INTERFACE MANAGEMENT OF OFFSITE BATHROOM CONSTRUCTION: PROCESS AND PEOPLE FACTORS

by

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Abstract

Interface management (IM) in its many forms (physical, contractual and organisational) has not received the management research it warrants in the construction sector. Offsite bathroom construction is seen as a sector of offsite construction that can aid the interface problems that are common in construction. However, interface problems that occur when using offsite bathrooms are considered to be as detrimental, if not more to the overall process when compared to traditional bathroom construction. This research will focus on organisational IM, through research into the relevant process and people factors required to mitigate potential IM problems in the offsite bathroom process.

A literature review of IM, offsite construction and traditional construction was conducted which identified 16 factors that could have an influence on the organisational IM of offsite bathroom construction. A further literature review was carried out for each factor to establish its connectivity to the holistic process of the IM of offsite bathrooms. A proforma was constructed which gathered quantitative and qualitative data from 82 interviewees, associated with eight case study projects. The methodology adopted was based on the pragmatism philosophical stance, which concurs with a mixed method approach to the collection and analysis of the data. The quantitative data was analysed using frequency tables and the Wilcoxon sign rank test. The quantitative data was analysed using thematic analysis.

The analysis identified nine of the 16 factors as main contributors to the IM of offsite bathroom construction. These nine factors consisted of six process factors: procurement, design management, supply chain management, health and safety, tolerance and quality. Three people factors were: communication, client/design team and the role of the project manager. A conceptual model was constructed to encapsulate each of the nine factors and their sub-factors. Important findings from the research identified the procurement route as both an enabler and a constraint, depending on its ability to allow early input from the main contractor and manufacturer to the uptake of offsite bathrooms. The cross-cutting importance of

the people factors to the successful implementation of the process factors identified the importance of the main contractor maintaining supervision of the manufacturer and the interface problems created from incomplete design. Further analyses of all the findings identified communication and the role of the project manager as the two most influential factors, with early and informal communication and strong leadership from the project manager relevant to all factors that affect the successful IM of offsite bathroom construction.

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Abbreviations

Accom	Accommodation
BOT	Build-Operate-Transfer
BRE	Building Research Establishment
CAD	Computer Aided Design
CBGPM	China's BOT Generic Process Model
CIOB	Chartered Institute of Building
CIRIA	Construction Industry Research and Information Association
D&B	Design and Build
GRP	Glass Reinforced Polyester
H&S	Health and Safety
IM	Interface Management
LCC	Life Cycle Costing
M&E	Mechanical and Electrical
MA	Military Accommodation
NBO	New Build Office
NBP	New Build Prison
NBSA	New Build Student Accommodation
PFI	Private Finance Initiative
PM	Project Manager
PPP	Public-Private Partnership
QA	Quality Assured
RH	Refurbishment Hotel
RIBA	Royal Institute of British Architects
SCM	Supply Chain Management
WLC	Whole Life Costing

Chapter 1 – Introduction

1.1 Introduction

This chapter will introduce the research in the form of a rationale. The research questions, aim and objectives will be stated to give boundaries to the extent of the research. An outline methodology will give a summary of the research methods chosen, including data collection and analysis. The contribution to knowledge of the thesis will be stated and a layout of the thesis will provide a summary of the content of the chapters.

1.2 Rationale for Research

The recent *Farmer Review* acknowledged that a high level of fragmentation and complexity currently resides within the UK construction industry and that a more modern approach that embraces offsite construction would contribute to the wellbeing of the industry (Farmer, 2016). The increased fragmentation within the construction process has led to interface management (IM) emerging as an important theme, worthy of more in-depth research than has been currently carried out within the discipline of construction project management (Fellows and Liu, 2012). Gibb (1999) argues that IM encompasses three distinct forms: physical interface, contractual interface, and organisational interface. This research will focus on organisational interface.

Offsite bathroom construction is considered to generate less interface problems in comparison to traditional bathroom construction (Blismas et al., 2006; Blismas and Wakefield, 2009; Kamali and Hewage, 2017). However, the impact of interface problems within the offsite bathroom process is also considered a constraint to the uptake of offsite bathrooms (Blismas et al., 2005; Rahman, 2014). Little to no significant research has been identified, which explores the holistic relationship of IM to offsite bathroom construction. Taylor (2009) argues that complex interfaces reside within offsite bathroom construction and that research in this area could turn a partial constraint wholly to a benefit.

Elnaas et al., (2014)argue that IM is an area of research that the construction industry can no longer afford to ignore in respect to offsite construction and offsite bathroom construction in particular. A review of literature will identify and justify the process and people factors that influence the organisational IM of offsite bathrooms, data will be collected and analysed. Culminating in the formation of a conceptual model to aid the effective management of offsite bathroom construction.

1.3 Purpose of the Research

As previously mentioned the process of construction has become increasingly complex and fragmented, such that the management of interfaces has become a major issue, which can affect the success of a project. This thesis will focus on a holistic approach to the IM of the offsite bathroom construction process, from design through to installation onsite. The synthesis of the literature identified nine process factors: procurement, supply chain management, whole life costing, health and safety, design management, lean construction, sustainability, tolerance, and quality. Seven people factors were also identified for study: communication, role of the project manager, culture, client and design team, perception, integration, and leadership. Their significance to the IM of offsite bathroom construction will be determined, which it is anticipated will contribute to the industry acknowledging the importance of the interface process, and understanding better its impact upon the overall process.

1.4 Primary Research Question

The literature review of the three main areas of traditional construction, offsite construction and IM led to the realisation that no substantive research had been carried out to answer the following research question:

What is the relationship between offsite construction and IM in the context of offsite bathroom installation?

1.4.1 Secondary Research Questions

To aid the realisation of the primary research question, it was considered prudent to include the following secondary research questions that would identify the 'What and How', the process and people factors which would influence the relationship of offsite construction and IM *What are the main process and people factors that significantly influence the IM of the manufacture and onsite installation of offsite bathrooms?*

How do process and people factors affect the relationship between offsite and IM?

1.5 Aim and Objectives

The above research questions and an initial review of the literature were fundamental in determining the aim of the research as follows:

To identify and understand the interconnectivity between the main process and people factors that influence IM in relation to the offsite manufacture and onsite installation of bathrooms in construction.

In order to achieve the aim, the following objectives were identified through the literature review as the building blocks that would lead to a realisation of the aim:

1. To determine and critically review the process and people factors that relate to the management of interfaces, focusing on offsite bