams and site construction management teams) ▪ Enhance concept designers' awareness about the implications of their designs on the post-tender design development and procurement documents ▪ Prepare standard and guidance documents for D & B project documentation focussing on WM ▪ Engage experienced professionals for the documentation process

5.8. Integrated CPS: Potential to Integrate Waste Minimisation Strategies

The questionnaire results showed that approximately 75% of respondents opined that integrated CPS are more pre-disposed to embed WM strategies. Therefore, interviewees were asked the question: why integrated CPS have such potential?

The overwhelming majority of the interviewees (16 out of 17) concurred with the survey findings and referred to three main reasons for the integrated procurement systems as being the most suitable CPS to integrate WM strategies:

- They allow early involvement of contractors at design and planning stages. This enables enhanced buildability, innovations (e.g. prefabrication) and alternatives, early supply chain involvement and their inputs to design, and opportunities for minimising variations;
- They enable single point responsibility for design and construction with the contractor being the one party having both responsibilities. This helps to minimise complications between the design stage and the construction stage, and simplifies the feeding-loop between design and construction stages; and
- They allow the transfer of the design risk to the contractors and consider WM as a competitive criterion at the bidding stage (commercial driver).

On the other hand, some interviewees argued that, even with an integrated system, WM could be compromised, if the D & B contractor does not have the capacity to meet the ‘true nature’ of D & B due to absence of in-house design teams.

5.9. Summary

This chapter aimed to present the findings of the semi-structured interviews that sought to investigate D & B procurement related waste origins and potential strategies to enhance WM practices. The chapter reported the key results that emerged from interviewees’ views related to current WM and management practices, D & B procurement practices, D & B related waste origins and suggestions to minimise D & B waste origins.

The chapter reported the need to identify waste inherent in the design; assess sub-contractors’ waste performance, and for improving procurement and planning activities. The chapter suggested four possible reasons that D & B system is dominant and has an increasing trend in use in the immediate future: risk transfer; government policies; project duration; and awareness about D & B system. The views emerged from the chapter also suggested that the current practice of D & B possibly more towards enhanced D & B and tends to hinder WM opportunities.

The chapter suggested that uncoordinated early involvement of project stakeholders, ineffective project communication and coordination, unclear allocation of WM responsibilities, and inconsistent procurement documentation impacts on waste generation. Results also gave an account of underlying reasons behind key waste origins with regard to D & B procurement approach. The chapter concluded that the ‘zero waste to landfill’ possibly be an achievable target; and forwarded interviewees’ suggestions to minimise waste in D & B projects.

The next chapter presents an amalgamation of key findings of the study, which are mapped into a framework that aims to minimise construction waste in D & B projects.

6. Framework Development and Validation

6.1. Introduction

This chapter presents the development and validation of the proposed Procurement Waste Minimisation Framework (PWMF) for Design and Build (D & B) projects (i.e. applicable for large scale D & B projects i.e. undertaken by top 100 UK contractors and consulted by top 100 UK quantity surveyors). The PWMF aims to diagnose Procurement Waste Origins (PWO) and attempts to identify potential WM improvement measures.

The first section presents the PWMF development, which is based on the findings from the literature review (chapter 3), questionnaire survey (chapter 4) and follow-up interviews (chapter 5). This section also describes the PWMF's development methodology and key components. The second section of this chapter presents the PWMF validation process by describing the methodological approach and analysing the results. The third section summarises the key improvement measures that emerged from the validation process, and presents key action taken to amalgamate measures proposed to improve the PWMF and potential future improvements for the PWMF. The final section presents key insights for the PWMF implementation strategy.

6.2. PWMF Design and Development

6.2.1. PWMF Development Methodology

The problem solving methodology is an approach that can be used to understand and explore means of improving the issues pertaining to a situation. The general problem solving methodology addresses a situation where what is happening is less than desirable, with the aim of rectifying the situation (Straker, 1995). DRIVE technique is one of the simplest ways to explain this methodology (Table 6.1). This methodology has been successfully applied in many sectors including construction. Serpell and Alarcon (1998) developed a Construction Process Improvement Methodology (CPIM) which aims to improve construction process and waste reduction (Figure 6.1). The basis of CPIM is a traditional problem solving methodology and similar to DRIVE.

Further, Serpell and Alarcon (1998) demonstrated that a successful application of the developed methodology improves project performance related processes and reduces construction waste.

Table 6.1. DRIVE technique

(DTI, [Online])

Define	the scope of the problem the criteria by which success will be measured and the agreed upon deliverables and success factors
Review	the current situation, understand the background, identify and collect information including performance, identify problem areas, improvements and 'quick wins'
Identify	improvements or solutions to the problem, required changes to enable and sustain the improvements
Verify	check that the improvements will bring about benefits that meet the defined success criteria, prioritise and pilot the improvements
Execute	plan the implementation of the solutions and improvements, agree and implement them, plan a review, gather feedback and review.

The key principles of CPIM methodology are: (1) a diagnostic of current issues (i.e. whether what is happening at present is less than desirable); and (2) an identification of improvement measures (i.e. aiming to forward improvement actions).

The application of general problem solving methodology to the results of this study (literature review, questionnaire survey, and interviews findings) helps to arrange the findings in a logical sequence (refer to chapter 2, section 2.9). The findings of this research covered mainly two key aspects: a diagnosis of PWO in construction; and an analysis and identification of PWO associated with improvement measures. The two key principles of the problem solving methodology provide a sound base to propose a framework for WM in D & B projects. A close scrutiny of DRIVE technique and CPIM shows that an implementation strategy (i.e. including a review or continual improvement process) for a comprehensive application of problem solving methodology is required. While an implementation strategy is not included as an integral part of the proposed PWMF, the research explores a potential implementation strategy for the PWMF in section 6.3.3.4.

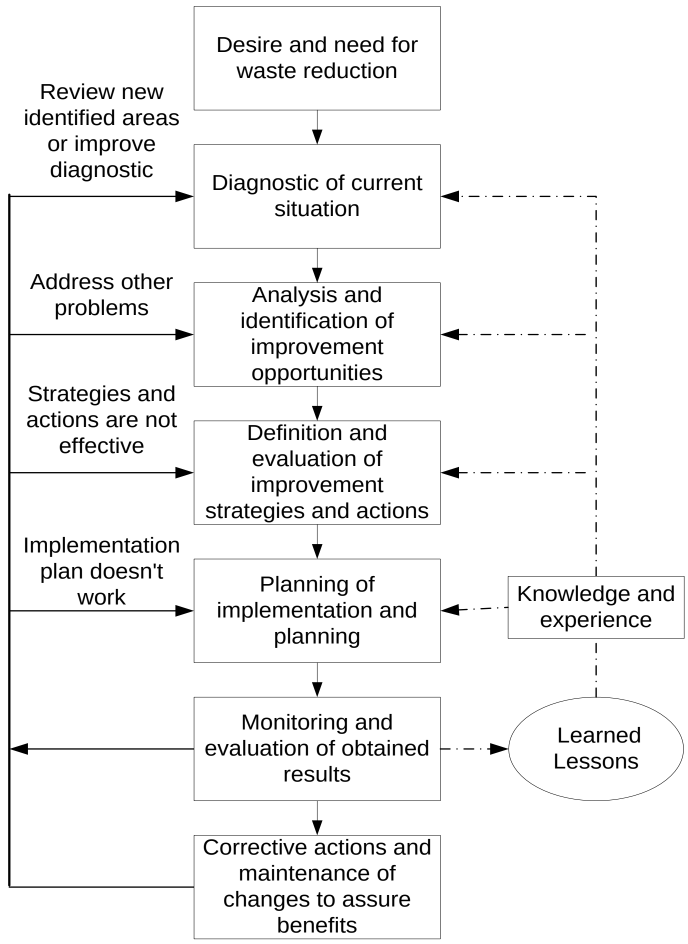

Figure 6.1. Construction Process Improvement Methodology (CPIM)

(Serpell and Alarcon 1998)

6.2.2. Aim of the PWMF

The proposed Procurement Waste Minimisation Framework (PWMF) for D & B projects diagnoses PWO and attempts to propose WM performance improvement measures. Particularly, the proposed PWMF is applicable at strategic – project management level for large scale D & B projects that are undertaken by top 100 UK contractors and consulted by top 100 UK quantity surveyors. Therefore, the contents of the proposed PWMF mainly forwarded to consultant project managers and construction procurement managers. It is expected that the proposed PWMF provides assistance for the professionals to identify potential PWO and respective WM improvement measures for at the initial stage of their project. Moreover, the PWMF contents may be interest of large public clients, quantity surveyors, contractor's project manager (s) and WM and management institutions.

6.2.3. Structure of the PWMF

The structure of the proposed PWMF constitutes three main aspects;

- **PWMF levels:** The PWMF constitutes two levels: (1) High-level PWMF presents an overview for key PWO and targeted areas or project parties for improvements; and (2) Four low-level PWMF components that are linked to high-level framework and provide detailed information to diagnose specific PWO and respective WM improvement measures.
- **PWMF axis:** Horizontal and vertical axes representing key PWO, and procurement WM process respectively. The procurement WM process consists of two stages: diagnosis and improvement measures for both the generic PWMF and the four dependent PWMF components.
- **Coding system:** The PWMF's content is guided through a coding system, which correlates the high-level PWMF and its low-level components on the one hand; and PWO and associated improvement measures within each PWMF component on the other.

Moreover, particular attention was given to the PWMF's layout which was devised in line with the conventional sequence of construction project stages (whenever applicable).

6.2.4. High-Level PWMF

The high-level PWMF is generic and provides an overview for major PWO and targeted areas or project parties that will drive the suggested improvements. The horizontal axis of the high-level PWMF denotes the four key procurement waste generators in construction emanating from the research (Appendix 2.5). In retrospect, the literature review identified several procurement related waste origins, which were assessed, prioritised and clustered in the results' analysis of the questionnaire survey and the follow-up interviews; culminating in the identification of four main thematic procurement waste production drivers (Table 6.2). These are: 'uncoordinated early involvement of project stakeholders'; 'ineffective communication and coordination'; 'unclear allocation of WM responsibilities' and 'inconsistent procurement documentation'.

Table 6.2. PWO themes development stages

After literature review	After questionnaire results	After interviews results
▪ Communication and coordination among parties and trades ▪ Contractor's involvement (i.e. early contribution to design stage) ▪ Method of tendering ▪ Procurement system process duration ▪ Allocated responsibility for decision making (i.e. design and construction) ▪ Type and form of contract	▪ Lack of stakeholders' involvement in the early design stage and procurement selection stage ▪ Poor communication and coordination among parties and trades ▪ Lack of allocated responsibility for decision making ▪ Incomplete or insufficient procurement documentation	▪ Uncoordinated early involvement of project stakeholders ▪ Ineffective communication and coordination ▪ Unclear allocation of WM responsibilities ▪ Inconsistent procurement documentation

As discussed in section 6.2.1, the vertical axis of the framework denotes the procurement WM process in which two distinct stages are represented: 'generic diagnosis' of waste origins associated with the four main PWO themes; and 'target areas/parties for improvements' associated with each waste origin (Appendix 2.5).

The high-level PWMF contents also link the sub-origins for each of the four PWO clusters; and their associated target areas or parties for improvements. The contents presented in the high-level PWMF are further detailed within four low-level PWMF components. involvement These are discussed below.

6.2.5. Low-Level PWMF Components

Each of the four low-level PWMF components represents one key PWO: (A) - Uncoordinated early involvement of project stakeholders; (B) - Ineffective communication and coordination; (C) - Unclear allocation of WM responsibilities; and (D) - Inconsistent procurement documentation. The low-level PWMF components follow the same rationale and design as the high-level PWMF with regard to the aspects denoted by the horizontal axis, vertical axis and the coding system (Figure 6.2). However, while the 'diagnosis' process remains unchanged compared to High-level PWMF, the 'target areas/parties for improvements changes to specific 'improvement measures'.

All identified PWO in the 'specific diagnosis' and related 'improvement measures' sections of low-level PWMF A, B, C and D stem from the findings of the study. For instance and as shown in Appendix 2.5, one of the PWO in the Low-level PWMF (A) is ‘clients usually assume that they do not need to be extensively involved during the early design stages of the project’ (A.1.1-1a). Results of this study reveal that collaborative working is one of the potential improvement measures to enhance stakeholders’ involvement in the early stages of a project. Therefore, improvement methods proposed for A.1.1-1a is to ‘investigate methods to enhance client’s early involvement (e.g. collaborative working practices for briefing, provide environmental wish lists to client)’ (A.1.1-2a). The approach was adopted to determine potential improvement measures for each sub-waste origin listed in the specific diagnosis process of all Low-level PWMF components.

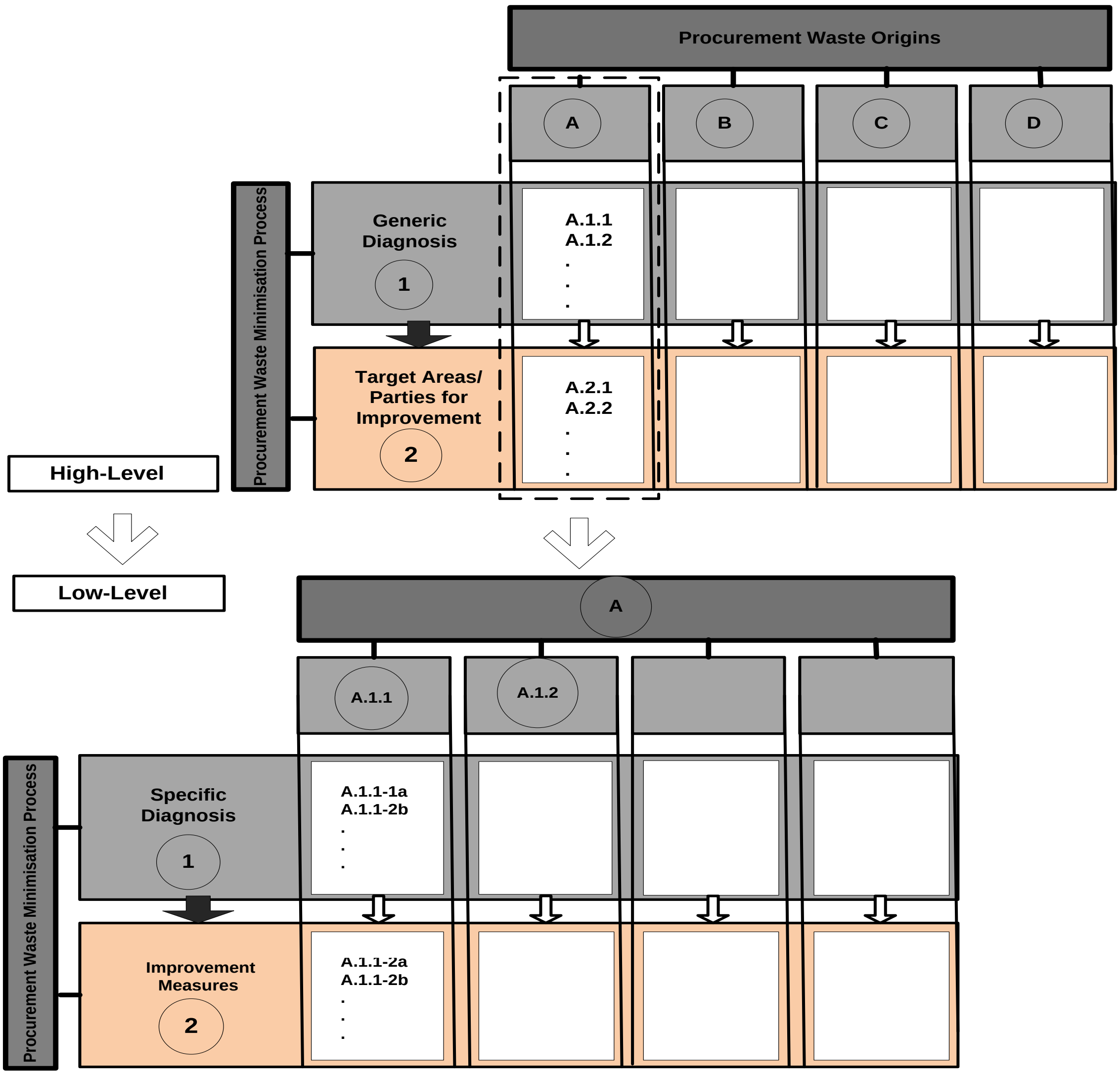

Figure 6.2. The link between high-level PWMF and low-level PWMF components

6.2.5.1 Low-level PWMF component (A): Uncoordinated early involvement of project stakeholders

The questionnaire findings reported that uncoordinated early involvement of project stakeholders' possibly has a high impact on construction waste generation. The follow up interviews investigated barriers and possible improvement measures for the early involvement of the client, contractor and designers, which are presented in the low-level PWMF (A) (Appendix 2.5).

Two main barriers to 'client early involvement' specifies in A.1.1. Correspondingly, an investigation of adequate methods to enhance clients' early involvement (i.e. collaborative working during briefing) and establishing good guidance and advise practice to clients on the financial benefits of WM were proposed. Similarly, two other key barriers are presented in A.1.2 in terms of 'contractor's early involvement'. The following improvement measures are presented: advise the client on the benefits of early involvement of contractor, allow sufficient time, and use of information technology methods for information sharing to overcome the contractor early involvement barriers. Equally, the low-level PWMF A.1.3 presents three barriers for 'designers' early involvement and presents the improvement measures to overcome the designers' early involvement barriers such as pre-tender design team novation and investigate methods and mechanisms to gain adequate information for pre-tender design process.

6.2.5.2 Low-level PWMF component (B): Ineffective project communication and coordination

In the light of the results provided in the study, limited communication and coordination among different project stakeholders, namely clients and designers; internal project sub-teams; contractors and designers; and contractor and sub-contractor, impact on waste generation. These are presented in the low-level PWMF (B) (Appendix 2.5).

Limited communication and coordination between client and designer arise due to three key issues that are presented in B.1.1. In order to address these issues, the framework suggests improvement measures such as establish a collaborative approach for capturing client requirements and establishing a communication protocol. The section B.1.2 presents issues that could accountable for 'limited communication and coordination among design sub-teams' such as traditional parallel working practices and complexity of client organisation. The same section provides several improvement measures for better communication and coordination among internal project sub-teams. Two specific hindrances are presented in the Low-level PWMF B.1.3 in terms of 'limited communication and coordination between contractor and designers'. In order to ensure better communication and coordination between contractor and designers, the framework specifies to establish partnered working structure through organisation of CPS and investigation and exploration of best practice methods and mechanisms. The low-level PWMF (B.1.4) also identifies three specific issues related to 'limited communication and coordination between the main contractor and sub-contractors'. Also, the same section specifies improvement measures to overcome those issues such as the development of an interface management system and setting up of an interactive working plan to work with client nominated sub-contractors.

6.2.5.3 Low-level PWMF (C): Unclear allocation of WM responsibilities

The research findings suggested that unclear allocation of WM responsibilities impacts on waste generation. Therefore, and as shown in Appendix 2.5, unclear allocation of WM responsibilities with regard to procurement managers, clients, designers and contractors are recognised in the low-level PWMF (C).

In terms of the 'procurement manager's (PM) role to allocate WM responsibilities at the procurement selection stage' (C.1.1); two PWO are presented. The framework specifies to explore WM best practices and guidelines to define and allocate responsibilities to all stakeholders and guide clients on the WM benefits at the procurement selection stage. The low-level PWMF C.1.2 also indicates that the client does not include clear WM responsibilities in project brief. In order to address these issues, the framework suggests measures such as to identify stakeholders' WM responsibilities collaboratively; update the project brief accordingly, and explore WM best practices to specify and allocate appropriate WM responsibilities. Two specific waste origins are presented in the low-level PWMF C.1.3 under 'designers' unclear WM responsibilities'. Accordingly, the framework specifies to define designers' responsibilities and mention specific WM responsibilities in tender and contract documents. The low-level PWMF C.1.4 also indicates three specific issues that are accountable for disjointed contractors' WM and management responsibilities. The suggested consequent improvement measures for the latter such as embracing a two-stage tendering process and devising clear roles and responsibilities for an on-site waste manager.

6.2.5.4 Low-level PWMF (D): Inconsistent procurement documentation

The study has suggested that how inconsistent procurement documentation possibly contributes to construction waste generation. Inconsistencies of procurement documents that are accountable for waste generation were related to client brief, drawings and specifications, PQQ, and tender and contract documents in the Low-level PWMF (D) (Appendix 2.5).

In terms of the 'client brief', two specific issues are indicated in the low-level PWMF D.1.1. In order to overcome these inconsistencies, the framework specifies to foster collaborative working practices, explore best practices, and prepare WM feasibility studies. The low-level PWMF D.1.2 unveils two indirect 'Pre-Qualification Questionnaire (PQQ)' waste sources and specifies improvement measures such as to develop PQQ by integrating WM criteria and devise PQQ in line with the brief WM requirements. Furthermore, three specific waste origins are indicated in the low-level PWMF D.1.3 relating to inefficient 'drawings and specifications'. Accordingly, framework specifies several improvement measures that include reviewing pre-tender drawings and specifications in order to acquire complete information before preparation of post tender designs and investigating best practice methods and mechanisms to coordinate between the brief and pre-tender outputs. The low-level PWMF D.1.4 specifies three key inconsistencies related to WM requirements in terms of 'tender and contract documents'. According the low-level PWMF (D) specifies improvement measures such as to devise tender provisions and contract conditions for WM, and devising model clauses to introduce WM performance incentives and penalties.

6.3. PWMF Validation

6.3.1. Validation Aim and Objectives

The aim of the PWMF validation is to refine and examine the appropriateness of the proposed Procurement Waste Minimisation Framework (PWMF) for D & B projects and discuss its implementation strategy. The following specifics of PWMF validation objectives are proposed:

1. determine the clarity and information flow of the proposed PWMF;
2. determine the information flow and appropriateness of the four Low-level PWMF components;
3. examine the appropriateness and practicalities of the proposed improvement measures; and
4. identify a potential implementation strategy for the proposed PWMF.

6.3.2. Validation Approach and Respondents' Profile

The PWMF validation process consists of three stages. Initially, as a pilot study, several discussions were conducted with seven construction management researchers at Loughborough University in order to refine the developed PWMF prior to the actual validation process (refer to section 2.10.2 and section 2.10.2.4). Then, the validation approach involved a pre-validation questionnaire followed by a series of semi-structured interviews with PM, SM, and QS. The validation questionnaire was conducted aiming to refine and validate PWMF in terms of clarity, information flow, and contents with regard to the high-level PWMF and the associated four low-level PWMF components (refer to section 2.10.2.1 and section 2.10.2.3). Subsequently, the validation interviews were conducted with the same respondents aiming to further refine and examine the appropriateness of the proposed PWMF in terms of issues raised from the validation questionnaire (such as clarity, information flow and improvement measures) and to discuss the PWMF implementation strategy (refer to section 2.10.2.2 and section 2.10.2.3).

Nine out of the seventeen interviewees from the second data collection stage (i.e. semi-structured interviews) agreed to participate in the final stage of the study; out of which only six participants were available to take part in the PWMF validation process. However, as shown in Table 6.3, two participants (PM22 and SM27) who did not participate in the previous data collection stages, were involved in the PWMF validation interviews 2 and 3, resulting in eight interviewees.

Table 6.3. PWMF validation: respondents' profile

Interview	PWMF pre-validation questionnaire & interviews' participants	Construction industry experience (years)	D & B projects experience (years)	Procurement experience (years)	WM and management experience (years)
Interview 1	PM13	30	25	10	2
	SM27	3	3	3	3
Interview 2	PM6	35	30	5	10
Interview 3	SM21	33	15	12	23
	PM22	30	3	25	5
Interview 4	SM5	9	7	7	9
Interview 5	QS10	20	20	20	5
Interview 6	QS13	15	10	8	6

The details of the methodological approach and process adopted for the PWMF validation are presented in chapter 02 section 2.10.2, while Figure 6.3 maps the adopted process and outcomes of the PWMF validation.

Figure 6.3. PWMF validation process map

The next section discusses the findings of the PWMF validation based on a total of eight completed pre-validation questionnaires and information gathered from eight semi-structured interviews.

6.3.3. PWMF Validation Results

6.3.3.1 High-level PWMF validation

The PWMF validation participants were asked to comment on the PWMF with regard to following aspects:

- Clarity of the structure;
- Information flow;
- Appropriateness of the four procurement waste origins and their respective contents; and
- Appropriateness and practicality of the proposed target areas/parties for improvement.

<u>Clarity of the PWMF structure</u>

The pre-validation questionnaire respondents were asked to rate the agreement level for the provided statements on clarity of the high-level PWMF from 1 (Strongly Disagree) to 5 (Strongly Agree). Results are shown in Table 6.4, which report that at least three-quarters of the respondents agree or strongly agree on the clarity of the proposed PWMF in terms of its structure, contents, PWO, and procurement WM process. Interestingly, all respondents stated that the content presented in the PWMF is familiar to them.

Table 6.4. Clarity of the High-level PWMF

(Pre-validation questionnaire respondents' views)

Clarity	**Strongly Disagree 1**	**Disagree 2**	**Neither Agree/ Disagree 3**	**Agree 4**	**Strongly Agree 5**
The structure of the proposed framework is clear			1 (12.5%)	3 (37.5%)	4 (50.0%)
The content presented in the framework is familiar				3 (37.5%)	5 (62.5%)
Clarity of procurement waste origins (A,B,C,D) is clear			2 (25.0%)	4 (50.0%)	2 (25.0%)
Clarity of procurement WM process (1,2) is clear			2 (25.0%)	4 (50.0%)	2 (25.0%)

All the interviewees mentioned that the proposed PWMF has a clear structure, which enables the user to view and understand links between elements of the proposed PWMF. For example, one interviewee mentioned that *'the PWMF content and links as well as the logic of how factors have been developed are clearly established and* *apparent'* (QS13). Another said that '*the PWMF guides to look at four principal PWO; waste generators; identifying critical areas and stakeholders that necessitate particular attention for improvement measures; and make informed decisions on WM actions across the project life cycle'* (PM6).

PWMF information flow

The pre-validation questionnaire respondents were asked to rate the agreement level for statements provided on the information flow of the High-level PWMF from 1 (Strongly Disagree) to 5 (Strongly Agree). As shown in Table 6.5, the majority of respondents reported that they agree or strongly agree that the information flow of the proposed PWMF is clear with regard to PWO, WM process, and the relationship between components of PWO and the respective WM actions.

Table 6.5. Information flow of the High-level PWMF

(Pre-validation questionnaire respondents' views)

Information flow	Strongly Disagree 1	Disagree 2	Neither Agree/ Disagree 3	Agree 4	Strongly Agree 5
The information flow of the framework is clear			2 (25.0%)	3 (37.5%)	3 (37.5%)
The information flow of procurement waste origins (A,B,C,D) is clear			2 (25.0%)	3 (37.5%)	3 (37.5%)
The information flow of procurement WM process (1,2) is clear			2 (25.0%)	3 (37.5%)	3 (37.5%)
The relationship between components of procurement waste origins (1,2,3,4) and procurement WM process (1,2) is clear			1 (12.5%)	4 (50.0%)	3 (37.5%)

The majority of the interviewees (6) agreed that the information flow of the proposed PWMF is clear and coherent. For instance, one interviewee stated that *'it* (*information flow) provides a generic diagnosis as to what the problems are and target areas with solutions to those problems'* (PM13).

Appropriateness of the four PWO clusters and their respective contents

All of the interviewees held a general agreement that the four PWO clusters and their contents are appropriate. Some of their responses were as follows:

> *'the four clusters are appropriate and comprehensive'* (QS10);
>
> *'the major and relevant aspects related to waste procurement sources are covered under the four clusters'* (PM13);

'the proposed four PWO cover the main points, it is a good piece of work, which brought together lots of different sections of current issues' (QS13); and

'covers the key points under PWO' (SM27).

<u>Appropriateness and practicality of the proposed target areas/parties for improvement</u>

Most of the interviewees (7) stated that the proposed target areas and parties are appropriate for improvements of procurement WM practices. One interviewee echoed this by stating that the '*PWMF covers all key target areas and parities for improvements to minimise the identified PWO*' (SM27).

<u>Procurement waste generation severity</u>

The pre-validation questionnaire respondents were asked to assess the four PWO clusters (A, B, C, D) in terms of waste generation severity by ranking them from 1 to 4 (i.e. 1 being the most severe). The results are shown in Table 6.6, which suggest that 'uncoordinated early involvement of project stakeholders' was ranked by most of the respondents (7) as very severe or severe. In contrast, almost all of the respondents agreed that 'inconsistent procurement documentation' is the least severe PWO.

Table 6.6. PWO severity ranking

(Pre-validation questionnaire respondents' views)

PWO clusters	**Most Severe 1**	**2**	**3**	**Least Severe 4**
(A) - Uncoordinated early involvement of project stakeholders	5 (62.5%)	2 (25.0%)	1 (12.5%)	
(B) - Ineffective communication and coordination		5 (62.5%)	2 (25.0%)	1 (12.5%)
(C) - Unclear allocation of WM responsibilities	3 (37.5%)	1 (12.5%)	2 (25.0%)	2 (25.0%)
(D) - Inconsistent procurement documentation			3 (37.5%)	5 (62.5%)

6.3.3.2 Low-level PWMF components validation

The pre-validation questionnaire respondents were asked to assess the impact that each PWO cluster (i.e. Low-level PWMF A, B, C, D) has on construction waste generation (High, Medium, Low). Table 6.7 indicates that all the respondents believed that 'uncoordinated early involvement of project stakeholders' has the highest impact on waste generation. The majority of respondents (6) also reported that 'ineffective communication and coordination' has an impact on construction waste generation. On the other hand, over half the interviewees (5) reported that 'inconsistent procurement documentation' has a medium impact on waste generation.

Table 6.7. Impact of PWO clusters on waste generation

(Pre-validation questionnaire respondents' views)

PWO clusters	High Impact	Medium Impact	Low Impact
(A) - Uncoordinated early involvement of project stakeholders	8 (100.0%)		
(B) - Ineffective communication and coordination	6 (75.0%)	2 (25.0%)	
(C) - Unclear allocation of WM responsibilities	5 (62.5%)	3 (37.5%)	
(D) - Inconsistent procurement documentation	2 (25.0%)	5 (62.5%)	1 (12.5%)

A specific section of the pre-validation questionnaire was dedicated to assess the importance of the proposed improvement measures the four Low-level PWMF components through an agreement scale from 1 (Strongly Disagree) to 5 (Strongly Agree). As shown in Table 6.8, most of the respondents (7 out of 8) 'agreed or strongly agreed' with all the proposed improvement measures for 'early involvement of project stakeholders'. Additionally, six respondents equally 'agreed or strongly agreed' on 'devising an interface management system and interactive working plan to work with sub-contractors' and 'clear allocation of WM responsibilities and improved procurement documentation' as major PWO in construction projects. This was followed by five respondents 'strongly agreeing' or 'agreeing' 'exploring opportunities for pre-tender design team novation'. The results of the interviews echoed the questionnaire findings, which were justified and summarised by a QS interviewee statement who stated that *'the available industry materials on the subject are not linked or integrated. This piece of work can potentially bring them all together and make it a very informative and user-friendly WM guidance document to aid procurement and contracting processes'* (QS10).

The interviewees were asked to assess the clarity and robustness of both PWO under the proposed 'specific diagnosis' and proposed 'improvement measure' for each low-level PWMF component. All the interviewees were content with the listed waste origins and respective improvement measures in the four Low-level PWMF components. The next section reports suggestions that were proposed by the interviewees for refining certain sub PWO and proposed WM improvement measures; and presents the key subsequent actions to refine and finalise the PWMF.

Table 6.8. Low-level PWMF: WM improvement measures ranking

(Pre-validation questionnaire respondents' views)

Improvement measures	**Strongly Disagree 1**	**Disagree 2**	**Neither Agree/ Disagree 3**	**Agree 4**	**Strongly Agree 5**
A - Early involvement of project stakeholders					
Investigate methods and best practice to enhance clients' early involvement			1 (12.5%)	3 (37.5%)	4 (50.0%)
Advise the client on the benefits of WM and early involvement of contractor in the pre-tender design stage				3 (37.5%)	5 (62.5%)
Allow sufficient time and use of efficient methods for information sharing during pre-tender design, tender and post-tender design stages				5 (62.5%)	3 (37.5%)
Explore opportunities for pre-tender design team novation			3 (37.5%)	3 (37.5%)	2 (25.0%)
Incorporate WM requirements into the brief, tender and contract documents to enhance designers' involvement				2 (25.0%)	6 (75.0%)
B - Better communication and coordination					
Establish collaborative briefing practices and sign-off the brief				3 (37.5%)	5 (62.5%)
Investigate best practice methods and mechanisms to establish a project communication and coordination protocol				4 (50.0%)	4 (50.0%)
Establish a partnered working structure through organisation of procurement system				2 (25.0%)	6 (75.0%)
Devise an interface management system and interactive working plan to work with sub-contractors			2 (25.0%)	3 (37.5%)	3 (37.5%)
C - Clear allocation of waste minimisation responsibilities					
Explore best practices and WM guidelines to define and allocate responsibilities to all stakeholders and incorporate them into procurement documents				4 (50.0%)	4 (50.0%)
Identify WM responsibilities collaboratively for all project stakeholders			1 (12.5%)	3 (37.5%)	4 (50.0%)
Explore opportunities for novation to keep design responsibilities consistent at the post tender design stage			1 (12.5%)	4 (50.0%)	3 (37.5%)
Allocate pre-tender design responsibilities to contractors through a two-stage tendering process			2 (25.0%)	3 (37.5%)	3 (37.5%)
Devise clear roles and responsibilities for an on-site waste manager			2 (12.5%)	1 (12.5%)	5 (62.5%)
D - Improved procurement documentation					
Examine best practices, prepare feasibility studies and foster collaborative working practices to capture clients' WM requirements and integrate them into the brief			1 (12.5%)	3 (37.5%)	4 (50.0%)
Devise Pre-Qualification Questionnaire in line with the client brief and integrate the WM and management criteria			2 (25.0%)	2 (25.0%)	4 (50.0%)
Review pre-tender drawings and specifications to acquire complete information before preparation of post-tender designs			2 (25.0%)	3 (37.5%)	3 (37.5%)
Investigate best practice methods and mechanisms to coordinate pre-tender design outputs and the brief			2 (25.0%)	4 (50.0%)	2 (25.0%)
Use WM best practice and optimum methods for specifications			1 (12.5%)	3 (37.5%)	4 (50.0%)
Devise tender provisions and contract conditions for WM (include measures for implementation and monitoring; penalties and rewards)				3 (37.5%)	5 (62.5%)

6.3.3.3 Improvement measures proposed for PWMF and modification actions taken

The interviewees put forward a number of recommendations to enhance the high-level PWMF and the corresponding four low-level PWMF components; these are listed and discussed in the following two sections.

High-level PWMF

Table 6.9 presents measures proposed by the interviewees for the improvement of the high-level PWMF and the actions taken to modify or/and refine it accordingly. The refined high-level PWMF is presented in Figure 6.4.

Table 6.9. Measures proposed for PWMF improvement: High-level PWMF

(Validation interviewees' recommendations and respective actions)

Proposed improvement measure	Action taken
Identify 'sub-contractors'' early involvement barriers' under A. (Ref. A in Figure 6.4) (Six interviewees)	▪ Re-worded A.1.2: '**Contractor and sub-contractors (if applicable) early involvement barriers**' ▪ Re-worded A.2.2: '**Contractor and sub-contractors (if applicable)**'
Allow provisions for 'other stakeholders' as a sub point under A: (e.g. End users, planners, and suppliers) (Ref. A in Figure 6.4) (Six interviewees)	▪ Inserted a new statement A.1.4: '**Other stakeholders (if any) early involvement barriers**' ▪ Inserted a new statement A.2.4: '**Other stakeholders (if any)**'
Improve the clarity of the role referred to as 'procurement manager' (Ref. C.1.1 and C.2.1 in Figure 6.4) (Six interviewees) i.e. 1. The term 'procurement manager' could be misleading and needs to be specifically termed as either the 'client's procurement manager' or 'project procurement manager'; 2. In some cases the project manager takes the responsibility of the procurement manager; in such instances the term 'project procurement manager' or 'project manager' can be used interchangeably	▪ Re-worded C.1.1: '**client's procurement manager/project manager**' ▪ Re-worded C.2.1: '**client's procurement manager/project manager**'

Procurement Waste Minimisation High Level Framework for Design and Build Projects

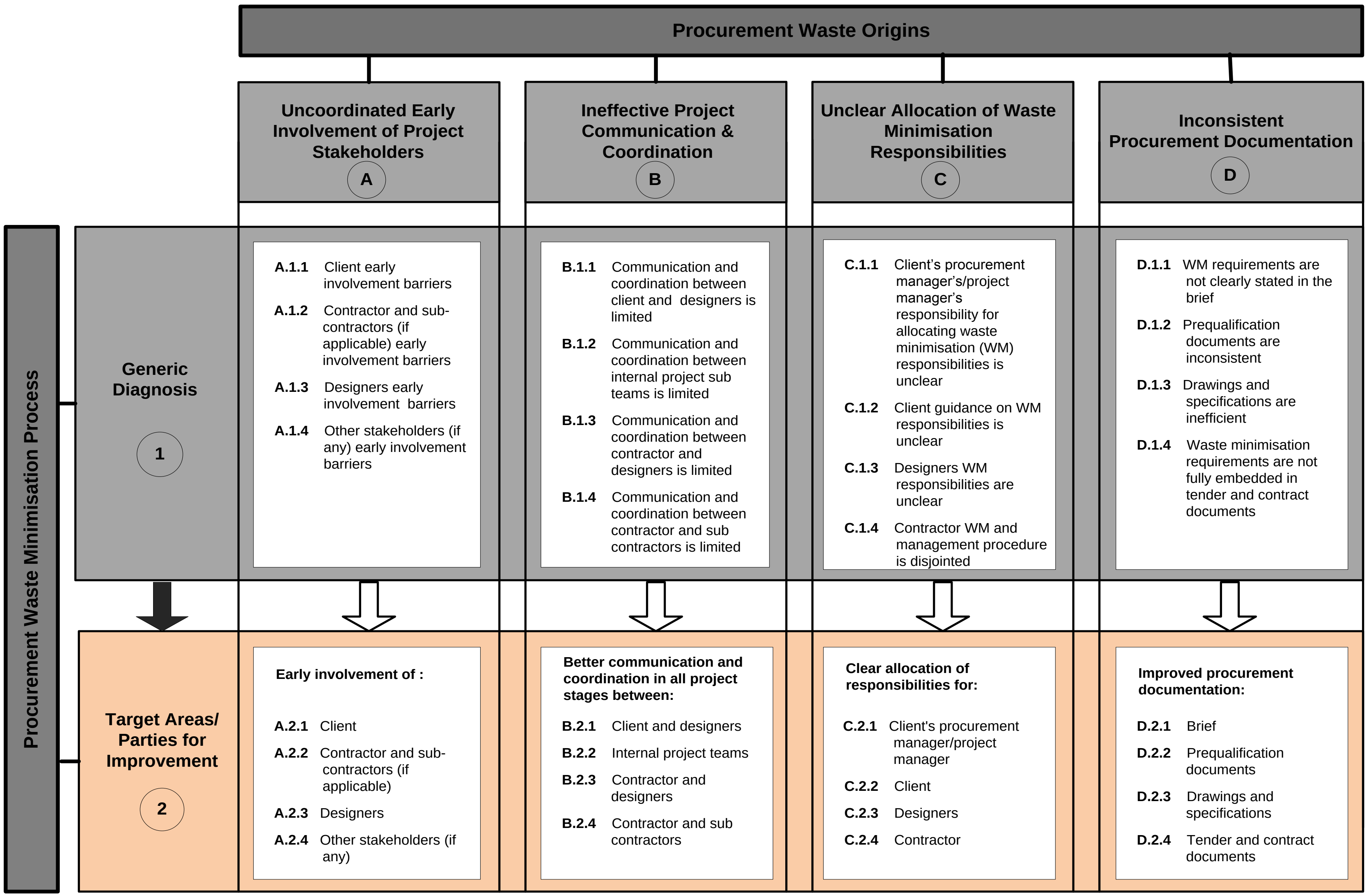

Figure 6.4. Procurement waste minimisation high-level framework for design and build projects

Low-level PWMF components

Table 6.10 presents measures suggested by the interviewees to improve the four Low-level PWMF components and the actions taken to modify or/and refine the four Low-level PWMF components accordingly. The refined four Low-level PWMF components are presented in Figure 6.5, Figure 6.6, Figure 6.7 and Figure 6.8.

Table 6.10. Measures proposed for PWMF improvement: Low-level PWMF components
(Validation interviewees' recommendations and respective actions)

Proposed improvement measures	Action taken
Emphasise that most clients do not consider both WM and its associated costs at the early stage of the project (Ref. A.1.1-1b in Figure 6.5) (Four interviewees)	▪ This issue is jointly covered under D.1.1-2a, D.1.1-1b, and A.1.1-1b in Low-level PWMF components
Identify sub-contractors' involvement under Low-level component A: This is a consequence of the change made in the High-level PWMF (A.1.2) (Ref. Table 6.7) Make Site Waste Management Plans (SWMPs) as a tender submission and evaluation requirement whereas client/consultants could bring back their designers at the tender evaluation stage to look at waste levels against designs (Ref. A.1.2-2a in Figure 6.5). (Five interviewees)	▪ Re-worded A.1.2-1a: 'Client is reluctant to appoint a contractor **and sub-contractors (if applicable)** in pre-tender design stage' ▪ Re-worded A.1.2-2a: 'Advise the client on the benefits of early involvement of contractor **and sub-contractors (if applicable)** in the pre-tender design stage (e.g. improved buildability); and **include SWMPs as a compulsory tender requirement**'
The main reason for designers' lack of engagement in WM can be attributed to the 'lack of education and awareness' about the impact of design on construction waste generation (Ref. A.1.3.1c in Figure 6.5) (Five interviewees)	▪ Re-worded A.1.3-1c: 'Concept designers believe that a fee should be allocated for WM; **designers' lack of knowledge and awareness about design WM**' ▪ Re-worded A.1.3-2c: 'Incorporate WM requirements in the brief, tender and contract documents; and **investigate best practice methods for designing out waste**'

Cont.

Proposed improvement measures	**Action taken**
Introduce 'two-stage tender approach' to address contractor early involvement barriers as it provides two way benefits: allows client to get some hold on costs (i.e., overheads and profits) and provides sufficient time to contractors to complete detailed designs (Ref. A.1.2-2b in Figure 6.5) (Four interviewees)	▪ Re-worded A.1.2-2b: 'Allow sufficient time and use of IT methods for information sharing during pre-tender design, tender and post-tender design stages; **and investigate opportunities for two-stage tendering approach**'
Improve the clarity of the role referred to as 'procurement manager'. This is a consequence of the change made in the High-level PWMF C.1.1 (Ref. Table 6.7) (Ref. C.1.1-1a, C.1.1-1b in Figure 6.7)	▪ Re-worded C.1.1-1a: '**The client's procurement manager/project manager** does not clearly define and allocate other stakeholders' responsibilities at procurement selection stage' ▪ Re-worded C.1.1-1b: 'The **client's procurement manager/project manager** does not advise and inform the client on WM benefits at the procurement selection stage'
An appointment of a waste manager may not be compulsory or feasible on a full time basis; in such cases a professional involved in the contractor's construction management team should be responsible for on-site WM and management (Ref. C.1.4.1b in Figure 6.7) (Six interviewees)	▪ Re-worded C.1.4-1b: 'Contractor fails to appoint a waste manager dedicated to on-site WM and management **and/or delegate relevant responsibility to a member of the on-site management team**. ▪ Re-worded C.1.4-2b: 'Devise clear roles and responsibilities for an on-site waste manager **and/or a member of the on-site management team**'
Emphasise the need of cascading client's objective/requirements, corporate responsibility targets, WM requirements in the brief (Ref. D.1.1-1a in Figure 6.8) (Four interviewees)	▪ This issue is jointly covered under B.1.1-1a, D.1.1-2a in Low-level PWMF components
Emphasise the need to introduce a set of WM and management related questions in PQQ to prevent more generalised answers to the PQQ questions thereby to simplify the PQQ evaluation process (Ref. D .1.2.2a in Figure 6.8) (Five interviewees)	▪ Revised D.1.2-2a: 'Develop PQQ by integrating the WM and management criteria **(e.g. Introduce a set of questions on WM and management)**

Several measures proposed for the PWMF improvement were identified as future work as they needed further investigations; and could help a wider adoption of the proposed PWMF. These are listed below.

- Develop a user guide (including glossary of terms).
- Include an outline of deliverables with regard to each PWO cluster to facilitate the PWMF user to understand the outcome required or what the user is supposed to do after the specific diagnoses of PWO and WM improvement measures in each Low-level PWMF component.
- Integrate a section by mapping existing tools, techniques, guidance documents, polices and legislation for WM under main issues stated in the PWMF, which could help practitioners, thereby enhancing the practicality of the PWMF.
- Work out a mechanism for the PWMF users to facilitate continual improvement.

Procurement Waste Minimisation Low Level Framework: Uncoordinated Early Involvement of Project Stakeholders

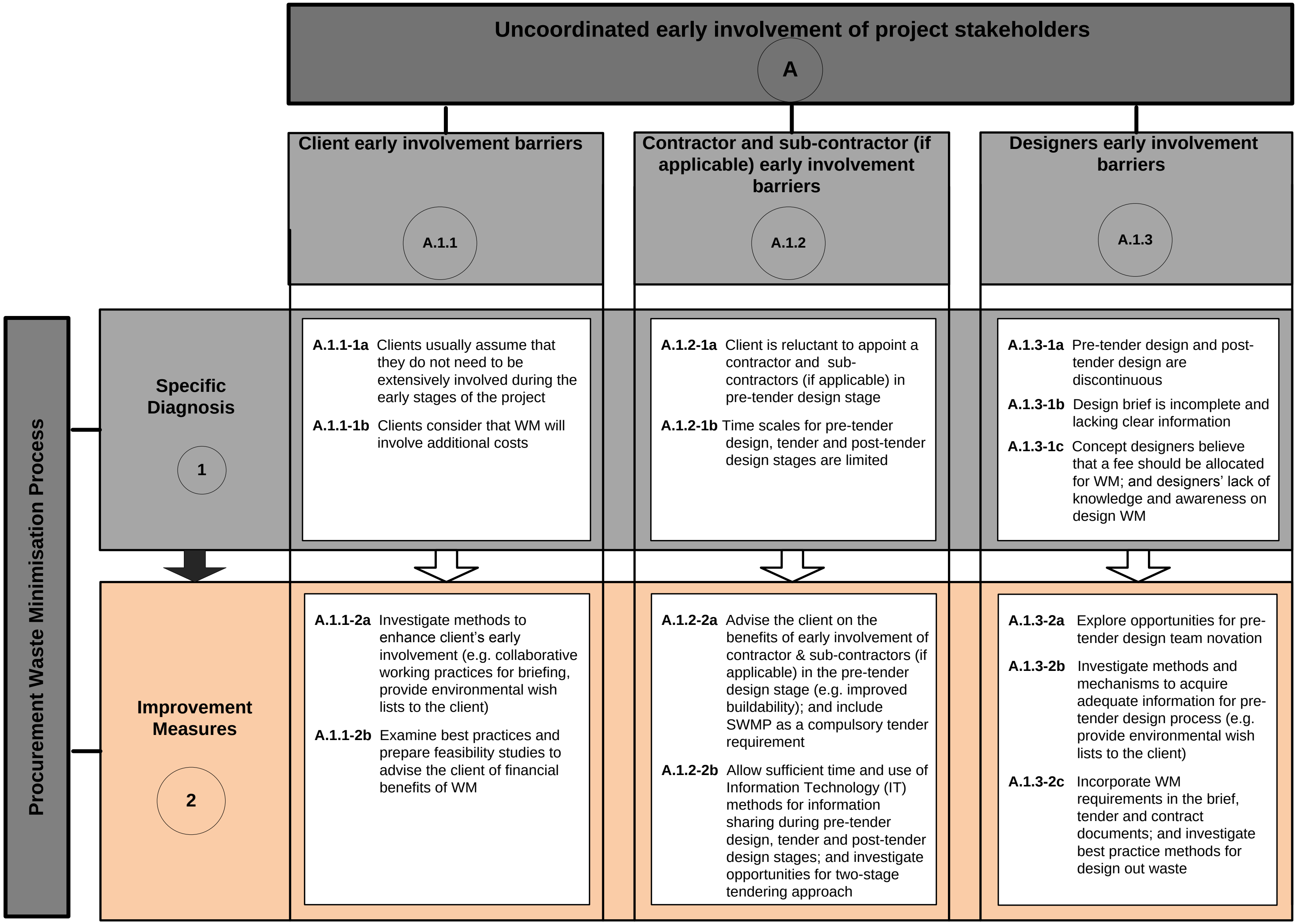

Figure 6.5. Procurement waste minimisation low-level framework: Uncoordinated early involvement of project stakeholders

Procurement Waste Minimisation Low Level Framework: Ineffective Project Communication & Coordination

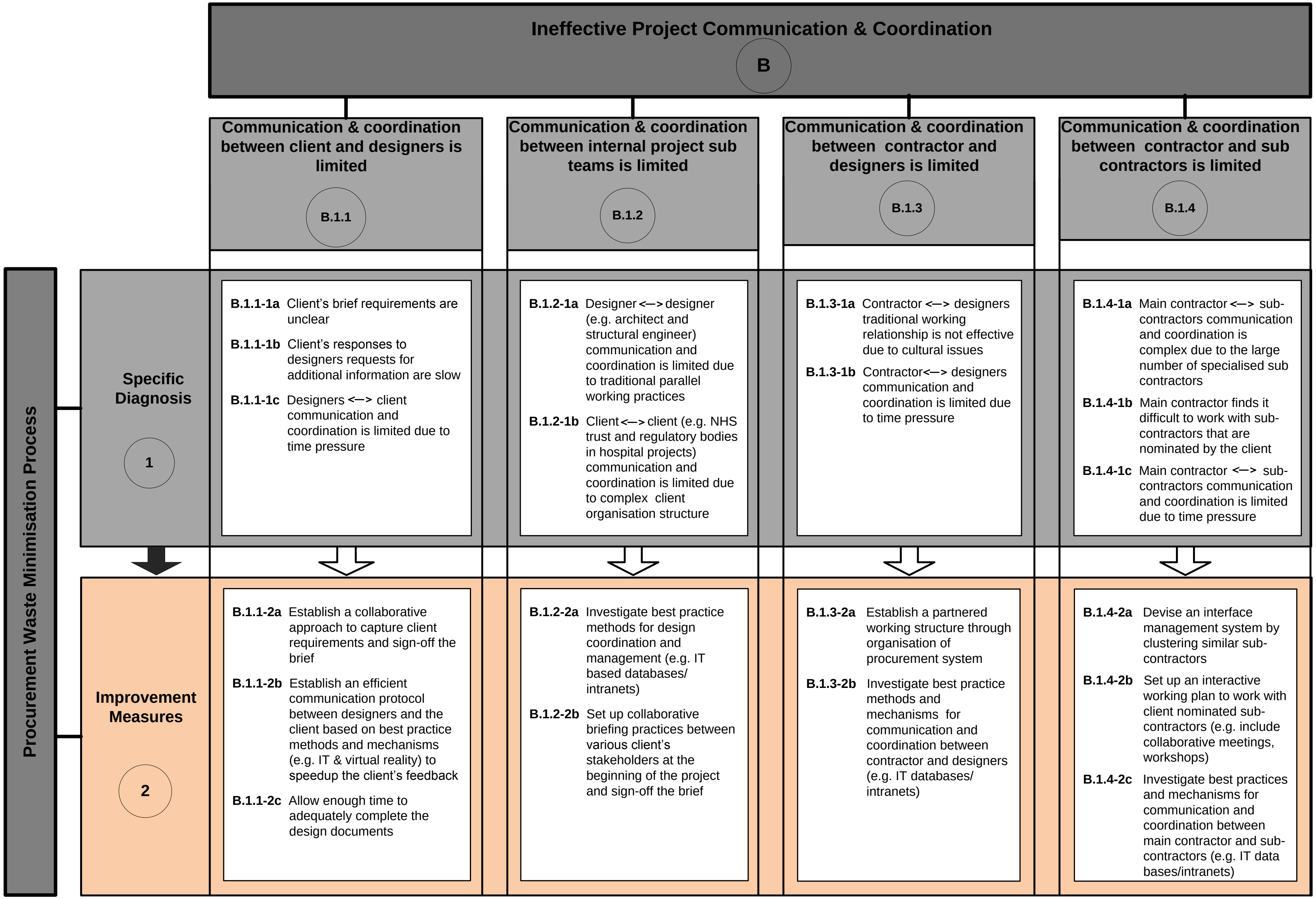

Figure 6.6. Procurement waste minimisation low-level framework: Ineffective project communication and coordination

Procurement Waste Minimisation Low Level Framework: Unclear Allocation of Waste Minimisation Responsibilities

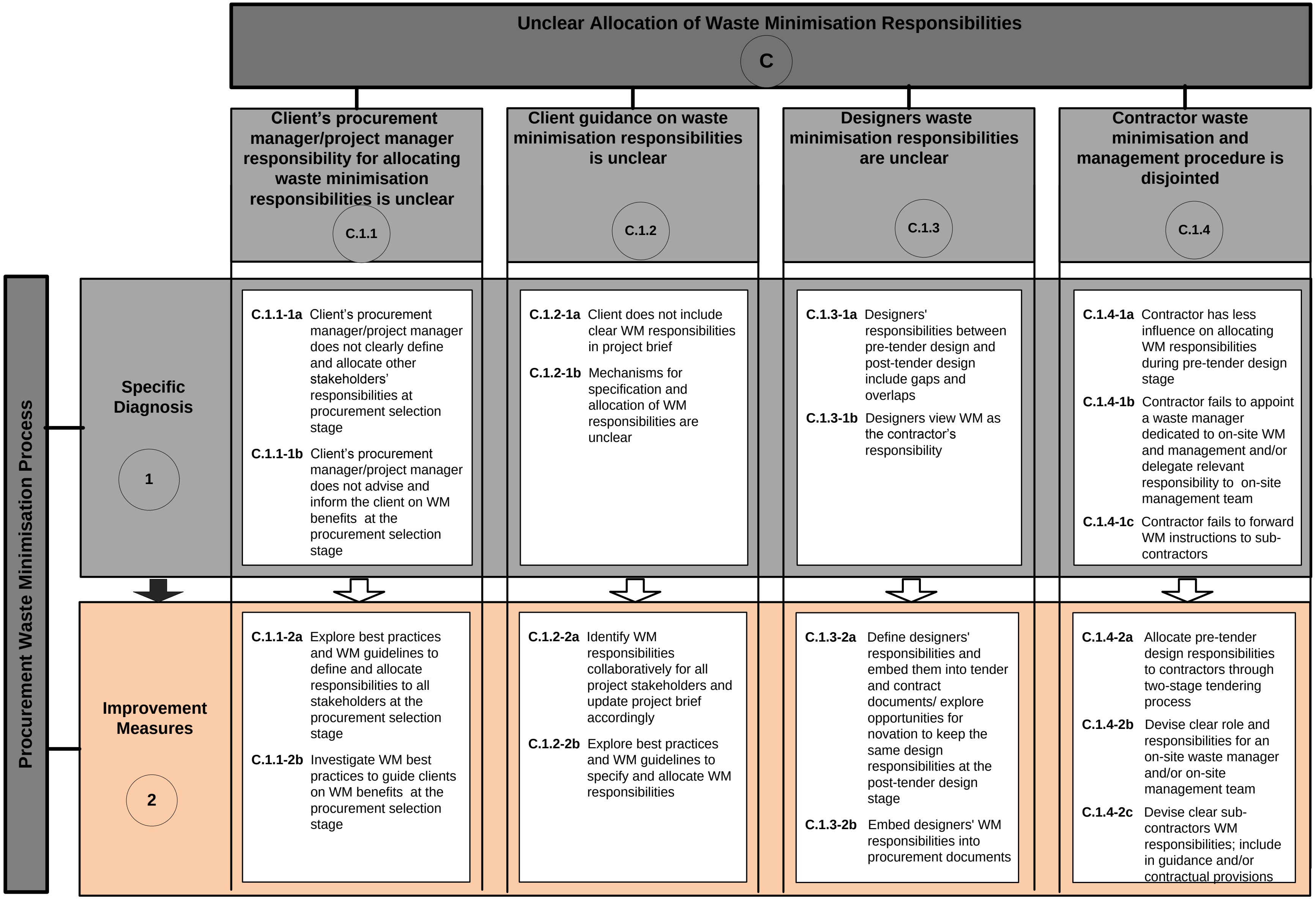

Figure 6.7. Procurement waste minimisation low-level framework: Unclear allocation of waste minimisation responsibilities

Procurement Waste Minimisation Low Level Framework: Inconsistent Procurement Documentation

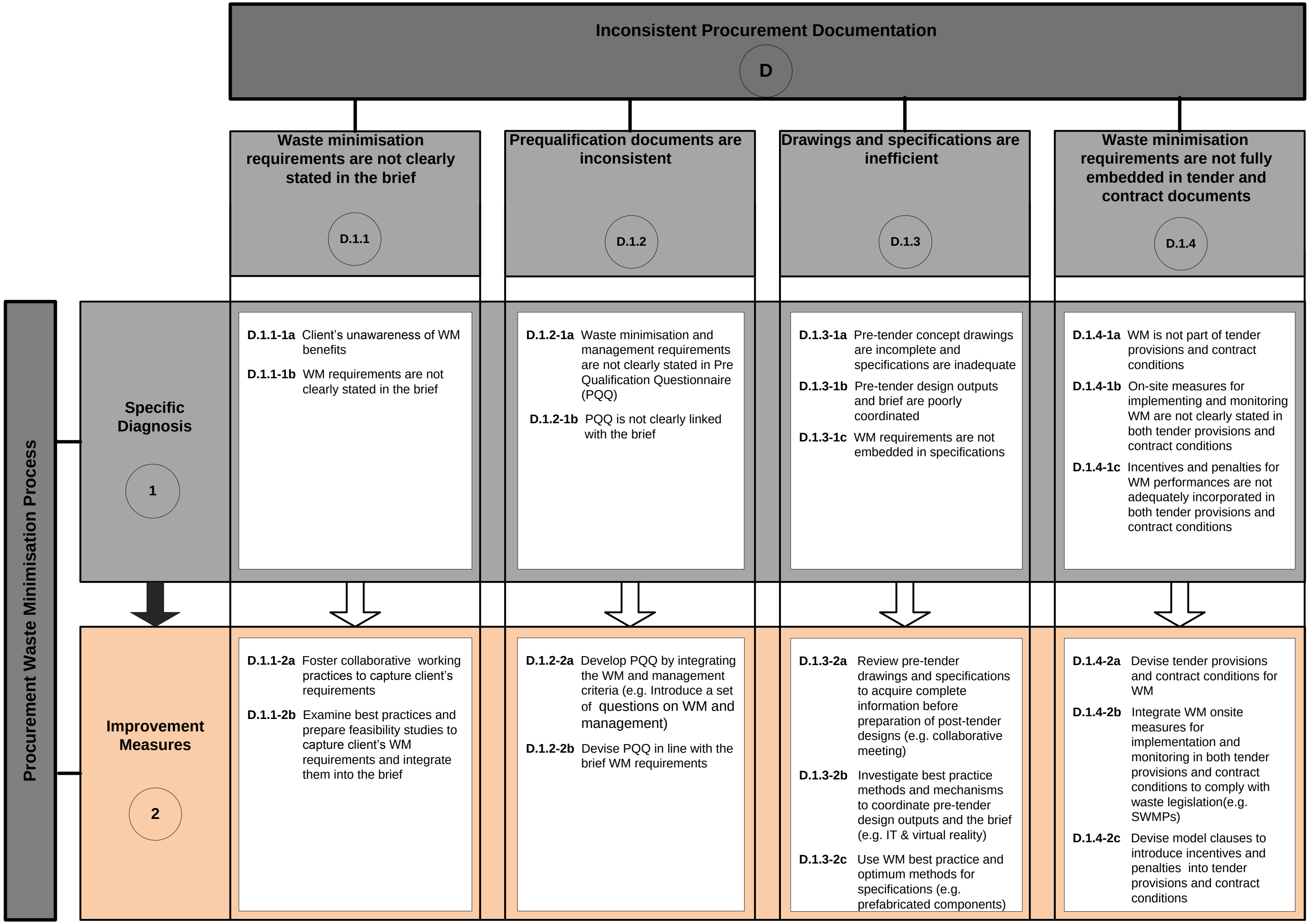

Figure 6.8. Procurement waste minimisation low-level framework: Inconsistent procurement documentation

6.3.3.4 PWMF implementation strategy

During the PWMF validation process, efforts were made to identify a potential implementation strategy for the PWMF. In light of achieving the above, the validation process aimed to investigate:

- a suitable implementation strategy (i.e. appropriate or relevant methods, tools and standards);
- level or degree of integration;
- responsibility of implementation;
- challenges; and
- incentives.

Potential PWMF implementation methods, tools and standards

In the pre-validation questionnaire, respondents were asked to select the most appropriate method(s) from a list of existing protocols/standards/tools to implement the proposed PWMF. It is apparent from Table 6.11 that all of the respondents believe that the proposed PWMF can be implemented in line with RIBA Plan of Work stages. Moreover, respondents recognised other potential ways of implementing the proposed PWMF within D & B projects: WRAP guide documents; JCT conditions of contract (D & B); RICS scope documents; and Government policies and legislation.

Table 6.11. Potential PWMF implementation methods, tools and standards

(Pre-validation questionnaire respondents' views)

Protocols/standards/tools	Frequency (Number of respondents)
RIBA Plan of Work Stages	8
ISO 14001 standard	2
Project management tools	2
other	5

Subsequently, the interviewees were asked how the proposed PWMF should be implemented within D & B projects. All the respondents reiterated that the proposed PWMF has a high potential to be implemented within the RIBA Plan of Work by following its stages. When probed for the reasons for their recommendation, they collectively argued that the contents presented in the PWMF are highly appropriate as they follow the sequential rationale of the RIBA Plan of Work stages; and the key stakeholders are routinely used to the RIBA Plan of Work in D & B projects. This was echoed by a QS who recognised that, *'aligning the PWMF structure and contents with the RIBA Plan of Work would be far more recognisable to the industry'* (QS10).

Even though all the interviewees recognised the RIBA Plan of Work as a suitable method to implement the proposed PWMF, several interviewees (5) stated that it may need additional effort to align the PWMF with RIBA Plan Work stages by stating 'what' needs to be done under each stage of the RIBA Plan of Work, i.e. identifying specific stakeholders' activities and responsibilities, and deliverables. Furthermore, interviewees indicated that in an attempt of PWMF-RIBA Plan of Work alignment exercise, the early stages of the RIBA Plan of Work should be carefully analysed. As such, the interviewees commended the PWMF improvement measure to devise a collaborative working approach and a mechanism for signing off the key activities.

Most of the interviewees (6) reported that the main contents of the PWMF have less opportunity to be implemented within the ISO 14001 standards '*because it is difficult to set an exact standard to cover every aspect of waste'* (SM27) as an interviewee stated. However, some interviewees suggested that the PWMF contents can simultaneously be identified in RIBA Plan of Work (i.e. what needs to be done) and comply with ISO14001.

The interviewees were asked whether they had an in-house specific document, tool, or policy that the proposed PWMF could be directly integrated into or used with. Most of the interviewees opined that they did not have such a potential PWMF implementation recipient. On the other hand, all of the interviewees stated that the contents presented in the PWMF are widely applicable to their current practices such as the company's sustainability and environment policy documents, SWMPs, design services agreement documents, and waste forecasting tools. One interviewee stated that the proposed PWMF could be used as a guide document at an institutional level by '*breaking down the PWMF contents into series of clauses relating back to responsibilities identified in Low-level PWMF (C) component, to be incorporated in the documentation of Low-level PWMF (D), having discussed requirements and expected outcomes with the stakeholders in Low-level PWMF (A) and communicated it as a part of Low-level PWMF (B)'* (QS10).

PWMF implementation Responsibility

The interviewees were asked about who would be the most appropriate individual to be responsible for implementing the proposed PWMF. All the interviewees held a view that the main responsibility should be allocated to someone who is involved at the start of a project, both at an organisational level and at project team level, who *'should need to drive the implementation of the proposed PWMF and make sure all the recognised issues are covered'* (PM6).

Organisational level: All the interviewees emphasised that the proposed PWMF implementation should be client-led at the organisational level. However, over half of the interviewees (5) mentioned that client organisation might not have the desirable WM background in terms of awareness, procurement waste origins, and improvement measures that are mapped and proposed in the PWMF. As a result, some of the interviewees suggested that the central government has an effective role in taking over the responsibility of implementing the PWMF; firstly, as a major client to public projects and secondly, as a policy maker. One interviewee mentioned that, *'the central or local government as a client should take the initiative such as target settings of their projects and legislative reforms'* (PM13) to implement the proposed contents of the PWMF.

Project team level: All the interviewees held a consensus that the client should be the entity to initiate the implementation of the proposed PWMF; and delegate responsibility to a project member who has the capacity to bring all project stakeholders together at the initial stage of the project. Most of the interviewees proposed that the client's project manager should take the responsibility of implementing the proposed PWMF, *'because the project manager is the client representative and ultimately should be accountable for the project performance. He/she may delegate part of responsibilities to relevant project stakeholders'* (QS10). However, several other interviewees mentioned that the client's procurement manager could also take the responsibility of implementing the PWMF *'as he/she is typically involved at the beginning of the project and responsible for procurement decisions'* (PM6).

<u>Challenges and incentives for PWMF implementation</u>

The interviewees were asked to list and describe possible challenges and incentives that might be associated with the implementation of proposed PWMF; their responses are summarised and discussed below.

Potential PWMF implementation challenges

- **Clients' commitment:** Some clients might not recognise WM as a significant aspect in their projects (i.e. due to unawareness of issues and benefits, inexperience). Besides, some clients could have a perception that the use of the PWMF may increase the project cost. In such occasions, the implementation of proposed PWMF would be problematic, as the PWMF needs to be client-driven.

- **Maintaining a balance between generic and specific applications:** The proposed PWMF needs to be generic enough to be applicable to the whole range of projects. Such a need arises due to variability in performance and delivery of projects (e.g. large construction projects). Furthermore, the PWMF also needs to be flexible, helpful, and specific enough to direct the users on what needs to be known (i.e. developing hyperlinks between PWO, mapping the existing resources available to address issues).
- **Clear implementation strategy:** Present PWMF laid out key PWO issues and improvement measures, but it should be improved into an implementation stage. Therefore, drawing out an implementable strategy for the proposed PWMF is a challenging task by enhancing important links between issues, activities and responsibilities of different parties, deliverables, and measurable targets.
- **Difficult to demonstrate actual benefits of using the PWMF:** One of the targeted outcomes of implementing the proposed PWMF is to minimise costs associated with construction waste. However, it is difficult to measure and demonstrate cost savings that originate from implementing the proposed PWMF. Therefore, it is essential to introduce benchmarking tools to demonstrate the cost savings of the PWMF implementation.

Potential PWMF implementation incentives

- **Reduced cost:** Construction projects tend to be awarded for the lowest bid due to the influence of current market conditions. This encourages clients to investigate effective ways to reduce project costs. Thus, on the one hand, clients will have the opportunity to ask for WM from contractors; and contractors will be more committed to considering WM practices to strive for a competitive advantage at the bidding stage on the other.
- **Current and future legislative compliance:** Increasing legislation on construction waste and government policies on sustainable construction form necessitates novel approaches in WM such as the PWMF.
- **Structure of the D & B procurement system:** The D & B procurement system allows bringing contractors into the early stages of the project. Therefore, the

PWMF provides the opportunity of working collaboratively with contractors who have a practical understanding of construction process and WM.

6.4. Summary

In this chapter, the PWMF development and validation process have been examined for D & B projects. The chapter has given an account of the structure, PWO and respective WM improvement measures for both High-level PWMF and its associated Low-level components.

The overall feedback on the PWMF validation objectives was positive in terms of its clarity, information flow, appropriateness, and practicability. The PWMF validation results showed that the developed PWMF has a clear structure and information flow. Also, validation results suggested that four PWO, associated sub-waste origins, proposed target areas/parties for improvements, and WM improvement measures proposed are appropriate both in terms of High-level and four Low-level PWMF components. The proposed PWMF has been further enhanced based on the validation participants' feedback and recommendations.

The validation results also reported that the implementation of the proposed PWMF has a potential to align with the RIBA Plan of Work stages and should be client-led at organisational and project level. Moreover, the validation results suggested that the contents presented in the PWMF are widely recognised in current company practices, which will facilitate its implementation. The next chapter presents a discussion of the research findings in light of existing literature.

7. Discussion

7.1. Introduction

This research set out with the aim of investigating the impact of Construction Procurement Systems (CPS) on waste generation to develop a Procurement Waste Minimisation Framework (PWMF). This chapter presents a discussion of themes emerging from the results of the research as presented in previous chapters. Specifically, the chapter provides important link(s) between chapters 3, 4, 5 and 6.

The first two sections of this chapter outline discussions of current WM and management practices and CPS practices. The third section discusses the relationship between CPS and construction waste generation. The fourth section discusses Procurement Waste Origins (PWO) emanating from the results of the study. The section considers potential waste-causing issues related to uncoordinated early involvement of stakeholders, ineffective communication and coordination, unclear allocation of responsibilities and inconsistent procurement documentation. The fifth section discusses improvement measures identified from the results to address waste causing issues and enhance WM practices. Subsequently, section six of the chapter attempts to review the validation results of the developed PWMF.

7.2. Waste Minimisation and Management Practices

Turning to the impact of government policies and legislation on current waste management practices, it is clear that legislation (i.e. Landfill Tax and Site Waste Management Plans) has had a greater impact on current waste management practices than policies (i.e. Sustainable Construction Strategy 2008 and Sustainable Procurement Action Plan 2007). This finding seems to be consistent with those of other studies (Osmani et al., 2008 and Chen et al., 2002) suggesting that legislation and penalising project stakeholders are major incentives which have impacted on WM practices. Another interesting finding that emerged was that study's respondents believe contractors' waste management practices have had a higher impact from government legislation and policies than quantity surveyor practices. There are several possible explanations for this result. It can be argued that the selected legislation and policies are directly targeted and relevant to contractors. Therefore, it could have shown higher impact on contractor practices. Alternatively, selected policies and legislation may have actually neglected the impact of quantity surveyors (consultants) on WM and management practices. However, this study's results clearly suggested that number of waste causes relate to quantity surveying practices such as procurement selection, tender and contract documentation and cost of waste. Apparently, there is very little evidence regarding policies and legislation in literature that focuses on WM and management related consultant practices (including Architects, QS, and project managers). Therefore, this could be an indication that the requirement of legislation and policies on WM and management targeting consultant practices to bring their attention and commitment to early WM actions.

Previous studies have noted that current WM and management practices have been more focused on the construction stage than the pre-construction or preparation/design stages (according to section 3.2.6). The results of this study show a similar trend, i.e. that the WM and management strategies being used in current projects have a greater focus on post-waste generation than pre-waste generation (Section 5.3). Moreover, this study emphasises that WM and management practices possibly to be expanded in order to eradicate waste causes by identifying waste inherent in design, procurement and planning stages and sub-contractors' waste performance. This is in line with recent research findings and recommendations of many studies which recommend that WM should be focussed on early project stages rather than on-site waste management (McDonalds and Smithers, 1996; Key et al., 2000; Osmani et al., 2008).

There was a consensus in the literature that elimination and reduction are the best and most efficient method for minimising the generation of waste and eliminating many waste disposal problems (section 3.2.3). The interviewees strongly suggest that 'zero waste to landfill' is an attainable target (section 5.7). Thus, the latter shows that current practice contains a strong attitudinal driver to minimise waste to landfill while former suggests that it is in line with the literature. Moreover, the questionnaire survey suggested that government legislation has a major impact on current waste management practices. Thus, the aforementioned attitudinal driver towards to zero waste to landfill could be seen as one of the positive consequences of government legislation on waste management. However, this study reported several challenges that may have to be overcome in order to achieve zero waste to landfill, such as additional costs and time associated with the process, client commitment, and limitations with existing methods for recycling (e.g. capacity of downstream stakeholders: waste recycling companies).

7.3. Procurement System Practices

7.3.1. Procurement Trend

Results of this study reported that integrated – D & B and separated – lump sum CPS are popular in current projects. Similarly, study's respondents believed that there is an increasing popularity of D & B as a single procurement system in the UK. Therefore, the results of this survey further substantiate the RICS Survey 2007 findings that reported the dominance of D & B which represented the largest percentage as a single procurement system in use, with a continued decline in traditional systems (i.e. Bills of Quantities).

On the question of why the D & B system is dominant and has an increasing trend in use, this study found several reasons: clients' preference for risk transfer (i.e. transfer design risks to contractors) as it allows cost certainty; government policies; project duration (i.e. speed of construction) and clients' awareness of the D & B procurement system. These findings are consistent with procurement selection studies where risk allocation/avoidance, cost certainty and speed/time certainty are key client requirement criteria in terms of procurement system selection (section 3.3.3). The research has also suggested that recent government procurement policies and initiatives may have an important influence on changing UK procurement trends towards integrated CPS (section 5.4.1).

Another important finding of this study is the higher popularity of the enhanced D & B procurement system compared to a traditional D & B procurement system (section 5.4.2). This is in agreement with Akintoye (1994), who found that novated and develop & construct share the majority of total D & B practices. Moreover, several other studies have noted that variants of the D & B system have emerged as a popular option for procurement such as Bound and Morrison (1993), Ndekugiri and Turner (1994), Chan (2000); and Doloi (2008). Furthermore, the current study reveals that clients prefer enhanced D & B, as it allows them to determine the building concept and assess the budget required before a D & B contractor is appointed. However, the study reveals a number of negative aspects. For example, enhanced D & B allows little opportunity for contractors to be influenced by the fundamental design, therefore, it reduces buildability of the design; limits the continuity of design responsibilities; and tends to increase cost if adequate time is not allowed at the tender stage to analyse risks associated with novation and design development. These points corroborate the findings of Akintoye and Fitgerald (1995), Siddiqui (1996), Chan (1999), Anumba and Evbuomwan (1997), and Ng and Skimore (2002). Therefore, these findings reinforce the existing knowledge and provide solid background to discuss these issues in light of procurement waste origins in forthcoming sections.

7.3.2. Sustainable Procurement

Results of this study reported that most of companies involved in the survey have in place a Sustainability Policy. This may be a positive indication that current practices are aware about issues pertinent to sustainable construction at strategic level (section 4.3.2). However, survey results reported that only a minority of companies have a Sustainable Construction Procurement Policy. This indicates that the current company practices may need further attention in terms of improving internal policies related to sustainable construction procurement.

In reviewing the literature, the importance of adopting appropriate CPS to deliver sustainable construction was noted (Ngowi, 1998; Rwelamila et al., 2000; OGC, 2007a). Questionnaire survey respondents strongly reported that they gave high priority for client requirements and project characteristics in terms of CPS selection. This is further supported in the findings of many studies, for example, Ratnasabapathy et al. (2006) and Chan et al. (2001). Moreover, not surprisingly, sustainability requirements were given a low priority as a CPS selection criterion, which in line with the findings of Adetunji et al. (2008) revealed that there is still no ‘level playing field’ as procurement practices have largely been focussed on price, whereas the commitment to sustainability issues has been low priority rather than a contractual deliverable. This suggests that even though the literature has recognised the importance of appropriate CPS in the context of achieving sustainable construction, current practices attribute a lower importance to sustainable procurement at an operational level. This may be due to fact that either clients/client representatives do not give their requirements adequately on sustainability/WM or the stakeholder who is responsible for CPS selection may not commit to capturing such requirements from clients/representatives at the CPS selection stage.

The literature highlighted the need to evaluate the distinct opportunities of different CPS for delivering sustainable construction projects (Pollighton, 1999; Addis and

Talbot, 2001; Stener, 2002). Thus, on the question of CPS's potential for delivering sustainable construction, the literature suggested that separated (traditional) systems appeared to be the most problematic while non-traditional systems (e.g. integrated and partnering systems) have a high potential for delivering sustainable construction (section 3.4). The results of this study suggested that D & B procurement system potential to help achieve sustainable construction. Furthermore, the results reported that the practice of D & B systems impacts positively on triple bottom line of the sustainability: on the environment by reducing material consumption and production of waste; on the economy by delivering value for money and allowing innovations; and socially by producing whole life sustainable building and contributing to community developments. However, the interviewees agreed that D & B can impact negatively on sustainability if certain requirements are not fulfilled (section 5.4.3), e.g. the absence of an experienced party to manage and coordinate D & B contractor's work process; if the client fails to indicate sustainability requirements to the D & B contractor; and if the D & B contractor is not involved early enough. In line with this, Ngowi (1998) mentioned that it is difficult to assure expertise of the D & B organisation and it may not be able to mitigate environmental impacts. This could be mainly due to the fact that environmental impacts are not fully exploited at the most influential design stages of a D & B project. Besides, the results reported that the D & B system potentially hinder economic sustainability in the long run due to the accumulation of design costs of unsuccessful tenders.

7.4. Construction Procurement Systems and Waste generation

Very little was found in the literature on the question of the relationship between CPS and construction waste generation. Instead, a small but growing body of literature emphasised the importance of assessing the relationship between CPS and construction waste generation. Findings of this research (section 4.5.3) clearly indicate that typically, the selected CPS for a project potential to have an impact on construction waste generation. More specifically, D & B and cost reimbursable have both reported a 'significant or high' impact on waste generation, whereas other CPS considered were reported as having a 'moderate' impact. The impact of separated - cost reimbursable system on waste generation is in line with the findings of Johanson and Walker (2007) who revealed that a large amount of waste is inherent owing to traditional contracting.

Surprisingly, while descriptive statistics results of questionnaire survey showed a high impact from D & B system on waste generation, qualitative analysis of respondents' views suggested that D & B system has a high potential to impact on 'minimising' construction waste generation mainly due to early contractor involvement at the design stage, which leads to effective decisions on design and planning WM. Therefore, contradictory quantitative and qualitative results call for further investigation. However, qualitative findings are in agreement with Tam et al. (2007a) study's findings, which showed that D & B system has a 'high' importance level in reducing construction waste due to involvement of contractor at the early design stage leading to improved constructability. Jaques (1998) and McDonald and Smithers (1996) also had similar views that alternative procurement methods offer more opportunities for reducing waste due to the involvement of contractors at the design stage creating a greater buildable design, planning and teamwork that allows for a logical sequence in construction and provides accurate and integrated project information.

Further investigations suggested that the D & B system has a high potential to impact on minimising construction waste as it allows: early contractor involvement; competitiveness of the design at the tendering stage; opportunities to work with a truly integrated supply chain from the beginning of the project; usually contractor to fixed contract sum; and minimum flexibility for variations (section 5.5). However, surprisingly, the survey results (quantitative) did not show a significant difference between the impact of integrated and separated systems on construction waste generation. Therefore, this suggests the need of further investigations with empirical evidences, possibly with precise waste quantification methods. Furthermore, a possible explanation for this is that current D & B practice has a greater share of enhanced D & B than traditional D & B (discussed in section 7.3). Findings in section 5.5 clearly suggest that enhanced D & B practices tend to generate more waste compared to traditional D & B. The key reasons are lack of early contractor involvement; incomplete concept design; tight tender process thus meaning that priorities are placed on development of existing concept drawings and pricing of them; and problems of communication and false relationships between concept design team and D & B contractors. These issues have been identified in the literature as disadvantages of enhanced D & B, yet the significance of current findings are in the context of waste generation. The latter findings further support the idea of McDonald and Smithers (1996) where they criticise enhanced D & B practice as it hinders WM opportunities. The main criticism is that the initial concept design is prepared without any input of the D & B contractor and detailed design preparation continues after a D & B contractor has been appointed. Moreover, the project cost is only based upon initial drawings and specifications where initial concept drawings may not have been produced with the aim of targeting WM (rather for the selection of contractor, and getting a price for the project).

The results of the questionnaire survey reported that CPS selection (i.e. RIBA Plan of Work Stages) at 'Technical Design (E)' and 'Production Information (F)' stages potential to have a significant or high impact on construction waste generation while CPS selection at the 'Appraisal (A)' stage has a minimum potential to impact on construction waste generation. The literature indicates that if the procurement selection decision is set back until stage E (Technical Design), it eliminates the opportunity of considering alternative CPS such as D & B system and management oriented systems. Apparently, the available CPS for the selection at Stage E and Stage F are separated systems. Therefore, correlating the former and the latter, it is further suggested that separated CPS possibly have a high impact on construction waste generation.

Integrated CPS have the most potential to integrate WM strategies while separated (conventional) systems have the least potential (section 4.6.2). Integrated systems allow the early involvement of contractor (i.e. for both design & construction processes), single point responsibility for design and construction, and competitiveness of the design at the tender stage (section 5.8). These findings also suggest the notion that CPS has an impact on construction waste generation. Moreover, the aforementioned findings are in agreement with Tam et al. (2007a); a study that showed that D & B significantly reduces waste mainly due to the involvement of contractor early design stage. In line with this, Johansen and Walker (2007) state that integrated systems help to minimise waste as they enable concurrent work processes and early involvement of downstream players into upstream stages. Furthermore, Masterman (2002) noted that the absence of a bill of quantities makes the valuation of variations extremely difficult and restricts client-driven variation during post contract stages; McDonalds and Smithers (1996) noted that the overlap of the design and phases possibly allow for more design development time to facilitate WM.

The findings of this research contradict Jaques (2000), and McDonalds and Smithers (1996) results which concluded that alternative procurement routes held no advantages over the traditional route in terms of WM. However, the findings of this research support McDonald and Smithers' (1996) critique of their own conclusion that alternative procurement routes held no advantages over the traditional route (but this may be more of a reflection upon the experience and interests of respondents than the waste control issue).

This rather contradictory result may be due to the fact that current studies are based on different CPS, which are grounded in definitions, cultural and legislative structures (discussed in section 3.4.2). Similarly, the results may also be highly dependent upon the respondents' experience, personal interests, and awareness of the current issue between CPS and waste generation. There had been a similar view from McDonald and Smithers (1996) and Jaques (2000). For example, one respondent of the questionnaire survey echoed the above reasons that: *'a procurement system could have a significant effect on the waste generated. However, it could promote a lot more influence than it does currently, as when it will take a much bigger cultural change. Then people accept how important the management of waste is on a construction project, there by CPS will be more influential in waste generation and minimisation'* (SM19). Therefore, in summary, the findings of this study incline towards the view that CPS have a potential to impact on construction waste generation, yet the study acknowledges and recommends further investigations into different CPS along with precise waste quantification methods.

7.5. Procurement Waste Origins

In reviewing the literature, only few authors have identified the potential waste generating characteristics associated with different CPS (i.e. Procurement Waste Origins) (section 3.2.5). Therefore, this study has attempted to identify key PWO and to refine them. An initial review of the relationship between CPS and construction waste generation helped to identify seven (7) potential PWO: parties' involvement (i.e. contractor early involvement and client involvement); communication and coordination among parties and trades; allocated responsibilities among parties for decision making; type and form of contract; procurement system process duration; method of tendering; and documentation. The distinct feature of the identified origins is that each of them varied for different CPS and thereby exerted an impact on waste causes associated with design, tender & contract, and construction differently (section 3.2.5).

Four (4) key PWO were identified and further transformed into more reflective PWO, based on the results of the questionnaire survey. Based on the results of section 5.6.1, section 5.6.2, section 5.6.3, section 5.6.4, and PWMF validation process (section 6.3), the identified PWO were further improved in terms of their clarity, focus and appropriateness. The results of the validation process suggest that the four waste origin clusters identified appropriately cover PWO. Consequently, the four PWO identified in this study are,

- Uncoordinated early involvement of project stakeholders;
- Ineffective project communication and coordination;
- Unclear allocation of waste minimisation responsibilities; and
- Inconsistent procurement documents.

This overall result has not been previously identified in literature, nor has it been extensively described in the context of the association between CPS and waste generation.

Both the literature and this research emphasise that one of the main reasons for the popularity of D & B is the ability to transfer risks to the contractor. Therefore, not surprisingly, the risk associated with construction waste is placed with the D & B contractor (section 4.5.1). However, even if such a risk transfer is evident, it appears that D & B system may still contribute to construction waste generation. Therefore, it can be argued that transferring risk to D & B contractor in terms of WM has not worked well to date. Furthermore, the following findings emerged from the literature review and questionnaire survey:

- The majority of current projects are being undertaken using D & B system;
- Contradictory results of the questionnaire survey (qualitative Vs quantitative) about the impact of D & B system on waste generation;
- D & B is likely to become popular in future projects; and
- D & B has shown a high potential to integrate WM strategies.

As such, the current study has focused on further investigations into the D & B procurement system. The forthcoming sections discuss results on the four PWO and their associated key causes of waste. While general discussions are presented at the start of each section, a detailed discussion of each issue will focus on the context of D & B procurement system.

7.5.1. Uncoordinated Early Involvement of Project Stakeholders

On the question of why a lack of early involvement of stakeholders (i.e. during design and procurement stages) has an influence on waste generation, the views of interviewees suggested that the uncoordinated early involvement of stakeholders most likely responsible for waste generation as it leads to incorrect decisions, misunderstandings, poor buildability, variations and reworks. This is in agreement with Poon (2007) who emphasised that waste reduction should be considered at an early stage and by all parties involved in the building process. Dainty and Brooke (2004) and Greenwood (2003) provided a similar view indicating that project stakeholders must be involved and committed to WM. Furthermore, Rwelamila et al. (2000) highlighted the project manager's inability to pull every stakeholder together.

The results in sections 4.5.4 suggest that the lack of contractor involvement in the early project stages most likely have an impact on construction waste generation. According to section 5.6.1, a lack of early involvement also limits the ability of the contractor to influence designing out waste and bringing inputs of sub-contractors and supply chain to the design process (e.g. producing buildable design layouts, innovative design and construction methods, methods for minimum material consumption). This is in agreement with McDonald and Smithers, 1996; Jaques, 1998; and Tam et al., 2007a. This study reveals two main barriers for early contractor involvement. Firstly, clients are reluctant to appoint a contractor at an early stage of the project, as they prefer to determine the basic building required (i.e. functionality, aesthetics, and budget required) before employing a D & B contractor. As discussed in section 7.3, the latter point is also a major reason for the popularity of enhanced D & B. The second barrier is time constraints. Specifically, section 5.6.1 states that time constraints restrict two-stage tendering opportunities and a comprehensive review of the whole design by D & B contractors during the tender process (i.e. due to enhanced D & B). This is mainly because D & B contractors give priority to pricing and developing detailed designs in order to win the project bid within the limited time available rather than doing a comprehensive review of concept drawings. The latter finding highlights that this issue arises 'during' the tender process. However, previous literature claims that time constraints are relevant to the pre and post tender stages of contractor involvement. For example, Chan (1999) who found inadequate time spent by the design team with the contractor at the 'end' of the tender period on detailed checking of errors and omissions.

Section 5.6.1 suggest that lack of early involvement of client/end user(s) has an impact on construction waste generation as it is potentially a direct cause of poor briefs and possibly creates mismatches between client requirements and physical construction resulting in rework. This finding is consistent with other studies that report a lack of client engagement over a project process that will undermine project performance (Akintoye, 1994; Molenaar and Songer, 1998), lack of adequate brief (Siddiqui, 1996) and late design changes (Anumba and Evbuomwan, 1997). Having noted that, this research suggests that the main barriers to the early involvement of clients in terms of D & B projects originate from their own perceptions. As discussed in section 5.6.1, clients do have a perception that they do not get extensively involved at the early stages of a project (they assume it is D & B contractor's responsibility to deliver the project). Similarly, clients do not prioritise WM at the early stage, having a perception that WM involves additional costs and time. This study also highlights that these perceptions exist mainly due to clients being inexperienced in construction; they also show that lack of early designer involvement is also an influential factor for waste generation. As discussed in section 5.6.1, the main barriers for early designer involvement are: discontinuity of design process due to enhanced D & B practices, incomplete and unclear information in the brief, and lack of proactive engagement for WM due to fee concerns. The issues discussed earlier, both related to client/end user and designer are consistent with previous literature, yet the significance of current findings is in the context of construction waste generation and WM.

7.5.2. Ineffective Communication and Coordination

The results of section 4.5.4 report that communication and coordination amongst parties and trades potentially have a significant or high impact on construction waste generation. Moreover, Section 5.6.2 reports ineffective project communication and coordination possibly have an impact on construction waste generation. Current findings also accord with previous literature (Tam et al., 2007a; McDonald and Smithers, 1996; Emmitt and Gorse, 1998), which highlighted the importance of enhancing communication and coordination in order to minimise waste generation. On the question of why poor communication and coordination impacts on waste generation, the results suggest that waste arises due to limited communication and coordination issues among project stakeholders, i.e. client-designers; internal project teams; and designer- contractor; and contractor-sub-contractors. Other common issues include time pressure, lack of contractual provisions and improper communication channels and tools.

The results demonstrate that issues which are accountable for ineffective communication and coordination leading to waste generation originate in enhanced D & B practices. The organisation of enhanced D & B system (i.e. due to concept architect involvement) restricts direct communication and coordination between client and D & B contractor. Limited communication and coordination between client and designers occurs due to the clients' inability to express clear requirements and slow client responses for additional information requests. Moreover, the results of this study suggest that having a complex client organisation structure and traditional parallel working practices between design teams creates limited communication and coordination.

Limited communication and coordination between designers and contractors (i.e. poor communication of initial drawings, details and design alterations from designer to D & B contractor) accords with previous literature. For instance, several studies noted that the lack of attention given to design coordination and communication is one of the design waste causes (Ekanayake and Ofori, 2000; Chen et al., 2002; Poon et al., 2004a; Kulathunga et al., 2005). Further, this study reveals that the prevalence of limited communication and coordination is largely due to the wider cultural issues of the construction industry such as privilege, fragmentation, power distance and trust between parties. These cultural problems tend to weaken the relationship between designer and contractor thereby resulting in poor communication and coordination. While this supports the previous research into cultural issues in construction industry, interestingly, this research has shown that the same issue does affect construction waste generation.

Another finding is the problem of limited communication and coordination between the main contractor (D & B contractor) and the sub-contractors; this also has a major potential to impact on construction waste generation (section 5.6.2). The involvement of large numbers of sub-contractors and difficulties of working with client-nominated contractors are key issues. Findings suggest that the main contractor faces two challenges: First, communication of the concept design to large number of sub-contractors for the design development process; secondly, the coordination of interfaces between different design sub-contractors in order to avoid repetitions and missing details.

One of the major causes of limited communication and coordination among stakeholders is the pressure imposed to reduce time spent on design, tendering and construction processes (section 5.6.2). This study's results are somewhat consistent with other research, which emphasises the problems of having insufficient time for pre-tender design and post-tender design activities. For instance, lack of sufficient pre-novation time accounts for poor design solutions and dissatisfaction in design team (Akintoyo and Fitgerald, 1995); inadequate time spent by the design team with the contractor at the end of the tender period causes a problematic transition process (Chan, 1998); and a successful contractor has to spend additional time to clarify client requirements, liaising with consultants, and seeking approvals for materials and design changes (Anumba and Evbouomwan, 1997). However, the literature is clear about limited communication and coordination in the context of waste generation. This research found that overlap in work schedules and parallel working restrict communication and coordination, resulting in delays and shortage of information leading to waste generation (e.g. alterations of work), but it does differ from some previous literature; e.g. overlaps of the design and construction processes allow for better communication (Masterman, 2002); more design development time facilitating WM (McDonalds and Smithers, 1996). That said, the finding somewhat accords with Keys et al. (2002) who argued that parallel working practices could bring WM lower down the priority list.

Another finding emerged from the results suggesting that the lack of contractual provisions account for poor communication and coordination, which in turn may impact on waste generation. This supports previous research that emphasised the need for contractual provisions to improve WM practices (Greenwood, 2003; Dainty and Brooke, 2004; Tam et al., 2007a). It is implicit that contractual provisions could have a direct impact on communication and coordination among project stakeholders.

7.5.3. Unclear Allocation of WM Responsibilities

The results of section 4.5.4 suggest that allocated responsibility for decision-making has a significant or high impact on waste generation. Moreover, the results in section 5.6.3 further report that unclear allocation of different responsibilities (i.e. design responsibilities; WM responsibilities; and procurement decision responsibilities) potential to have an impact on construction waste generation. This finding aligns with Emmitt and Grose (1998) who recommended a re-assessment of building procurement in order to control waste focussing on individual responsibility and communication within the 'temporary' procurement team. Greenwood (2003) also emphasised the need for identifying and communicating the responsibility for WM.

Prior studies have noted that contractors bear a major responsibility for implementing 'waste management' strategies, whereas other stakeholders take limited responsibility. This is quite apparent because the implementation of waste management strategies mostly has to be undertaken at the construction stage under the contractor's supervision. However, the present study was targeted at determining the current project stakeholders' responsibility for implementing WM strategies. The results strongly suggest contractors (approximately 90%) bear major responsibility for implementing WM, whereas designers and client/client representatives hold comparatively less responsibility. The result is somewhat debatable that whichever stakeholder has the responsibility of implementing WM strategies should be involved at the early stages of a project. Reviews of current procurement practice clearly indicate that although the majority of current projects are undertaken using D & B and lump sum, waste generation is considerably high due to cost reimbursable and D & B. Therefore, this raises the question of whether or not contractors are actually involved in the early stages of projects and allow the implementation of WM strategies effectively or do designers and client representatives need to bear more responsibility for implementing WM strategies than they have presently? While the former needs further investigation, the latter was addressed in the study pointing out that client or client representatives should take on the responsibility of dictating WM requirements at the outset of a project and designers should design out waste. These findings seem to be consistent with Osmani et al. (2008) and Coventry and Guthrie (1998) who argued that designers should also take a major responsibility for WM.

The unclear allocation of design responsibilities is reported as a major factor in construction waste generation (section 5.6.3). Gaps and overlaps of responsibilities (e.g. interface designs, material selection) between concept design teams and D & B contractors complicate the design decision-making process. The results show that the latter issue arises mainly due to enhanced D & B where design responsibility is shared between concept architect (pre-tender design) and a D & B contractor (post-tender design). Similarly, the same issue can arise within D & B contractor's design team (i.e. concept architect (if novated), other designers, sub-contractors). A possible explanation for the unclear allocation of design responsibilities might be working difficulties faced by the design team as a consequence of novation and its change in employer: pre-novation working for the client and post-novation working for contractor (Chappell, 1994; Speed, 1995). However, Anumba and Evbouomwan (1997) pointed out that there is significant rework and duplication inherent, where the initial consultants are not novated to the successful contractor i.e. develop and construct. This suggests that novated D & B is better than develop and construct in terms of clarity of design team responsibilities.

One of the key findings is that WM responsibilities may not be defined clearly and shared adequately among project stakeholders (section 5.6.3). Both client and designers have a perception that WM is the contractor's responsibility. Consequently, clients do not provide clear guidance on WM responsibilities in the client/project brief and there is less control over design changes (variation) directed by the designers. This also accords with previous observations in section 4.5.1 that contractors bear a major responsibility for implementing WM strategies in current projects, whereas designers and client/client representatives hold comparatively little responsibility. In line with this, previous research has noted that improvement of attitudes towards waste is essential for effective waste control processes (Teo and Loosemore, 2001; Kulathunga et al., 2006). However, clients and designers should take responsibility for defining and allocating WM responsibilities (attitude change). But mechanisms for specification and allocation of WM responsibilities are also unclear (e.g. WM guidelines/standards, incentives). This is in line with Sterner (2002), who indicated that methods which assist clients in their assessment are essential in procurement, tender evaluation and evaluation of environmental impacts of materials.

Another major finding relates to decision making at the procurement selection stage with regard to identification, allocation and monitoring of WM responsibilities. In this respect, the results suggested that the procurement manager's (or project manager's) responsibility for allocating WM responsibilities is unclear. Therefore, procurement managers often fail to define and allocate others' responsibilities clearly at the procurement selection stage. This links to other waste generating issues such as unclear design responsibilities and unclear WM responsibilities, lack of stakeholder involvement and limited communication and coordination. The underlying reason could be a lack of understanding of both architectural and practical concerns that link to construction waste. Moreover, the PM does not advise and inform the client on WM benefits, and does not express WM requirements or assess contractors' waste track records at the procurement selection stage. The findings in section 3.3.3 report that current practice does not consider WM or sustainability requirements as key criteria at the procurement selection stage. Moreover, Teo and Loosemore (2001) agree that managers should engender positive attitudes towards waste at operative level on a construction project (section 3.2.6).

Contractors' disjointed WM and management processes are also suggested as accountable for unclear allocation of WM responsibilities. The contractor has less influence on allocating WM responsibilities during the pre-design stage. This is mainly due to enhanced D & B practices. Unclear on-site waste responsibilities (between D & B contractor and sub-contractors) also have a share of the problem, particularly where a D & B contractor fails to appoint a party dedicated to onsite WM and management and fails to forward WM instructions to sub-contractors.

7.5.4. Inconsistent Procurement Documentation

This study's results suggest that inconsistent procurement documents possibly have an impact on construction waste generation. On the question of why incomplete or insufficient procurement documents have an influence on waste generation, procurement documents are prepared and used at different stages of a project, therefore, if such documents are not aligned with each other and provided sufficient details, this impacts on waste generation. The current study reports several inconsistencies in procurement documents that can account for waste generation: client brief, drawings and specifications, pre-qualification questionnaires, and tender and contract documents.

One of the key concerns is that other procurement documents are dependent on the brief. Thus, a poor brief appeared to cause multiple effects on waste generation. In terms of D & B, client brief requirements are significant (compared to separated procurement system) as it is the only available source of information along with specifications for D & B contractors (concept drawings available with enhanced D & B) at the initial stage of project. Having said that, section 4.4.2 and section 5.6.4, reported that while client requirements are given a high priority for procurement selection, WM requirements were not evident as a priority. According to Section 5.6.4, one of the main reasons for waste generation is a lack of information on client requirements; WM requirements are not clearly stated in the brief, in turn it is likely to generate more waste, as there is no driver for WM from the brief. However, clients may also be unaware of WM benefits.

Pre-qualification documents may be inconsistent and not used effectively for WM and management (section 5.6.4). Current PQQ documents, in practice, do not focus much on both WM and management. They do not provide adequate provisions for WM even though there are ample opportunities available to make qualifying parties aware of what WM standards would need to be achieved. Further the PQQ is not inter-linked with client brief requirements and qualification questions are generic and do not deliver project specific WM requirements.

There was a strong agreement among interviewees that incompleteness of drawings was a major cause of waste generation D & B (section 5.6.4). This arises mainly with the enhanced D & B variant. Results suggest that specifications are important for D & B contractors as an integral part of design documents where design is absent (i.e. with traditional D & B) or partially developed (i.e. enhanced D & B). The specification document is significant because it is the main source for communication - transferring design details and material information. Having reported that, the current practices of specification writing impact significantly on waste generation as some specifications are inadequate (e.g. unclear, generic, unrealistic). The main reason is that specifications are assembled in a very generic form rather than in a way which considers the purpose of a particular project. Similarly, WM requirements are not embedded into the specifications. One of the reasons may be that designers who write specifications expect the D & B contractor to take overall responsibility for WM with regard to a certain specification. This also accords with section 7.5.3. Poor coordination between pre-tender design outputs (i.e. concept drawings and specifications) and client brief have a direct impact on waste generation. Moreover, the latter may have multiple effects on waste generation, as both these documents are key components of D & B tender document and later in the contract documents. These findings somewhat concur with previous research results into design waste causes (section 3.2.5). For example, unclear specifications can be responsible for selection of low quality materials and products (Bossink and Brouwers, 1996; Ekanayake and Ofori, 2000, Kulathunga et al., 2005; Osmani et al., 2006; 2008); detailing errors/ lack of information in the drawings (Gavailan and Bernold, 1994; Ekanayake and Ofori, 2000; Kulathunga et al., 2005; Osmani et al., 2006; 2008) and lack of influence of contractors (Bossink and Brouwers, 1996).

Only a minority of respondents thought that type and form of contract had a direct impact on waste generation (section 4.5.4). This is somewhat in agreement with the interview results (section 5.6.4), in which respondents agreed that tendering and contract documents do not necessarily impact on waste generation. Instead, the results of section 5.6.4 suggest that tendering and contract documents are not being used effectively for WM and management. In particular, it is revealed that WM is not part of tender provisions or contract conditions thereby restricting the stakeholders' WM opportunities (i.e. absence of stakeholders' proactive ownership in terms of WM). This is in line with Baldwin et al. (1998) who highlighted the issue that contracts could produce waste because of their contractual set-up where waste is accepted as part of loss or profit. However, the literature also suggests inconsistencies (i.e. errors, incompleteness) of tender and contract documents' impact on waste generation (Skolyles and Skoyles, 1987; Bossink and Brouers, 1996; Ekanayake and Ofori, 2000).

Moreover, the results suggest that current documents are lacking in provisions/clauses to guide, implement and monitor (e.g. waste target setting, performance indicators, and measurements) D & B contractors' WM actions at both on-site and pre-construction stages. Specifically, there is a need for additional contract clauses focussing on measures to quantify waste. Such measures also need to be easily implemented and audited. It is clear that incentives and penalties for WM performances are not adequately incorporated within both tender provisions and contract conditions. These findings support previous studies which emphasised the need to incorporate tender & contract clauses targeting WM and environment requirements (Sterner, 2002; Greenwood, 2003; Dainty and Brooke, 2004; Tam et al., 2007a).

By comparing the results of the waste generation severity ranking of PWO (section 6.3.3.1) and the impact assessment of PWO on waste generation (section 6.3.3.2), uncoordinated early involvement of project stakeholders has the most critical impact in terms of waste generation. Though both ineffective communication and coordination, and unclear allocation of WM responsibilities have been given a low waste generation severity ranking compared to uncoordinated early involvement of project stakeholders, the impact on waste generation is relatively high. Inconsistent procurement documentation has the least waste generation severity and the least impact on waste generation compared to other waste origins, yet the results suggest that its impact on waste generation cannot be disregarded. This comparison suggests that uncoordinated early involvement of project stakeholders has a major impact on waste generation compared to other factors. Thus, this reinforces previous views that project stakeholders should be involved early and committed for WM (Greenwood, 2003; Dainty and Brooke, 2004; Poon, 2007). Moreover, it confirms Emmit and Grose's (1998) recommendation that the focus needs to be on individual responsibility and communication within the temporary procurement team.

7.6. Improvement Measures

According to the literature review (section 3.2.6), there are a number of approaches evident for WM and management in construction of which the majority are focussed on site waste management. The results highlight three common improvement measures that could be embedded with current D & B practices in order to minimise the four PWO, they are: the introduction of collaborative working, the allowance of contractual provisions, and the appointment of experienced and task-specific professionals. In addition to common improvement measures, the study reports a number of improvement measures that are specific to each PWO cluster (section 5.7.2).

According to section 5.7.1, the introduction of a collaborative work setting at the beginning of D & B project could have effect to minimise waste associated with four PWO. The concept of collaborative working is highly encouraged (section 3.3.4.4) with the modern view of CPS, based on trust, collaboration and ethical behaviour rather than traditional structures and legal frameworks (Walker and Hampson, 2003). But there is little evidence available in the literature on collaborative working as an approach to WM. A possible explanation for this might be that approaches are fragmented (i.e. because WM and management approaches focus either on construction stage or design stage) rather than considering the whole project as a management framework (i.e. CPS). Therefore, the improvement methods evident in the literature for WM/management are mainly project stage specific. Moreover, techniques that attempt to create an effective project management process may not be considered. However, in line with the above, Baldwin et al. (1998) emphasised the need for partnerships and demonstrating good examples to contractors and clients.

‘Risk sharing’ or integrating characteristics of framework/collaborative/joint venture procurement concepts to D & B system appears to be the right move in terms of WM. Results also show that conducting collaborative meetings and learning sessions and the use of collaborative working software and web-based applications could be effective mechanisms for achieving a collaborative work setting. Having said that, the results highlight advantages as well as challenges of using collaborative working software and web-based systems highlighting that it is necessary to gain proper knowledge on the setting up and management of such applications in order to successfully establish an effective collaborative work setting.

The results of section 5.7.1 suggest that contractual provisions need to be firmly established in order to enhance WM practices. Moreover, contractual provisions should aim to reinforce the early involvement of stakeholders, efficient communication and coordination, define and allocate responsibilities clearly and precise procurement documentation process. This finding supports the idea that it is essential to introduce special tender provisions and contract clauses at the pre-contract stage to target WM (Section 3.2.6). For instance, Greenwood (2003) recommended a fully integrated WM system at the contractual stage enabling the identification and communication of the responsibilities for WM between all project stages. This research goes beyond the latter idea because the results suggest rewards-oriented contract conditions rather than penalties. The introduction of conditions towards penalties may generate negative consequences such as the risk of an inflated contract sum, adverse effects on relationships and work progress, discouraging innovative methods and difficulties in measuring or setting exact targets. However, the latter finding does not support the view of Dainty and Brooke (2004) who suggested introducing contract clauses to penalise poor waste performances. The current results suggest that the only way a penalty can be applicable is where measurable targets can be set out. Importantly, penalties should be embedded into conditions that consider all stakeholders who have responsibility for waste generation. This accords with several studies such as McDonalds and Smithers (1996) who recommended a clear tendering mechanism that allows designers' waste reduction efforts to be reflected in the final tender price; and Tam et al. (2007a) who suggested that contractual requirements mandatorily require main contractors to implement quality and environment management. Furthermore, results suggest that potential conditions could be focussed on embedding a target cost approach. However, results also suggest that rewards do not have to be given in monetary terms.

The appointment of experienced and task-specific professionals is an important prerequisite for improving early involvement of stakeholders, effective communication and co-ordination, clearly allocating responsibilities and quality of procurement documentation. This is somewhat in line with Pasquire (1999) who proposed that the construction management team must recognise the role of environmental and specialist consultants as an integral part of the procurement process. However, the findings do not propose the appointment of completely new professionals, instead it suggests the appointment of experienced professionals with redefined and extended job roles in order to enhance awareness and responsibilities in such a way as to reduce waste origins. Jorgenson and Emmitt (2009) also highlighted the importance of project participants' understanding of the specific project context at all levels of design and planning activities and the procurement method for waste elimination.

Turning to other results on improvement measures, a number of specific measures emerged which targeted the four procurement waste origins (section 5.7.2). In order to improve early project stakeholder involvement, investigating two stage-tendering opportunities, various methods to enhance contractor's ability to involve early in the project, WM benchmarking, alterations to legislation targeting stakeholder involvement in WM and use of stakeholder management systems have emerged as potential actions.

In terms of achieving better communication and coordination, conducting regular meetings/workshops/training, development of project specific gateway process and signs from them, establishment of a project specific protocol for communication and coordination, setting up an inter-active working plan and interface management system and maintaining adequate time provisions have been highlighted as important measures.

It has also reported the need for defining and allocating responsibilities for stakeholders with regard to aspects that can impact on waste generation such as source of variations, design responsibilities between concept and destined designs and supply chain responsibilities. Moreover, investigating best practice methods and guidelines on WM have also been suggested as aids for clear definition and allocation of responsibilities. Novation has also seen as a possible option to maintain the continuity of design responsibilities at the post tender design stage when the project is on an enhanced D & B route (i.e. novated D & B is better than develop and construct variant in terms of continuity of design responsibilities).

The research reports measures in terms of achieving improved procurement documentation. Fostering collaborative practices, examining best practices and preparation of feasibility studies are seen as appropriate for capturing clients' WM requirements and integrating them into the brief. PQQs need to be developed to integrate WM and management criteria. A comprehensive review of pre-tender drawings and specification is proposed to acquire complete information before preparation of post tender drawings (i.e. with enhanced D & B system). Best practice methods and mechanisms to coordinate pre-tender design outputs and the brief, and when writing specifications to embed WM requirements should be investigated and tender provisions and contract conditions devised for WM. WM measures for implementation and monitoring in both tender provisions and contract conditions to comply with waste legislation should be integrated on site. Furthermore, model clauses can act as aids for tender and contract documentation process, introducing incentives and penalties with regard to WM and management.

The specific improvement measures reported in this study are echoed in the work of other researchers, but most were in different focuses and contexts (discussed in section 3.2.6).

7.7. Procurement Waste Minimisation Framework

Integrated CPS (i.e. D & B procurement system) have a high potential to minimise construction waste and allow opportunities for integrating WM strategies compared to other major systems. Nevertheless, it has also reported several major issues that challenge true WM opportunities of D & B system. Therefore, the aim of the developed PWMF is to present a mechanism to diagnose such challenges, i.e. procurement waste origins and potential improvement measures to enhance WM practices in D & B projects.

The PWMF development was based on (1) key concepts of general problem solving methodology and (2) key findings that emanated from the research. Framework validation results suggested that the developed PWMF has a clear structure and information flow. Thus it enables users to view and understand links between elements of the framework (section 6.3.3.1). Therefore, this is possibly a clear indication that the adaptation of concepts of general problem-solving methodology to develop PWMF was a success. Similarly, there has been general agreement among evaluators that the four PWO and their contents appropriately cover waste origins, proposed target areas/parties and WM improvement measures (section 6.3.3.1). Hence, the findings presented in the PWMF focus appropriately on diagnosing issues of waste generation and providing potential WM improvement measures with regard to D & B projects. Having noted that, there are several ways of improving the PWMF that have emerged from the validation process; some are quick modifications/refinement actions and could be taken in order to refine the PWMF within the current scope of the research, but others need further investigation, e.g. to make the PWMF into a commercial tool.

The validation results suggest that the PWMF has a capability to comply with different methods, tools, and standards available in the construction industry (e.g. RIBA Plan of Work, WRAP guidance documents, JCT Conditions of Contract). There is a high potential to implement the PWMF by aligning with the RIBA Plan of Work; the RIBA Plan of Work is well-known among construction industry professionals and Emmitt and Gorse (1998) concluded that WM should be seen as a continuing process at all stages. In addition, the results suggest that the PWMF could be widely applicable and relevant for current company practices.

Results of the study highlight that someone who is involved early in the project should take the responsibility of implementing the PMWF. Specifically, it should be client-led, both at the organisational level and at project team level. Therefore, this further substantiates the preceding discussion that WM should be client driven from the early stages of a project. However, it is highlighted that PWMF implementation may not be successful if the client/the client organisation does not have required WM awareness. Therefore, a client-led delegation should be responsible for PWMF implementation with a professional (i.e. project manager, procurement manager) who can bring all project stakeholders together from the early stages to completion of the project. Moreover, it is central government that could play an important role by implementing the current framework or contents of it in major public projects. Also, there is a possibility of embedding contents of PWMF when reforming future waste legislation and policies. This may help to disseminate PWMF contents to practice in the long term.

Validation results report several factors that incentivise the PWMF implementation process. Current market conditions usually demand award contracts at the lowest price. Thus, WM should be a priority for D & B contractor to get competitive advantage at tender stage; this incentivises the PWMF implementation process. Similarly, increasing legislation and policies related to construction waste and sustainable construction urge novel approaches for WM. Former and latter incentives were seen as key drivers of WM in section 3.2.4.2 and section 3.2.4.3. Moreover, the organisation structure of D & B procurement system itself facilitates the implementation of PWMF as it enables collaborative working by allowing the early involvement of the contractor.

Several challenges have been highlighted with regard to the implementation of PWMF. One of the major challenges revealed in terms of implementing PWMF is client commitment. If the client does not give priority to WM within a project, the implementation of PWMF would be problematic. Another challenge associated with PWMF implementation is to maintain the balance between generic applications (i.e. it should be able to applicable whole range of D & B projects considering variance in performance and delivery) and specific applications (i.e. directing the PWMF users on what needs to be known by developing hyperlinks between PWO and mapping the existing resources available). As noted earlier, drawing out an implementable strategy for PWMF is another challenging task (to enhance important links among issues, activities, and responsibilities of different parties, deliverables, and measureable targets). Another challenge highlighted in this regard is to demonstrate the actual benefits of using the PWMF; particularly, the way of measuring and demonstrating the cost savings originating from the implementation of the PWMF.

7.8. Summary

This chapter has presented a discussion of the emerging themes from the results of the research. The chapter has given an insight into the current practice of WM and management and CPS. Furthermore, the chapter has discussed the results which emerged regarding the relationship between CPS and construction waste generation, PWO, and the developed PWMF.

The discussion reveals that current WM and management practices are reported to have a greater focus on the post-waste generation scenario rather than the pre-waste generation scenario. It has also reported that current practices have a strong attitudinal driver to minimise waste to landfill. Also, it has suggested that WM and management practices could be expanded in order to minimise waste causes associated with design, procurement and planning stages, and sub-contractors' waste performance.

D & B system's dominant and increasing trend in use as a single procurement system in the UK has been discussed. Enhanced D & B procurement system is more popular compared to the traditional D & B procurement system as it allows clients to determine building concepts and assess budgets required before a D & B contractor is involved in the project. Also, a number of negative critiques of enhanced D & B have been discussed.

The relationship between CPS and construction waste generation has been debated. The discussion suggested that typically, the selected CPS for a project could have an impact on construction waste generation. The D & B system has shown a high potential to have an impact on minimising construction waste and particular reasons behind such impact of D & B system have been identified. Enhanced D & B practices generated more construction waste than traditional D & B. Also, key reasons behind why enhanced D & B tend to produce more waste have been presented. Integrated CPS's potential to integrate WM strategies have been discussed, highlighting key WM characteristics of integrated systems.

Four PWO have been focused on (i.e. uncoordinated early involvement of project stakeholders; Ineffective project communication and coordination; Unclear allocation of WM responsibilities; and Inconsistent procurement documents), highlighting their sub waste causes in the context of the D & B procurement system. The uncoordinated early involvement of project stakeholders found in most critical PWO in terms of waste generation severity ranking of PWO and impact of PWO on waste generation. Similarly, PWO associated improvement measures have been discussed, highlighting both common and specific measures for WM.

Subsequently, the developed PWMF has been discussed giving particular consideration to its adopted development methodology, structure, information flow, appropriateness and practicality of contents, and implementation strategy. The PWMF includes key PWO and associated sub-waste origins, target areas/parties for improvements and WM improvement measures. Several potential improvement actions with regard to the PWMF have also been identified. The next chapter presents the conclusions of the study and its recommendations.

8. Conclusions and Recommendations

8.1. Introduction

The preceding chapters presented the findings of the empirical study. This chapter focuses on drawing out general conclusions and recommendations from the findings of the study. The first section of the chapter presents how this research has achieved its established aim and objectives. The subsequent section of this chapter provides the key contribution of this research. Thereafter, the chapter discuses research limitations. Finally, the chapter presents a number of recommendations for industry, policy-makers and further research.

8.2. Achievement of the Research Aim and Objectives

The aim of the research was to develop a PWMF. In pursuing this aim, seven objectives were established. The fulfilment of each of the objectives is forwarded in the following sections.

8.2.1. Fulfilment of the First Objective

The first objective was to examine construction WM drivers, waste origins and causes of construction, and construction WM approaches. In this regard, the literature review enabled gain insights into drivers of construction WM in the UK context, identify and classify construction waste origins and review WM approaches along the lines of design (preparation/design stage), tender and contract (preconstruction stage), and construction stage. Consequently, the literature review findings in the area of construction waste clearly showed that none of the main studies had yet investigated either how waste causes are influenced by different CPS or WM approaches in the context of CPS.

8.2.2. Fulfilment of the Second Objective

The second objective was to critically review and evaluate current CPS and sustainable procurement practices in the UK. In this regard, the literature review, questionnaire survey and interviews findings enabled insights to basic forms of CPS are being used, CPS trend, procurement section factors and sustainable procurement practices in the UK construction industry. The research findings reported that both sustainability requirements and WM/management are not priority factors for CPS selection and little consideration had yet been given to evaluating different CPS in terms of their capacity for delivering sustainable construction. Findings suggested that separated CPS (i.e. traditional) could be the most problematic in terms of delivering sustainable construction while integrated and partnering CPS has a high potential for delivering sustainable construction. Results reported that traditional D & B procurement system could be having high potential to help achieve sustainable construction if compared to enhanced D & B procurement system.

8.2.3. Fulfilment of the Third Objective

The third objective was to determine the relationship between CPS and waste generation in construction. The literature review showed an emergent relationship between CPS and WM/generation whilst a thorough investigation into the impact of CPS on WM/generation was not evident. Also, a limited number of current studies showed contradictory conclusions. Findings of the literature review, questionnaire survey and interviews reported that integrated CPS have high potential for WM while separated CPS appear as the most problematic.

8.2.4. Fulfilment of the Fourth Objective

The fourth objective was to identify a common set of PWO. A sequential approach was adopted to identify the PWO (discussed in section 7.5) and their sub-waste causes. Thus, the findings of literature review (initial identification of waste causes), questionnaire survey (prioritising key causes and transforming into more reflective waste origins), interviews (refinement and sub causes identification), and framework development and validation process (refinement and validation) were contributed to fulfil this objective. Consequently, the current study discloses four PWO.

- Uncoordinated early involvement of project stakeholders
- Ineffective communication and coordination
- Unclear allocation of WM responsibilities
- Inconsistent procurement documentation

8.2.5. Fulfilment of the Fifth Objective

The fifth objective was to evaluate the procurement system with the most potential for WM against PWO and identify specific improvement measures for WM. Thus, D & B procurement system was identified as the most potential CPS for further evaluation based on the findings of preceding objectives. The interview results reported that traditional D & B system has high potential to reduce construction waste more than its enhanced D & B variant. The results also gave an account for several issues (sub-waste origins) that contribute to waste generation within D & B procurement approach along the line of four PWO and provided a number of measures to address such sub-waste origins.

8.2.6. Fulfilment of the Sixth Objective

The sixth objective was to develop a PWMF based on identified PWO and improvement measures for WM. Thus, this research has developed a PWMF for projects procured using D & B procurement system. The PWMF development process was based on the concept of problem-solving methodology and the key findings emerging from the research (a desk-based study). The proposed framework has two levels: high-level, which is generic; and detailed for four low-level components. The PWMF contents guide the user by diagnosing PWO, WM improvement measures and target areas/parties for improvements.

8.2.7. Fulfilment of the Seventh Objective

The seventh objective was to validate the developed PWMF. Thus, the validation process was aimed at determining the clarity, information flow, appropriateness of PWO and their detailed contents; appropriateness and practicability of proposed improvement measures; and to identify potential implementation strategies for the PWMF. In order to fulfil validation objectives, a combination of questionnaires (pre-validation) and interviews were undertaken. The overall feedback on validation objectives was positive, together with several suggestions for improvement to the PWMF. It has the potential to align with several methods/tools/standards available in the construction industry.

8.3. Contribution of the Research

There are several key contributions that are outcomes of this research. These outcomes have not been offered by other studies and they are presented in the following sub-sections.

8.3.1. Contribution to Theoretical Understanding: Waste Minimisation; Construction Procurement and Research Methodology

The study has gone some way towards enhancing understanding of how CPS impacts on WM/generation. The research has emphasised that the influence of selected CPS and its effects on waste origins of design, tender & contract, and construction cannot be ignored. Thus, the current study has provided a novel perspective for WM research providing directions for a holistic WM approach (i.e. consider the impact of CPS as it envelopes all stages of a project) rather than limiting the focus into single stage of a project; specifically those researching waste origins, waste causes and approaches to WM. In addition, the current findings add to a growing body of literature on WM and construction procurement to enhance sustainable construction practices.

The current findings reported implications for developing and implementing WM interventions and legislation/policies. Furthermore, the findings of the research form the basis for developing generic guidelines for transferring WM best practices directly within D & B approach and set best practice examples that can be adopted for other procurement approaches. The research findings also have implications for developing practices and guidelines to achieve sustainable procurement. The interactions of key issues emerging from the study provide important aspects that can be incorporated into standard documents in the practice (e.g. RIBA Plan of Work, JCT contract conditions).

The research has enabled insights into the subjective perceptions of professionals (i.e. procurement managers, sustainability managers and quantity surveyors) to be obtained with regard to the relationship between CPS and WM/generation, PWO and associated WM measures. Having a philosophical stance of pragmatism and by adopting a mixed-method research strategy, the current study contributes to the debate around the suitability of mixed methods research in construction management.

8.3.2. Insights into Procurement Waste Origins and Improvement Measures

Previously, very little has been known of the influence of selected CPS on different waste causes associated with design, tender and contract and construction. The current study has identified four key waste origins that could be responsible for impacting on construction waste generation due to CPS. Furthermore, the research has provided a contribution to understanding other sub-waste origins that are associated with the main PWO identified in the context of D & B procurement system. Consequently, the research has proposed several measures to eradicate identified PWO and their sub-waste causes. Thus, this potentially helps to develop the current state of WM practices as well as sustainable procurement practices.

8.3.3. Procurement Waste Minimisation Framework for D & B Procurement System

The study has presented a PWMF for projects procured using the D & B procurement system. The framework has brought research findings together and attempts to diagnose PWO (i.e. including sub-waste causes), relevant WM improvement measures and target areas/parties for improvements. This framework provides the basis for WM within D & B projects, not only to diagnose potential waste causes but also suggesting potential measures for WM. Thus, this framework contributes to literature on WM approaches.

The contents of the PWMF support the early involvement of project stakeholders, effective communication and coordination, clear allocation of WM responsibilities and enhanced procurement documentation.

8.4. Research Limitations

A number of important caveats need to be noted: Firstly, the study followed a mixed method sequential procedure. Therefore, there may be the issue of the direct effect of one method upon the other method, due the fact that the issues under investigation are being exposed to more than one method. For instance, respondents' responses to the interview questions could be influenced by their earlier participation in the questionnaire survey. The extent to which such influential issues impacted on the current study and the study's outcome is difficult to determine. Hence, it is important to note that the study's results should not be treated as a methodological effects free outcome.

Secondly, the research respondents sample was drawn from the UK's top 100 contractor practices and the UK's top 100 quantity surveyor practices. Although, the current study attempted to draw an appropriate and best possible sample for the research (as indicated in section 2.7.3, section 2.8.2, section 2.10.2.3), it would have been slightly different if it was a larger sample size and a different sample frame. However, there was a great difficulty of reaching respondents for face-to-face interviews, as the respondents' companies were located in a wide geographical area within the UK. This was a key reason for limiting the study sample (particularly for interviews) considering the availability of time and resources involved in reaching the respondents.

Thirdly, even though the study was able to reveal four common PWO, the PWMF development was limited to D & B procurement system. The measures that were taken to validate the developed PWMF have been discussed in detail in section 6.3. However, the generalisability of the developed PWMF is limited to the interview sample population and cannot be generalised to a wider population or universe. As the framework development of the research has targeted the D & B procurement system, the research findings can be generalised only to the previously mentioned population with confidence. Moreover, the study was not specifically designed to evaluate interrelationships among four PWO; instead four PWO clusters were considered and evaluated individually.

Finally, limitations originating from the nature of the questions/topic being investigated are acknowledged. There is a possibility that respondents were reluctant to disclose current practices concerning their company. Although respondents were assured that their responses would be treated confidentially and there would not be any adverse impacts on their organisation, it is difficult to assess the extent to which this was a success in gaining exact responses. Similarly, the researcher noticed that several participants were reluctant to declare a complete opinion on certain issues raised (e.g. when they were asked company specific WM and management methods, policies). Furthermore, in this regard, the research would have been even more successful, if all the participants were aware and had greater experience in aspects of both procurement and construction waste.

8.5. Recommendations

Considering the findings and conclusions of this research, a number of key recommendations can be made to industry, policy makers and further research in order to improve current practices.

8.5.1. Industry

This study reports the issue that integrated CPS provide better opportunities for WM. However, this research does not recommend clients or procurement advisors to merely select the D & B procurement system by considering the potential opportunities for waste reduction. Instead, this study suggests to consider key opportunities and improvement actions for WM when they selected D & B system as the main approach for procuring the project based on other procurement selection criteria (i.e. client requirements, client characteristics, project characteristics, and external factors). Certainly, if the project procurement selection criteria place high priority on WM, it is recommended that key findings of this study and the PWMF play a major role in procurement decision making.

This study reports that enhanced D & B procurement system could contributes to more waste generating issues (compared to traditional D & B procurement system), mainly due to lack of contractor involvement at concept design development stage and discontinuity of design responsibilities. Thus, it is recommended to ensure to gain contractor’s experience at the concept design stage either by engaging an experienced contractor on a temporary basis for the concept design development process or acquiring the services of a contractor organisation to review concept design before call for tenders.

This study emphasises the client-driven initiatives and client commitment as an essential element for WM. Client education level, awareness and negative attitudes about WM issues hinder opportunities for WM within construction projects. Therefore, a client-led delegation of WM responsibilities to other professionals is recommended. Furthermore, if there is no client-led commitment, a proactive engagement of professionals is necessary. Particularly, procurement manager /project manager should take on the main responsibility for coordinating early involvement of project stakeholders, maintaining effective communication and coordination, identifying, allocating and monitoring other stakeholders’ WM responsibilities.

WM requirements should be incorporated into project documentation at all levels: client's brief, PQQ, specifications and drawings, and tender and contract documentation. Also, the documentation process should be well coordinated throughout the project process (i.e. through WM instructions, guideline, provisions or conditions). Furthermore, this study highlighted that construction companies have given little attention to developing internal policies on sustainable procurement. Therefore, this research recommends that company policies on sustainable procurement should be strengthened and made operational within their projects.

The research recommends that procurement managers/project managers consider sustainability requirements at the project-procurement system selection stage and embed them into project management process. Furthermore, construction project teams should attempt to establish a collaborative working culture within their project/ selected procurement approach.

8.5.2. Policy Makers

This study reports that cultural issues in the construction industry have a considerable impact on waste generation (e.g. uneducated and inexperienced clients, traditional attitudes, fragmentation, and power distance). Thus, policy makers should focus on a wider cultural change in the construction industry.

Government policies and legislations relating to sustainable construction need to be further reviewed in order to encourage the early involvement of project stakeholders and make all stakeholders responsible for WM from the early stage of the project (e.g. encourage collaborative procurement approaches). Furthermore, the research reported that WM could be achieved through the collective effort of all stakeholders. As such, a positive commitment from all project stakeholders is essential to act on their specific WM responsibilities. Thus, this study recommends the establishment of a structured 'waste credit system' to assess organisational and individual WM performance for each project team member to drive collective and holistic WM agenda.

According to the present research, client commitment and client led initiatives are essential for WM. Therefore, this study recommends government to set best practice WM examples by leading from the front. Particularly, large public projects can set examples to private clients by incorporating aspects of procurement WM. Such initiatives could help to disseminate best practice to other types of clients and establish much needed cultural changes as well. It is also recommended to further improve government and institutional initiatives to enhance awareness of WM practices within construction projects and having a focus towards integrated CPS.

This study reports that actions on WM should begin at the initial project stages. As such, this study recommends that WM requirements at the early project planning and procurement stages should be clearly emphasised in new or revised environmental legislation. For example, the SWMPs Legislation as it stands requires to record the amount and type of waste produced on a construction site, how it will be reused, recycled or disposed. Therefore, the SWMPs Legislation could be extended to make a compulsory requirement to identify project specific waste origins and work out a plan to communicate how such waste origins are identified and evaluated, and associated improvement measures are put in place during the early project stages.

8.5.3. Further Research

This study reports its findings based on the subjective opinions of respondents. Consequently, the study revealed several issues that need to be further confirmed with empirical evidences. Precise waste quantification methods may be used to measure the actual waste generation levels of construction projects that are procured through different CPS. This could enable further insights about the relationship between CPS and construction waste generation.

The developed PWMF is only limited to projects that are procured using the D & B procurement approach. Therefore, current research could be extended to study other CPS in depth. Particularly, there is a high potential to focus on separated CPS as they still have a considerable share of current procurement practices and are the most problematic in terms of waste generation.

The current status of the knowledge on the issues under investigation, time limitations and resources limitations were taken into account in deciding on an appropriate research design to answer the research questions raised. Consequently, a cross sectional research was adopted for the study. The views of experienced managers are limited to three categories on the main research issues investigated. Some of the characteristics of D & B projects may change depending on several factors such as project size, complexion of stakeholders, location and project duration. Also, the findings may have different if other project stakeholders' opinions were gained. Therefore, it is recommended that future studies consider different project characteristics of D & B procurement system (e.g. project size, project duration), get totally temporary project teams involved, and use different strategies (e.g. case studies) to investigate waste origins and improvement measures.

A number of possible future studies could be recommended to improve PWMF in terms of its wider adoption. The developed PWMF does not include existing tools, techniques, guidance documents, policies and legislation that are available for WM. Thus, this study recommends the mapping of existing tools, techniques, guidance documents, policies and legislation, and incorporates them into the developed PWMF. It is also recommended to investigate deliverables related to each PWO and incorporate them into the framework as appropriate. The present study does not include a user guide. Therefore, it is suggested to devise a user guide including a glossary of terms used. Such a study will enable to the introduction of a gateway between four PWO clusters. Furthermore, based on the evidence provided in this research, further research can be focused to devise a clear implementation strategy and devise mechanism for continuous improvement for PWMF within D & B projects.

There is little evidence in the literature in terms of a comprehensive review about sustainability performances of different CPS. Although current research made an attempt to investigate whether D & B helps or hinders sustainable construction, there is a need for further research that can be undertaken in order to identify enablers and disablers that are associated with different CPS to achieve sustainable construction. Such a study would bring benefits to client and procurement managers for decision making on CPS selection.

The establishment of a collaborative working culture within temporary project procurement teams has emerged as an appropriate approach to address many issues that are responsible for waste generation. Therefore, this study recommends in-depth research to explore avenues of incorporating features that contribute towards collaborative working into the D & B procurement approach.

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Appendices

List of Publications

1. GAMAGE, I.S.W., OSMANI, M. and GLASS, J. 2007. Assessing the relationship between procurement systems and waste generation in construction. In: *EGBU, C.O., and TONG, M.K.L, Proceedings of the Third Scottish Conference for Postgraduate Researchers of the Built and Natural Environment (PRoBE*), *20-22 November 2007, Glasgow*, *UK*, Glasgow Caledonian University, pp.149-157.

2. GAMAGE, I.S.W., OSMANI, M., and GLASS, J., 2008. Research approach to investigate the relationship between waste generation and procurement systems. *In: PROVERBS, D.G., AHADZIE, D.K. and SURESH, S*., *Proceedings of the ARCOM Doctoral Workshop: Advancing Theory Development in Construction Project Management Research, 5th March 2008, Wolverhampton, UK*, Association of Researchers in Construction Management and Wolverhampton University, pp.1-7.

3. GAMAGE, I.S.W., OSMANI, M., and GLASS, J., 2009. An investigation into the impact of procurement systems on waste generation: the contractors' perspective. In: *DAINTY., A., Proceedings of 25th Annual ARCOM Conference*, *7-9 September 2009, Nottingham, UK*, Association of Researchers in Construction Management, pp.1031-1040.

4. Two research journal papers are in process based on:

    I. the combined results of questionnaire survey and semi-structured interviews (Draft) – Journal of Construction Management and Economics

    II. the design, development, and validation of the Procurement Waste Minimisation Framework for Design and Build projects.

Appendix 2.1. Respondent Sample Distribution

Respondents			Questionnaire Survey	Semi-Structured Interviews	PWMF Validation: Questionnaire & Interviews
UK Top 100 Contracting Organisations	Procurement Managers	PM1	√	x	x
		PM2	√	x	x
		PM3	√	x	x
		PM4	√	√	x
		PM5	√	x	x
		PM6	√	√	√
		PM7	√	x	x
		PM8	√	x	x
		PM9	√	√	x
		PM10	√	x	x
		PM11	√	√	x
		PM12	√	x	x
		PM13	√	√	√
		PM14	√	x	x
		PM15	√	x	x
		PM16	√	x	x
		PM17	√	x	x
		PM18	√	x	x
		PM19	√	x	x
		PM20	√	x	x
		PM21	√	x	x
		PM22	x	x	√
	Sustainability Managers	SM1	√	x	x
		SM2	√	√	x
		SM3	√	x	x
		SM4	√	x	x
		SM5	√	√	√
		SM6	√	x	x
		SM7	√	x	x
		SM8	√	√	x
		SM9	√	x	x
		SM10	√	x	x
		SM11	√	x	x
		SM12	√	x	x
		SM13	√	x	x
		SM14	√	x	x
		SM15	√	x	x
		SM16	√	x	x
		SM17	√	x	x
		SM18	√	x	x
		SM19	√	√	x
		SM20	√	x	x
		SM21	√	√	√
		SM22	√	√	x
		SM23	√	x	x
		SM24	√	x	x
		SM25	√	x	x
		SM26	√	x	x
		SM27	x	x	√

Respondents			Questionnaire Survey	Semi-Structured Interviews	PWMF Validation: Questionnaire & Interviews
UK Top 100 Quantity Surveying Organisations	Quantity Surveyors	QS1	√	x	x
		QS2	√	x	x
		QS3	√	√	x
		QS4	√	x	x
		QS5	√	√	x
		QS6	√	x	x
		QS7	√	x	x
		QS8	√	√	√
		QS9	√	x	x
		QS10	√	√	√
		QS11	√	x	x
		QS12	√	√	x
		QS13	√	√	x
		QS14	√	x	x
		QS15	√	x	x
		QS16	√	x	x
		QS17	√	x	x
		QS18	√	x	x
		QS19	√	x	x

Appendix 2.2. Questionnaire Survey Documents

Mr. Inoka Gamage
Department of Civil & Building Engineering
Loughborough University
Leicestershire
LE11 3TU.

23rd July 2008

Dear Sir/Madam

RE : Questionnaire : Procurement related Construction Waste

This questionnaire is part of a doctoral research study that sought to develop a procurement waste minimisation framework by determining the relationship between waste generation and procurement systems. Your responses are important in enabling to obtain as full an understanding of as possible of these current issues.

Increasing government environmental legislation is having a serious impact on current waste management practices in construction projects. The current approaches for waste minimisation focus on design and construction stages. However, there is a call for a holistic waste minimisation approach in the early stages of projects. Thus, this research focuses on integration of waste minimisation strategies at the early stages of project by developing a resource efficient procurement framework. An integral part of my research methodology is to capture the views on the impact of construction procurement systems on site waste. This questionnaire is destined for construction procurement managers, sustainability or environmental managers and senior quantity surveyors.

It is expected that the questionnaire should take no longer than 15-20 minutes to complete. If you would like to be sent findings of this research questionnaire please tick the relevant section at the end of the questionnaire and I will forward a summary of findings in September.

I would be very grateful if you could return the completed questionnaire using the enclosed self-addressed envelope by Friday 22nd August 2008.

Thank you in advance for your help in conducting this research and I look forward to receiving the completed questionnaire.

Please note that the information you provide will be treated in the strictly confidential and no information regarding any individual respondent or organisation will be made public. The findings of your questionnaire and others will be used as one of the main data set for my PhD degree study at the Loughborough University.

Yours Sincerely,

Inoka Gamage

Questionnaire - Procurement related Construction Waste

The aim of this questionnaire is to examine the impact of construction procurement systems on onsite waste generation.

All information provided will be treated strictly confidential and no information regarding any individual respondent or organisation will be made public.

1. Background

1.1 Please provide the following information.

Name: ....
Company: ....
Position in the company: ....
Experience in the field (Years): ....
Email address: ....
Number of employees in the company: ....

1.2 In what areas is your company active? (Please tick any that apply)

- Sectors: ☐ Public ☐ Private
- Project types: ☐ Buildings ☐ Civil Engineering
- Nature of work: ☐ New Construction ☐ Refurbishment, Repair and Renovation
- Building type: ☐ Residential ☐ Commercial ☐ Industrial ☐ Social ☐ Leisure ☐ Other, please specify ....

2. Current Sustainable Construction Practices

2.1 Does your company have any of the following policies in place? (Please tick one box per line)

- Sustainability Policy ☐ No ☐ Yes ☐ In progress
- Sustainable Construction Procurement Policy ☐ No ☐ Yes ☐ In progress
- Sustainable Waste Management Policy ☐ No ☐ Yes ☐ In progress
- Other, Please specify below
  .... ☐ Yes ☐ In progress
  .... ☐ Yes ☐ In progress

2.2 Please rate the impact of the following policies and legislation on your current waste management practices. (Please circle as follows: 1- No impact, 2- insignificant impact, 3- some impact, 4- significant impact or 5- major impact)

	No impact				Major impact
• Landfill Tax	1	2	3	4	5
• Site Waste Management Plans (SWMPs)	1	2	3	4	5
• Sustainable Construction Strategy 2008	1	2	3	4	5
• Sustainable Procurement Action Plan 2007	1	2	3	4	5
• Other, please specify below					
....	1	2	3	4	5
....	1	2	3	4	5

2.3 To what extent do you use the following strategies to manage construction waste in your projects?
(Please circle as follows: 1- Not used, 2- used in few projects, 3- used in some, 4- used in most or 5- used in all projects)

	Not used				Used in all projects
• Logistics management system (e.g. product transport, handling)	1	2	3	4	5
• Offsite construction	1	2	3	4	5
• On time delivery and bulk ordering	1	2	3	4	5
• Procurement waste minimisation guide/framework	1	2	3	4	5
• Other, please specify below					
…………………………………………………………………………	1	2	3	4	5
…………………………………………………………………………	1	2	3	4	5

3. Current Construction Procurement Practices

3.1 Who is responsible for the selection and implementation of construction procurement systems in your company (Please tick one box)

- Procurement manager ☐
- Design manager ☐
- Quantity surveyor ☐
- Commercial manager ☐
- Project manager ☐
- Other, please specify ……………………………………

3.2 How important are the following procurement criteria when selecting a procurement system for your projects? (Please circle as follows: 1– Not important, 2- insignificant, 3- some how important, 4- significant or 5- highly important)

	Not important				Highly important
• Client requirements (e.g. quality)	1	2	3	4	5
• Client characteristics (e.g. public, experienced)	1	2	3	4	5
• External factors (e.g. political, legal)	1	2	3	4	5
• Project characteristics (e.g. size, type,)	1	2	3	4	5
• Sustainability requirements (e.g. waste reduction, pollution)	1	2	3	4	5
• Other, please specify below					
……………………………………………………………..	1	2	3	4	5

3.3 In your current projects, which of the following project stakeholders are responsible for implementing waste minimisation strategies? (Please circle as follows: 1- No responsibility, 2- insignificant responsibility, 3- some responsibility, 4- significant responsibility or 5- full responsibility)

	No responsibility				Full responsibility
• Clients/client representatives	1	2	3	4	5
• Contractors	1	2	3	4	5
• Designers	1	2	3	4	5
• Government/regulatory bodies	1	2	3	4	5
• Material manufactures and suppliers	1	2	3	4	5
• None of the above (please tick the box)	☐				
• Other, please specify below					
……………………………………………………………..	1	2	3	4	5

4. Procurement Systems and Waste Generation

4.1 What is the impact of the following procurement systems selection stages on construction waste generation? (Please circle as follows: 1- No impact, 2- insignificant impact, 3- moderate impact, 4- significant impact or 5- high impact)

	No Impact				High Impact
• Appraisal	1	2	3	4	5
• Design brief	1	2	3	4	5
• Concept	1	2	3	4	5
• Design development	1	2	3	4	5
• Technical design and production information	1	2	3	4	5

4.2 I. To what extent are the following procurement systems used in your current projects?
(Please circle as follows: 1- Not used, 2- used in few projects, 3- used in some, 4- used in most or 5- used in all projects)

II. Typically, what impact does each procurement system have on construction waste generation?
(Please circle as follows: 1- No impact, 2- insignificant impact, 3- moderate impact, 4- significant impact or 5- high impact)

	I. Used Procurement Systems					**II. Waste Generation Impact**				
	Not Used				**Used in all projects**	**None**				**High**
Separated (Traditional) Systems										
• Cost reimbursable	1	2	3	4	5	1	2	3	4	5
• Lump sum	1	2	3	4	5	1	2	3	4	5
• Re measurement	1	2	3	4	5	1	2	3	4	5
• Other, please specify below										
…………………………………………	1	2	3	4	5	1	2	3	4	5
Integrated Systems										
• Design and build	1	2	3	4	5	1	2	3	4	5
• Develop and construct	1	2	3	4	5	1	2	3	4	5
• Package deal	1	2	3	4	5	1	2	3	4	5
• Private Finance Initiative (PFI)	1	2	3	4	5	1	2	3	4	5
• Turn key	1	2	3	4	5	1	2	3	4	5
• Other, please specify below										
…………………………………………	1	2	3	4	5	1	2	3	4	5
Management Oriented Systems										
• Construction management	1	2	3	4	5	1	2	3	4	5
• Design and manage	1	2	3	4	5	1	2	3	4	5
• Management contracting	1	2	3	4	5	1	2	3	4	5
• Other, please specify below										
…………………………………………	1	2	3	4	5	1	2	3	4	5

4.3 Please use the space below to add any other comments regarding the relationship between construction procurement systems and construction waste generation.
………
………
………

4.4 What effects do the following procurement related waste origins have on construction waste generation?
(Please circle as follows: 1– No effect, 2-insignificant effect, 3- moderate effect, 4- significant effect or 5- major effect)

	No effect				**Major effect**
• Communication and coordination among parties and trades	1	2	3	4	5
• Contractor involvement (i.e. early contribution to design stage)	1	2	3	4	5
• Method of tendering	1	2	3	4	5
• Procurement system process duration	1	2	3	4	5
• Allocated responsibility for decision making (i.e. design and construction)	1	2	3	4	5
• Type and form of contract	1	2	3	4	5
• Other, please specify below					
………………………………………………………………………	1	2	3	4	5
………………………………………………………………………	1	2	3	4	5

4.5 Please use the space below to add any other comments regarding the procurement related waste origins and waste generation.
………
………
………
………

5. Future Trends and Improvements

5.1 Since April 2000, the UK government has recommended that projects be procured by integrated procurement routes such as PFI, prime contracting, or design and build.

Do you think this has caused a change to the selection of procurement systems generally? (Please tick one box)

No change ☐ Insignificant change ☐ Moderate change ☐ Significant change ☐ Major change ☐

5.2 Please use the space below to add additional comments regarding the trend in construction procurement systems.

……
……
……

5.3 Based on your experience, do any of the following procurement systems have potential to integrate waste minimisation strategies? (Please circle as follows: 1 – No potential, 2-insignificant potential, 3- moderate potential, 4- significant potential or 5- major potential)

	No potential				Major potential
• Integrated systems	1	2	3	4	5
• Management oriented systems	1	2	3	4	5
• Separated (traditional) systems	1	2	3	4	5
• Other, please specify below					
……………………………………………………………	1	2	3	4	5

6. Further Comments

Please use the space below to add any other comments regarding the correlation between procurement systems and construction waste generation.

……
……
……
……
……
……
……
……

7. Further Research

Please tick as appropriate.

7.1 Would you like to receive a summary of the report findings? Yes ☐ No ☐

7.2 We will be carrying out interviews with selected respondents to discuss the questionnaire findings and best industry practice.
Would you be willing to take part in a follow-up interview? Yes ☐ No ☐

Thank you for your time and effort taken in completing this questionnaire.

Please return the questionnaire in the enclosed self-addressed envelope.

Inoka Gamage
Department of Civil and Building Engineering
Loughborough University
Leicestershire
LE11 3TU

Phone: 07912214906
Email: W.G.Inoka-Shyamal@lboro.ac.uk

Appendix 2.3. Interview Documents

Inoka Gamage
Department of Civil and Building Engineering
Loughborough University
Leicestershire
LE11 3TU

INTERVIEW SCHEDULE

Design & Build and Its Relationship with Waste Minimisation Strategies

AIM

The aim of this interview is to ask you about Design & Build related waste origins and potential waste minimisation strategies that can be integrated into a D & B approach. An approximate breakdown of the interview is shown below.

Opinions from the leading 100 UK Contractors and 100 UK Quantity Surveying firms have already been gathered through a recently conducted postal questionnaire survey. Through further detailed interviews, we hope to eventually develop a waste minimisation framework for those using D & B.

The interview should take approximately 45 minutes. All responses will remain confidential. Any information indicating your identity will be removed and will not be linked to your responses.

If you have any queries at all, please contact me at 07912214906 or by email W.G.Inoka-Shyamal@lboro.ac.uk .

AGENDA

We would like to discuss following topics during the interview:

1. Background Information
2. Sustainable Practice of Design and Build Procurement System
3. Design and Build Procurement Related Waste Origins and Suggestions to Minimise Waste
4. Further Thoughts

Please find the attached,

1. The interview schedule
2. Participant information sheet
3. Copy of the informed consent form

Section 1 Background Information

The aim of this section is to identify the respondent's background information.

1.1 How many years have you been working as a Sustainability Manager, Procurement Manager or Quantity Surveyor?

1.2 Please describe your involvement in procurement activities during your career?

1.3 Please describe your involvement in waste minimisation during your career?

1.4 What waste minimisation strategies are being used in your current projects?

Section 2 Sustainable Practices of Design and Build Procurement System

The aim of this section is to evaluate sustainable practices of Design and Build procurement system and its significance on waste generation.

2.1 Our survey suggests that D & B is dominant now, but do you think this will remain in the immediate future?

2.2 Based on your experience do you think D & B helps or hinders sustainable construction?

2.3 Our questionnaire survey revealed that D & B is the most proven procurement system in terms of the impact of waste generation (after traditional – cost reimbursement). In your experience how does D & B impact on waste? Reduce waste? or Increase waste?

Section 3 Design and Build Procurement related Waste Origins and Suggestions to Minimise Waste

The aim of this section is to evaluate D & B related waste origins and suggestions to minimise waste. The issues raised here were identified through our survey as important.

3.1

1. Why does a **lack of stakeholders' involvement in early design stage and procurement selection stage** have an impact on construction waste generation?

11. What measures would you suggest to enhance stakeholders' involvement in the early design stage and procurement selection stage?

3.2

1. Why does **poor communication and coordination among parties and trades** have an impact on construction waste generation?

11. What measures would you suggest to enhance communication and coordination among parties and trades?

3.3

1. Why does **lack of allocated responsibility for decision making (i.e. design and construction)** have an impact on construction waste generation?

11. What measures would you suggest for proper allocation of responsibility for decision making?

3.4

1. Why does **incomplete or insufficient procurement documentation** have an impact on construction waste generation?

11. What actions would you suggest for precise procurement documentation?

3.5 Are there any significant wastes that originate because of D & B being selected? (Such as lack of supervision/management in construction stage for quality of materials and workmanship, overlapping design and construction process complicate the management of design process)

3.6

1. In our questionnaire survey, 74.6% of respondents said integrated procurement systems have major potential to integrate waste minimisation strategies. In your view why do integrated procurement systems (i.e. Design & build) have such potential to integrate waste minimisation strategies?

11. If your senior management asked you to attain zero on site waste in future D & B projects, how would you react? What would you do?

Section 4 Further Thoughts

If there are any other issues which you feel are pertinent to this research please feel free to raise them now.

Thank you so much for participating in this study.

Design & Build and Its Relationship With Waste Minimisation Strategies
Participant Information Sheet

This Interview is part of a doctoral research study that sought to develop a waste minimisation framework for Design & Build (D & B) system by determining the relationship between procurement systems and on site material waste generation. Your responses are important in enabling to obtain as full an understanding of as possible of these current issues pertaining to the study.

Investigators

Research Student	Supervisor	Supervisor
Inoka Gamage	Mohamed Osmani	Jacquiline Glass
Email: W.G.Inoka-Shyamal@lboro.ac.uk	Email:	Email:
Tel : 01509 228749	Tel:	Tel:
Mob : 07912214906		

Department of Civil and Building Engineering, Loughborough University, Loughborough, Leics. LE11 3TU

Research Background and Aim

Increasing government environmental legislation is having a serious impact on current waste management practices in construction projects. The current approaches for waste minimisation focus on design and construction stages. However, there is a call for holistic waste minimisation approach in early stages of projects. This research focuses on integration of waste minimisation strategies at the early stages of project by developing a resource efficient procurement framework. An integral part of my research methodology is to capture the views on the impact of construction procurement systems on site waste. Thus, opinions from the leading 100 UK contractors and 100 UK Quantity Surveying firms have already been gathered through a recently conducted postal questionnaire survey. As a result, the aim of these in person interviews to investigate about Design & Build related waste origins and potential waste minimisation strategies that can be integrated into a D & B approach seeking to develop waste minimisation framework.

Interview

The in-person interview includes questions about the brief background of the participant, sustainable practice of D & B procurement system, D & B procurement related waste origins and suggestions to minimise D & B procurement waste origins. The interview would last approximately 45 minutes and would be arranged at a time convenient to your schedule. You may wish to consult other staff in your organization regarding any factual questions, but I would ask that any opinions expressed be your own. To ensure the accuracy of your input, I would ask your permission to audio record the interview (Recording Device: Digital Voice Recorder: Olympus VN- 2100 PC). Participation in the interview is entirely voluntary and there are no known or anticipated risks to participation in this study. You may decline to answer any of the questions you do not wish to answer.

All information you provide will be treated in the strictly confidential and no information regarding any individual respondent or organisation will be made public, and the data collected will be kept in a secure location and confidentially disposed after 5 years. Similarly, your name and the name of your organization will not appear in any thesis or publication resulting from this study. After the data have been analyzed, you will receive a copy of the summary report, only if you would be interested in greater detail. Further, after you have read this information and asked any questions you may have, I will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

If you have any questions regarding this study, or would like additional information about participation or any other, please contact me at any time or you can also contact my supervisors using aforementioned contact information.

Thank you in advance for your interest and assistance with this research.

Yours truly,

Inoka Gamage
PhD Candidate

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Design & Build and Its Relationship with Waste Minimisation Strategies

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence.

I agree to participate in this study.

Your name ______________________________

Your signature ______________________________

Signature of investigator ______________________________

Date ______________________________

Appendix 2.4. Questionnaire Survey Data: Missing Value Analysis

QUESTION 2.2

	N	Missing		No. of Extremes[b]	
		Count	Percent	Low	High
Landfill Tax	63	2	3.1	0	0
Site Waste Management Plans	63	2	3.1	0	0
Sustainable Construction Strategy 2008	61	4	6.2	.	.
Sustainable Procurement Action Plan 2007	59	6	9.2	0	2

a. . indicates that the inter-quartile range (IQR) is zero.

b. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

QUESTION 2.3

	N	Missing		No. of Extremes[a]	
		Count	Percent	Low	High
Logistics management system	60	5	7.7	0	0
Off site construction	61	4	6.2	1	0
On time delivery and bulk ordering	60	5	7.7	1	0
Procurement waste minimisation guide/framework	61	4	6.2	8	0

a. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

QUESTION 3.1

Procurement selection and implementation responsibility

N	Valid	64
	Missing	1

QUESTION 3.2

	N	Missing		No. of Extremes[a]	
		Count	Percent	Low	High
Client requirements	64	1	1.5	0	0
Client characteristics	63	2	3.1	4	0
External factors	64	1	1.5	2	0
Project characteristics	64	1	1.5	0	0
Sustainability requirements	64	1	1.5	1	0

a. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

QUESTION 3.3

	N	Missing		No. of Extremes[b]	
		Count	Percent	Low	High
Clients/client representatives	65	0	.0	0	0
Contractors	65	0	.0	3	0
Designers	65	0	.0	3	0
Government/regulatory bodies	64	1	1.5	0	2
Material manufactures and suppliers	64	1	1.5	0	0

a. . indicates that the inter-quartile range (IQR) is zero.

b. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

QUESTION 4.1

	N	Missing		No. of Extremes[a]	
		Count	Percent	Low	High
Appraisal	64	1	1.5	0	0
Design brief	64	1	1.5	2	0
Concept	64	1	1.5	3	0
Design development	64	1	1.5	0	0
Technical design and production information	64	1	1.5	0	0

a. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

QUESTION 4.2.1

	N	Missing	
		Count	Percent
Cost reimbursable	62	3	4.6
Lump sum	64	1	1.5
Re measurement	63	2	3.1
Design and build	64	1	1.5
Develop and construct	64	1	1.5
Package deal	62	3	4.6
Private Finance Initiative (PFI)	63	2	3.1
Turn key	62	3	4.6
Construction management	62	3	4.6
Design and manage	61	4	6.2
Management contracting	62	3	4.6

QUESTION 4.2.2

An influence of the responses of question 4.1.1 on 4.1.2 could be observed from the complied data analysis. In question 4.1.1, the respondents were asked to indicate the extent of the use of procurement systems in respondents' current projects whilst in 4.1.2 respondents were asked to rate 'typically' the impact of construction procurement system on waste generation (i.e. irrespective of the use in their projects).
A close observation of the data revealed that some respondents had responded to 4.1.2 in two ways: 1. not rated (i.e. Response for 4.1.1 is 'not used' then response for 4.1.2 is 'no response') 2. No impact (i.e. Response for 4.1.1 is 'not used' then response for 4.1.2. 'no impact'). The main reason could be that these respondents rated the question 4.1.2 being in an assumption that there is 'no impact on waste generation due to particular procurement system, because the particular system(s) was not in use their current projects. Therefore, these respondents cannot be disregarded as non-respondents or missing data, because they actually attempted to respond the question. Yet, the influence caused by the question 4.1.1 on question 4.1.2 has to be considered in the data analysis. Thus, such influences identified and categorised into '**Not used – no impact/no response' category (see below table). Initially, the data was analysed without the influenced data and later apportioned the influenced data category percentages based on the ratios of non-influenced data to arrive at final percentages for the question 4.1.2.
After having identified and categorised influential data, the missing data analysis indicated that 2 respondents did not answer for all sections in this question. Hence, it was decided to remove those two respondents from the 4.1.2 data analysis. Then, further analysis indicated that all items in the question have missing values which is less than 10% of the total number of respondents. Thus, it confirmed that while total sample remaining at 63, the score of no data was the appropriate index for the analysis of this question.

	N	Missing	
		Count	Percent
Cost reimbursable	62	1	1.6
Lump sum	63	0	.0
Re measurement	62	1	1.6
Design and build	62	1	1.6
Develop and construct	61	2	3.2
Package deal	60	3	4.8
Private Finance Initiative (PFI)	61	2	3.2
Turn key	59	4	6.3
Construction management	59	4	6.3
Design and manage	59	4	6.3
Management contracting	58	5	7.9

Procurement System	Respondents Views (Percentage)						
	None	**Insignificant impact**	**Moderate impact**	**Significant impact**	**High impact**	**None influenced percentage**	**Not used** – no impact/ no response**
Separated Systems							
Cost reimbursable	4.8	16.1	22.6	32.3	9.7	85.5	14.5
Lump sum	4.8	23.8	46.0	15.9	4.8	95.2	4.8
Re measurement	4.8	19.4	41.9	19.4	6.5	91.9	8.1
Integrated Systems							
Design and build	3.2	17.7	33.9	29.0	12.9	96.8	3.2
Develop and construct	3.3	14.8	36.1	18.0	6.6	78.7	21.3
Package deal	6.7	10.0	53.3	6.7	3.3	80.0	20.0
Private Finance Initiative (PFI)	6.6	11.5	39.3	9.8	6.6	73.8	26.2
Turn key	5.1	10.2	33.9	5.1	1.7	55.9	44.1
Management Oriented Systems							
Construction management	3.4	6.8	49.2	11.9	10.2	81.4	18.6
Design and manage	3.4	18.6	33.9	11.9	3.4	71.2	28.8
Management contracting	3.4	20.7	44.8	6.9	1.7	77.6	22.4

QUESTION 4.4/4.5

	N	Missing	
		Count	Percent
Communication and coordination among parties and trades	63	2	3.1
Contractor involvement (i.e. early contribution to design stage)	63	2	3.1
Method of tendering	63	2	3.1
Procurement system process duration	63	2	3.1
Allocated responsibility for decision making (i.e. design and construction)	63	2	3.1
Type and form of contract	62	3	4.6

QUESTION 5.1/5.2
There were no missing data in this question.

QUESTION 5.3

	N	Missing		No. of Extremes[a]	
		Count	Percent	Low	High
Integrated systems	63	2	3.1	0	0
Management oriented systems	63	2	3.1	0	0
Separated (traditional) systems	63	2	3.1	0	4

a. Number of cases outside the range (Q1 - 1.5*IQR, Q3 + 1.5*IQR).

Appendix 2.5. PWMF Validation Documents

Framework Validation Questionnaire:

Procurement Waste Minimisation Framework for Design and Build Projects

Aim

The aim of this validation questionnaire is to refine and validate procurement waste minimisation framework in terms of clarity, information flow and contents in terms of generic and detailed components.

The proposed framework is a part of doctoral research study that sought to develop a procurement waste minimisation framework for design and build projects

The proposed framework is based on the findings of following completed activities:

- Literature review
- Questionnaire survey: 100 top UK Contractors and 100 top UK Quantity Surveying practices
- 17 follow-up interviews with procurement managers, sustainability managers and quantity surveyors

Framework Overview

The proposed framework consists of two levels:

1. Generic framework (high level) and
2. Four detailed framework components (low level).

Four (4) key findings: Uncoordinated early involvement of project stakeholders; ineffective communication and coordination; unclear allocation of waste minimisation responsibilities; and inconsistent procurement documentation, emanating from the research, forming the basis of the framework. Each of these 4 components is separately illustrated and analysed.
The procurement waste minimisation process for both generic framework and four detailed framework components consists of two stages:

1. Diagnosis
2. Improvement measures

Thank you in advance for your help in conducting this research and I am looking forward to seeing you at the validation interview.

Please note that the information you provide will be treated strictly confidential and no information regarding any individual respondent or organisation will be made public. The findings of your questionnaire and others will be used as one of the main data set for my doctoral study at Loughborough University.

Yours sincerely,

Inoka Gamage
Department of Civil & Building Engineering
Loughborough University
Leicestershire
LE11 3TU

Framework Validation Questionnaire:

Procurement Waste Minimisation Framework for Design and Build Projects

The aim of this validation questionnaire is to refine and validate procurement waste minimisation framework in terms of clarity, information flow, and contents with regard to generic and detailed components.

All information provided will be treated strictly confidential and no information regarding any individual respondent or organisation will be made public.

Section 1 Background

1.1 Respondent (Please tick the relevant box):

Procurement Manager ☐ Sustainability Manager ☐ Quantity Surveyor ☐

1.2 Please provide your experience relevant to the following;

- Design and build projects (years) :................................
- Procurement activities (years) :................................
- Waste minimisation and management activities (years) :................................

Section 2 Generic Framework Validation

Please refer the attached framework (Page 1) to answer the following questions.

2.1 Please rate from 1 to 5 your agreement level for the following statements (Please circle following appropriately; 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree/Disagree, 4 = Agree, and 5 = Strongly Agree)

	Strongly Disagree				Strongly Agree
Clarity					
• The structure of the proposed framework is clear	1	2	3	4	5
• The content presented in the framework is familiar	1	2	3	4	5
• Clarity of procurement waste origins (A B C D) is clear	1	2	3	4	5
• Clarity of procurement waste minimisation process (1 2) is clear	1	2	3	4	5
Information flow					
• The information flow of the framework is clear	1	2	3	4	5
• The information flow of procurement waste origins (A B C D) is clear	1	2	3	4	5
• The information flow of procurement waste minimisation process (1 2) is clear	1	2	3	4	5
• The relationship between components of procurement waste origins (A B C D) and procurement waste minimisation process (1 2) is clear	1	2	3	4	5
Other (please specify below)					
....	1	2	3	4	5
....	1	2	3	4	5

1

2.2 Please rank the four procurement waste origin clusters (A B C D) in terms of waste generation severity (Please rank 1 to 4 in the relevant box below; 1 being the most severe)

- (A) Uncoordinated early involvement of project stakeholders ☐
- (B) Ineffective communication and coordination ☐
- (C) Unclear allocation of waste minimisation responsibilities ☐
- (D) Inconsistent procurement documentation ☐

Section 3 Detailed Framework Components Validation

Please refer the attached framework (Page 2, Page 3, Page 4 and Page 5) to answer the following questions.

3.1 What impact does each procurement waste origin cluster have on construction waste generation? (Please circle appropriately: Low, Medium, High)

	Waste Generation Impact		
(A) Uncoordinated early involvement of project stakeholders	**Low**	**Medium**	**High**
(B) Ineffective communication and coordination	**Low**	**Medium**	**High**
(C) Unclear allocation of waste minimisation responsibilities	**Low**	**Medium**	**High**
(D) Inconsistent procurement documentation	**Low**	**Medium**	**High**

3.2 Please rate from 1 to 5 your agreement level for the following proposed waste minimisation improvement measures (Please circle following appropriately; 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree/Disagree, 4 = Agree, and 5 = Strongly Agree)

Improvement Measures	**Strongly Disagree**				**Strongly Agree**
(A) **Early involvement of project stakeholders** (page 2)					
• Investigate methods and best practices to enhance the client's early involvement	1	2	3	4	5
• Advise the client on the benefits of waste minimisation and early involvement of contractor in the pre-tender design stage	1	2	3	4	5
• Allow sufficient time and use of efficient methods for information sharing during pre-tender design, tender and post-tender design stages	1	2	3	4	5
• Explore opportunities for pre-tender design team novation	1	2	3	4	5
• Incorporate waste minimisation requirements into the brief, tender and contract documents to enhance designers involvement	1	2	3	4	5

2

B **Better communication and coordination** (page 3)					
• Establish collaborative briefing practices and sign-off the brief	1	2	3	4	5
• Investigate best practice methods and mechanisms to establish a project communication and coordination protocol	1	2	3	4	5
• Establish a partnered working structure through organisation of procurement system	1	2	3	4	5
• Devise an interface management system and interactive working plan to work with sub-contractors	1	2	3	4	5
C **Clear allocation of waste minimisation responsibilities** (Page 4)					
• Explore best practices and waste minimisation guidelines to define and allocate responsibilities to all stakeholders and incorporate them into procurement documents	1	2	3	4	5
• Identify waste minimisation responsibilities collaboratively for all project stakeholders	1	2	3	4	5
• Explore opportunities for novation to keep design responsibilities consistent at the post tender design stage	1	2	3	4	5
• Allocate pre-tender design responsibilities to contractors through two-stage tendering process	1	2	3	4	5
• Devise clear role and responsibilities for an on-site waste manager	1	2	3	4	5
D **Improved procurement documentation** (Page 5)					
• Examine best practices, prepare feasibility studies and foster collaborative working practices to capture client's waste minimisation requirements and integrate them into the brief	1	2	3	4	5
• Devise Pre-Qualification Questionnaire in line with the client brief and integrate the waste minimisation and management criteria	1	2	3	4	5
• Review pre-tender drawings and specifications to acquire complete information before preparation of post-tender designs	1	2	3	4	5
• Investigate best practice methods and mechanisms to coordinate pre-tender design outputs and the brief	1	2	3	4	5
• Use waste minimisation best practice and optimum methods for specifications	1	2	3	4	5
• Devise tender provisions and contract conditions for waste minimisation (include measures for implementation and monitoring; penalties and rewards)	1	2	3	4	5

Section 4 Implementation Strategy

Please select the best method(s) from the following protocols/standards/tools to implement the proposed framework (please tick all that apply)

- RIBA Plan of Work Stages ☐
- ISO 14001 standard ☐
- Project management tools ☐
- Other ☐

Section 5 Further Comments

Please use the space below to add any other comments regarding the framework (i.e. improvement measures, implementation strategy)

....
....
....
....
....
....
....
....

Thank you for taking part in the framework validation process

Inoka Gamage
Department of Civil and Building Engineering
Loughborough University
Leicestershire
LE11 3TU
Phone: 07912214906
Email: W.G.Inoka-Shyamal@lboro.ac.uk

Framework Validation Interview Schedule

Procurement Waste Minimisation Framework for Design and Build Projects

AIM

The aim of this interview is to refine and examine the appropriateness of the proposed procurement waste minimisation (i.e. in terms of issues raised from the validation questionnaire such as clarity, information flow and improvement measures) and to discuss the framework implementation strategy.

The interview should take approximately 1 hour and the information expected from respondents will be used to further refine the proposed procurement waste minimisation framework for design and build projects. An approximate breakdown of the interview is shown below.

All responses will remain confidential. Any information indicating your identity will be removed and will not be linked to your responses.

Thank you in advance for your help in conducting this research and I look forward to seeing you at the validation interview.

AGENDA

We would like to discuss the following topics during the interview;

A	Generic Framework Validation	(10 minutes)
B	Detailed Framework Components Validation	(25 minutes)
C	Implementation Strategy	(20 minutes)
D	Further Thoughts	(5 minutes)
	Total	(60 minutes)

Thank you

Inoka Gamage
PhD Scholar
Department of Civil and Building Engineering
Loughborough University
Leicestershire
LE11 3TU

Please feel free to contact me should you need any further clarification:
Mobile: 07912214906 ; Email: W.G.Inoka-Shyamal@lboro.ac.uk

Section A Generic Framework Validation

A1 Based on your responses to the validation questionnaire, please comment on the following:

- Clarity of the generic framework structure
- Information flow and appropriateness of the four procurement waste origin clusters (A B C D) and their respective contents
- Appropriateness and practicality of the proposed improvement measures

Section B Detailed Framework Components Validation

B1 What are the strengths, weaknesses and suggestions (if appropriate) related to 'A' **Uncoordinated early involvement of project stakeholders** for both waste origins and proposed improvement measures?

B2 What are the strengths, weaknesses and suggestions (if appropriate) related to 'B' **Ineffective communication and coordination** for both waste origins and proposed improvement measures?

B3 What are the strengths, weaknesses and suggestions (if appropriate) related to 'C' **Unclear allocation of waste minimisation responsibilities** for both waste origins and proposed improvement measures?

B4 What are the strengths, weaknesses and suggestions (if appropriate) related to 'D' **Inconsistent procurement documentation** for both waste origins and proposed improvement measures?

Section C Implementation Strategy

C1 How can the proposed framework be implemented within design and build projects? For example,

- strategy for implementation
- appropriate/relevant methods, tools and standards
- to what level/degree should it be integrated?
- who could/should take responsibilities?
- what are the challenges?
- what are the incentives?

Section D Further Thoughts

D1 Please feel free to comment on any further issues/suggestions that are pertinent to this proposed framework.

Thank you so much for participating in this study.

Procurement Waste Minimisation High Level Framework for Design and Build Projects

Procurement Waste Minimisation Process

	Procurement Waste Origins			
	Uncoordinated Early Involvement of Project Stakeholders (A)	**Ineffective Project Communication & Coordination** (B)	**Unclear Allocation of Waste Minimisation Responsibilities** (C)	**Inconsistent Procurement Documentation** (D)
Generic Diagnosis (1)	**A.1.1** Client early involvement barriers **A.1.2** Contractor early involvement barriers **A.1.3** Designers early involvement barriers	**B.1.1** Communication and coordination between client and designers is limited **B.1.2** Communication and coordination between internal project sub teams is limited **B.1.3** Communication and coordination between contractor and designers is limited **B.1.4** Communication and coordination between contractor and sub contractors is limited	**C.1.1** Procurement manager's responsibility for allocating waste minimisation (WM) responsibilities is unclear **C.1.2** Client guidance on WM responsibilities is unclear **C.1.3** Designers WM responsibilities are unclear **C.1.4** Contractor WM and management procedure is disjointed	**D.1.1** WM requirements are not clearly stated in the brief **D.1.2** Prequalification documents are inconsistent **D.1.3** Drawings and specifications are inefficient **D.1.4** Waste minimisation requirements are not fully embedded in tender and contract documents
Target Areas/ Parties for Improvement (2)	**Early involvement of :** **A.2.1** Client **A.2.2** Contractor **A.2.3** Designers	**Better communication and coordination in all project stages between:** **B.2.1** Client and designers **B.2.2** Internal project teams **B.2.3** Contractor and designers **B.2.4** Contractor and sub contractors	**Clear allocation of responsibilities for:** **C.2.1** Procurement Manager **C.2.2** Client **C.2.3** Designers **C.2.4** Contractor	**Improved procurement documentation:** **D.2.1** Brief **D.2.2** Prequalification documents **D.2.3** Drawings and specifications **D.2.4** Tender and contract documents

Procurement Waste Minimisation Low Level Framework: Uncoordinated Early Involvement of Project Stakeholders

Uncoordinated early involvement of project stakeholders (A)

Procurement Waste Minimisation Process	Client early involvement barriers (A.1.1)	Contractor early involvement barriers (A.1.2)	Designers early involvement barriers (A.1.3)
Specific Diagnosis (1)	**A.1.1-1a** Clients usually assume that they do not need to be extensively involved during the early stages of the project **A.1.1-1b** Clients consider that WM will involve additional costs	**A.1.2-1a** Client is reluctant to appoint a contractor in pre-tender design stage **A.1.2-1b** Time scales for pre-tender design, tender and post-tender design stages are limited	**A.1.3-1a** Pre-tender design and post-tender design are discontinuous **A.1.3-1b** Design brief is incomplete and lacking clear information **A.1.3-1c** Concept designers believe that a fee should be allocated for WM
Improvement Measures (2)	**A.1.1-2a** Investigate methods to enhance client's early involvement (e.g. collaborative working practices for briefing, provide environmental wish lists to the client) **A.1.1-2b** Examine best practices and prepare feasibility studies to advise the client of financial benefits of WM	**A.1.2-2a** Advise the client on the benefits of early involvement of contractor in the pre-tender design stage (e.g. improved buildability) **A.1.2-2b** Allow sufficient time and use of Information Technology (IT) methods for information sharing during pre-tender design, tender and post-tender design stages	**A.1.3-2a** Explore opportunities for pre-tender design team novation **A.1.3-2b** Investigate methods and mechanisms to acquire adequate information for pre-tender design process (e.g. provide environmental wish lists to the client) **A.1.3-2c** Incorporate WM requirements in the brief, tender and contract documents

Procurement Waste Minimisation Low Level Framework: Ineffective Project Communication & Coordination

Procurement Waste Minimisation Process

Ineffective Project Communication & Coordination (B)

	B.1.1 Communication & coordination between client and designers is limited	B.1.2 Communication & coordination between internal project sub teams is limited	B.1.3 Communication & coordination between contractor and designers is limited	B.1.4 Communication & coordination between contractor and sub contractors is limited
Specific Diagnosis (1)	**B.1.1-1a** Client's brief requirements are unclear **B.1.1-1b** Client's responses to designers requests for additional information are slow **B.1.1-1c** Designers <—> client communication and coordination is limited due to time pressure	**B.1.2-1a** Designer <—> designer (e.g. architect and structural engineer) communication and coordination is limited due to traditional parallel working practices **B.1.2-1b** Client <—> client (e.g. NHS trust and regulatory bodies in hospital projects) communication and coordination is limited due to complex client organisation structure	**B.1.3-1a** Contractor <—> designers traditional working relationship is not effective due to cultural issues **B.1.3-1b** Contractor <—> designers communication and coordination is limited due to time pressure	**B.1.4-1a** Main contractor <—> sub-contractors communication and coordination is complex due to the large number of specialised sub contractors **B.1.4-1b** Main contractor finds it difficult to work with sub-contractors that are nominated by the client **B.1.4-1c** Main contractor <—> sub-contractors communication and coordination is limited due to time pressure
Improvement Measures (2)	**B.1.1-2a** Establish a collaborative approach to capture client requirements and sign-off the brief **B.1.1-2b** Establish an efficient communication protocol between designers and the client based on best practice methods and mechanisms (e.g. IT & virtual reality) to speedup the client's feedback **B.1.1-2c** Allow enough time to adequately complete the design documents	**B.1.2-2a** Investigate best practice methods for design coordination and management (e.g. IT based databases/ intranets) **B.1.2-2b** Set up collaborative briefing practices between various client's stakeholders at the beginning of the project and sign-off the brief	**B.1.3-2a** Establish a partnered working structure through organisation of procurement system **B.1.3-2b** Investigate best practice methods and mechanisms for communication and coordination between contractor and designers (e.g. IT databases/ intranets)	**B.1.4-2a** Devise an interface management system by clustering similar sub-contractors **B.1.4-2b** Set up an interactive working plan to work with client nominated sub-contractors (e.g. include collaborative meetings, workshops) **B.1.4-2c** Investigate best practices and mechanisms for communication and coordination between main contractor and sub-contractors (e.g. IT data bases/intranets)

Procurement Waste Minimisation Low Level Framework: Unclear Allocation of Waste Minimisation Responsibilities

Unclear Allocation of Waste Minimisation Responsibilities (C)

Procurement Waste Minimisation Process

	C.1.1	C.1.2	C.1.3	C.1.4
	Procurement manager's responsibility for allocating waste minimisation responsibilities is unclear	**Client guidance on waste minimisation responsibilities is unclear**	**Designers waste minimisation responsibilities are unclear**	**Contractor waste minimisation and management procedure is disjointed**
Specific Diagnosis (1)	**C.1.1-1a** Procurement Manager (PM) does not clearly define and allocate other stakeholders' responsibilities at procurement selection stage **C.1.1-1b** PM does not advise and inform the client on WM benefits at the procurement selection stage	**C.1.2-1a** Client does not include clear WM responsibilities in project brief **C.1.2-1b** Mechanisms for specification and allocation of WM responsibilities are unclear	**C.1.3-1a** Designers' responsibilities between pre-tender design and post-tender design include gaps and overlaps **C.1.3-1b** Designers view WM as the contractor's responsibility	**C.1.4-1a** Contractor has less influence on allocating WM responsibilities during pre-tender design stage **C.1.4-1b** Contractor fails to appoint a waste manager dedicated to on-site WM and management **C.1.4-1c** Contractor fails to forward WM instructions to sub-contractors
Improvement Measures (2)	**C.1.1-2a** Explore best practices and WM guidelines to define and allocate responsibilities to all stakeholders at the procurement selection stage **C.1.1-2b** Investigate WM best practices to guide clients on WM benefits at the procurement selection stage	**C.1.2-2a** Identify WM responsibilities collaboratively for all project stakeholders and update project brief accordingly **C.1.2-2b** Explore best practices and WM guidelines to specify and allocate WM responsibilities	**C.1.3-2a** Define designers' responsibilities and embed them into tender and contract documents/ explore opportunities for novation to keep the same design responsibilities at the post-tender design stage **C.1.3-2b** Embed designers' WM responsibilities into procurement documents	**C.1.4-2a** Allocate pre-tender design responsibilities to contractors through two-stage tendering process **C.1.4-2b** Devise clear role and responsibilities for an on-site waste manager **C.1.4-2c** Devise clear sub-contractors WM responsibilities; include in guidance and/or contractual provisions

Procurement Waste Minimisation Low Level Framework: Inconsistent Procurement Documentation

Inconsistent Procurement Documentation (D)

Procurement Waste Minimisation Process	Waste minimisation requirements are not clearly stated in the brief (D.1.1)	Prequalification documents are inconsistent (D.1.2)	Drawings and specifications are inefficient (D.1.3)	Waste minimisation requirements are not fully embedded in tender and contract documents (D.1.4)
Specific Diagnosis (1)	**D.1.1-1a** Client's unawareness of WM benefits **D.1.1-1b** WM requirements are not clearly stated in the brief	**D.1.2-1a** Waste minimisation and management requirements are not clearly stated in Pre Qualification Questionnaire (PQQ) **D.1.2-1b** PQQ is not clearly linked with the brief	**D.1.3-1a** Pre-tender concept drawings are incomplete and specifications are inadequate **D.1.3-1b** Pre-tender design outputs and brief are poorly coordinated **D.1.3-1c** WM requirements are not embedded in specifications	**D.1.4-1a** WM is not part of tender provisions and contract conditions **D.1.4-1b** On-site measures for implementing and monitoring WM are not clearly stated in both tender provisions and contract conditions **D.1.4-1c** Incentives and penalties for WM performances are not adequately incorporated in both tender provisions and contract conditions
Improvement Measures (2)	**D.1.1-2a** Foster collaborative working practices to capture client's requirements **D.1.1-2b** Examine best practices and prepare feasibility studies to capture client's WM requirements and integrate them into the brief	**D.1.2-2a** Develop PQQ by integrating the WM and management criteria **D.1.2-2b** Devise PQQ in line with the brief WM requirements	**D.1.3-2a** Review pre-tender drawings and specifications to acquire complete information before preparation of post-tender designs (e.g. collaborative meeting) **D.1.3-2b** Investigate best practice methods and mechanisms to coordinate pre-tender design outputs and the brief (e.g. IT & virtual reality) **D.1.3-2c** Use WM best practice and optimum methods for specifications (e.g. prefabricated components)	**D.1.4-2a** Devise tender provisions and contract conditions for WM **D.1.4-2b** Integrate WM onsite measures for implementation and monitoring in both tender provisions and contract conditions to comply with waste legislation(e.g. SWMPs) **D.1.4-2c** Devise model clauses to introduce incentives and penalties into tender provisions and contract conditions

Framework Validation Interview

Procurement Waste Minimisation Framework for Design and Build Projects

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence.

I agree to participate in this study.

Your name ______________________________

Your signature ______________________________

Signature of investigator ______________________________

Date ______________________________

Appendix 4.1. Kruskal Wallis H Test – Mean Rank Tables

Impact of Policies and Legislation on Current Waste Management Practices				
	Respondent category	N	Mean Rank	Asymp. Sig.
Landfill Tax	Procurement Managers	21	40.69	.006
	Sustainability Managers	25	31.18	
	Quantity Surveyors	17	22.47	
	Total	63		
Site Waste Management Plans	Procurement Managers	21	37.64	.001
	Sustainability Managers	25	36.22	
	Quantity Surveyors	17	18.82	
	Total	63		
Sustainable Construction Strategy 2008	Procurement Managers	21	34.62	.004
	Sustainability Managers	25	35.26	
	Quantity Surveyors	15	18.83	
	Total	61		
Sustainable Procurement Action Plan 2007	Procurement Managers	21	32.57	.040
	Sustainability Managers	24	33.21	
	Quantity Surveyors	14	20.64	
	Total	59		

Current Use of Different Strategies to Manage Construction Waste				
	Respondent category	N	Mean Rank	Asymp. Sig.
Logistics Management system	Procurement Managers	21	38.24	.001
	Sustainability Managers	25	31.78	
	Quantity Surveyors	14	16.61	
	Total	60		
Off site construction	Procurement Managers	21	33.29	.687
	Sustainability Managers	25	29.54	
	Quantity Surveyors	15	30.23	
	Total	61		
On time delivery and bulk ordering	Procurement Managers	21	35.29	.190
	Sustainability Managers	25	29.32	
	Quantity Surveyors	14	25.43	
	Total	60		
Procurement waste minimisation framework	Procurement Managers	21	32.95	.778
	Sustainability Managers	25	30.56	
	Quantity Surveyors	15	29.00	
	Total	61		

Procurement selection criteria				
	Respondent category	N	Mean Rank	Asymp. Sig.
Client Requirements	Procurement Managers	21	29.50	.109
	Sustainability Managers	24	30.00	
	Quantity Surveyors	19	38.97	
	Total	64		
Client Characteristics	Procurement Managers	21	26.33	.165
	Sustainability Managers	24	33.48	
	Quantity Surveyors	18	36.64	
	Total	63		
External Factors	Procurement Managers	21	26.02	.099
	Sustainability Managers	24	33.98	
	Quantity Surveyors	19	37.79	
	Total	64		
Project Characteristics	Procurement Managers	21	34.36	.117
	Sustainability Managers	24	27.00	
	Quantity Surveyors	19	37.39	
	Total	64		
Sustainability Requirements	Procurement Managers	21	37.14	.037
	Sustainability Managers	24	35.08	
	Quantity Surveyors	19	24.11	
	Total	64		

Project Stakeholders' Responsibility for Implementing Waste Management Strategies				
	Respondent category	N	Mean Rank	Asymp. Sig.
Clients/Client representatives	Procurement Managers	21	32.74	.821
	Sustainability Managers	25	31.66	
	Quantity Surveyors	19	35.05	
	Total	65		
Contractors	Procurement Managers	21	37.48	.346
	Sustainability Managers	25	30.86	
	Quantity Surveyors	19	30.87	
	Total	65		
Designers	Procurement Managers	21	30.62	.661
	Sustainability Managers	25	35.34	
	Quantity Surveyors	19	32.55	
	Total	65		
Government and Regulatory bodies	Procurement Managers	21	36.81	.284
	Sustainability Managers	25	32.14	
	Quantity Surveyors	18	27.97	
	Total	64		
Material manufacturers and suppliers	Procurement Managers	21	38.24	.081
	Sustainability Managers	25	32.62	
	Quantity Surveyors	18	25.64	
	Total	64		

Impact of Procurement selection Stage on Construction Waste Generation				
	Respondent category	N	Mean Rank	Asymp. Sig.
Appraisal	Procurement Managers	20	33.48	.285
	Sustainability Managers	25	35.66	
	Quantity Surveyors	19	27.32	
	Total	64		
Design brief	Procurement Managers	20	34.15	.106
	Sustainability Managers	25	36.56	
	Quantity Surveyors	19	25.42	
	Total	64		
Concept	Procurement Managers	20	32.22	.099
	Sustainability Managers	25	37.62	
	Quantity Surveyors	19	26.05	
	Total	64		
Design Development	Procurement Managers	20	37.30	.294
	Sustainability Managers	25	30.56	
	Quantity Surveyors	19	30.00	
	Total	64		
Technical design and Production Information	Procurement Managers	20	36.38	.488
	Sustainability Managers	25	30.94	
	Quantity Surveyors	19	30.47	
	Total	64		

Effect of Procurement Waste Origins on Construction Waste Generation				
	Respondent category	N	Mean Rank	Asymp. Sig.
Communication and coordination among parties and trades	Procurement Managers	21	36.71	.009
	Sustainability Managers	25	34.06	
	Quantity Surveyors	16	20.66	
	Total	62		
Contractor involvement	Procurement Managers	21	35.83	.110
	Sustainability Managers	25	32.38	
	Quantity Surveyors	16	24.44	
	Total	62		
Method of tendering	Procurement Managers	21	32.31	.087
	Sustainability Managers	25	35.84	
	Quantity Surveyors	16	23.66	
	Total	62		
Procurement system process duration	Procurement Managers	21	35.38	.054
	Sustainability Managers	25	33.90	
	Quantity Surveyors	16	22.66	
	Total	62		
Allocated responsibility for decision making	Procurement Managers	21	34.12	.114
	Sustainability Managers	25	33.84	
	Quantity Surveyors	16	24.41	
	Total	62		
Type and form of contract	Procurement Managers	21	29.48	.423
	Sustainability Managers	25	35.00	
	Quantity Surveyors	16	28.69	
	Total	62		

Construction Procurement Trend				
	Respondent category	N	Mean Rank	Asymp. Sig.
Construction Procurement Trend	Procurement Managers	21	37.19	.402
	Sustainability Managers	25	31.04	
	Quantity Surveyors	19	30.95	
	Total	65		

Potential Construction Procurement Systems to Integrate Waste Minimisation Strategies				
	Respondent category	N	Mean Rank	Asymp. Sig.
Integrated systems	Procurement Managers	21	36.00	.398
	Sustainability Managers	25	30.66	
	Quantity Surveyors	17	29.03	
	Total	63		
Management Oriented	Procurement Managers	21	29.07	.471
	Sustainability Managers	25	31.76	
	Quantity Surveyors	17	35.97	
	Total	63		
Traditional	Procurement Managers	21	30.00	.797
	Sustainability Managers	25	33.18	
	Quantity Surveyors	17	32.74	
	Total	63		

Appendix 4.2. Internal Reliability: Cronbach's Alpha Values

QUESTION 2.2

Case Processing Summary

		N	%
Cases	Valid	59	90.8
	Excluded[a]	6	9.2
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.786	4

QUESTION 2.3

Case Processing Summary

		N	%
Cases	Valid	60	92.3
	Excluded[a]	5	7.7
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.686	4

QUESTION 3.2

Case Processing Summary

		N	%
Cases	Valid	63	96.9
	Excluded[a]	2	3.1
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.237	5

QUESTION 3.3

Case Processing Summary

		N	%
Cases	Valid	64	98.5
	Excluded[a]	1	1.5
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.253	5

QUESTION 4.1

Case Processing Summary

		N	%
Cases	Valid	64	98.5
	Excluded[a]	1	1.5
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.704	5

QUESTION 4.2.1

Case Processing Summary

		N	%
Cases	Valid	59	90.8
	Excluded[a]	6	9.2
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.674	11

QUESTION 4.2.2

Case Processing Summary

		N	%
Cases	Valid	56	86.2
	Excluded[a]	9	13.8
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.883	11

QUESTION 4.4

Case Processing Summary

		N	%
Cases	Valid	62	95.4
	Excluded[a]	3	4.6
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.777	6

QUESTION 5.3

Case Processing Summary

		N	%
Cases	Valid	63	96.9
	Excluded[a]	2	3.1
	Total	65	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.460	3

Appendix 5.1. Interviewee Profile and Background Information

Respondents Profession (Procurement Managers)	Experience in the Construction Industry	Career (Key Involvements)		
		Professional Career	**Procurement activities**	**Waste Management and Minimisation**
PM13	30	Quantity surveyor(18 years); Design manager or coordinator (10 years); Group strategic procurement and business improvement manager (2 year - up to now)	Involved in most of the procurement systems in practice - career experience all related to design and build projects	Looking at the waste strategic levels: reduce waste both design and construction by looking at the commercial side of the waste. Attempts to reduce waste at tender stage makes more competitive and waste reduction at construction stage to maximise the profit
PM9	41	Quantity surveyor(26 years); Post contract and procurement manager (15 years)	Involved in all major procurement systems. Post contract work- procuring sub-contract work	Follow the main contractor's waste management guidelines and polices; and attempts to comply with any legislations in place
PM11	25	Engineer (2 years); Quantity surveyor and Post contract manager (23 years)	Involved from the beginning to the end for most procurement systems: identification of tender packages, documentation process and selection of the best contractor	Procure overall logistics package for contract - waste management is a part of logistics work package
PM6	35	Engineer (6 years); Project manager /Contracts manager (14 years). Procurement and Quality manager-Associate director (10 year)	Managing contracts; in charge for procurement of all materials from the view of ensuring what stated in specifications and what is required before the job	Responsible for waste minimisation plans, waste management plans, and Environment management aspects in company level
PM4	31	Quantity surveyor (28 years); Commercial director (3 years)	Procuring sub-contractors, external design consultants, including design and build contracts PFI, non-traditional and traditional	Encourage design supply chain consultants to design waste out. Direct supply chain minimise waste, more alone lines of logistics sub-contractors.

Respondents Profession (Sustainability Managers)	Experience in the Construction Industry	Career (Key Involvements)		
		Professional Career	**Procurement activities**	**Waste Management and Minimisation**
SM19	27	Procurement manager (15 years); Quality manager (8 years); Environmental & sustainability manager (4 years)	Directly involved /assist with procurement related to sustainable issues. Management contracting - Procurement of trade contractors. Involved in projects that followed different procurement routes	Implement company's sustainability agenda – Involved in waste minimisation and reuse, recycling activities. Assist project with design of certain comments; choice of materials; help to supply chain management
SM2	18	Environment, safety, Quality manager (8 years); Sustainability manager (10 years)	Sub-contractor and material procurement; design and build	Looks at best practices: methods to minimise waste; environmental impacts of the recycling process, segregation, and on site activities. Interpret legislation and policies related to waste and environment and make sure company procedures are in place to incorporate them
SM22	11	Site Manager/Contract manager (7 years) ; Sustainability manager (4 years)	Site manager – procurement of sub-contractors; contract management; involved in different types of projects procurement systems	Waste segregation activities, monitor and report performances. Development of sustainable construction practices with in company. SWMP template preparation and incorporate regulations requirements in to company policies
SM21	33	Procurement manager (30 years); Sustainability manager (3 years)	Project Procurement activities over 30 years – involved in various procurement systems, procurement of sub-contractors and materials.	Advisory role; site waste management – measure and analyse. Improve company waste measurement data base. Working with waste disposal and management companies
SM6	8	Environmental - Sustainability Manager (8 years)	Design and build, PFI, working with supply chain	Advisory role in terms of waste minimisation and management.
SM8	18	Design Manager and Sustainability and technical services director (18 years)	Academic work related to supply chain integration and procurement selection; work experiences with design consultants	Off-site manufacturing; standardisation of building components.

Respondents Profession (Quantity Surveyors)	Experience in the Construction Industry	Career (Key Involvements)		
		Professional Career	**Procurement activities**	**Waste Management and Minimisation**
QS5	30	Private Quantity Surveyor (PQS); Construction Design Management (CDM) coordination	Involved in tendering and negotiation process; selection, payments of subcontractors and suppliers on behalf of clients. Experienced with traditional competitive tendering, two stage tendering, negotiated, lump sum, drawing and spec, bills of quantitative, cost plus, design and build - wide range of procurement options	Specifically building in to particular requirements in to the tender documents from clients. Prepare tender documents and incorporate clients various standards, different yard sticks - eco home - sustainable homes and specific requirements.
QS8	8	Quantity Surveyor; Cost manager	Project procurement works; Procurement of sub-contract works, tender documentation and its process, Contract administration, selection of tenders	Very little; include waste minimisation /management requirements to tender documents along with HSQE
QS3	29	Quantity Surveyor	Traditional procurement routes and design and build procurement routes, planned-cost procurement, and management-contracted-type procurement routes, and various hybrids of those, guaranteed maximum price procurement routes, PFI variants	Don't get involved in waste minimisation a great deal. I mean we don't prescribe enough details about waste minimisation or management should be achieved.
QS13	20	Private Quantity Surveyor - different levels - Construction management - Director	Throughout the project process – Experienced in traditional procurement – Integrated systems: majority of design and build systems & design and development	Involvement really led by BREAM ratings and sustainable targets. BREAM is the main one. Depends on the client - SWMP try to incorporate clients requirements to our standard documents.
QS12	15	Quantity surveyor	Virtually experienced with every procurement method in practice: conventional, design and build, management contracting partnering two stage approach	Include waste and sustainable requirements in procurement documents as appropriately - depending on what the client wants to achieve. Evaluate tender sections related to waste, environment and sustainability.
QS10	Over 20	Contractors quantity surveyor; PQS - Client organisation	Procurement of trade and sub-contractors packages, procurement of major projects - basically all major procurement options; commercial management	Site waste reconciliation, design for manufacture - design re-engineering - Producing site waste management plans - pre demolition audits – company sustainability policies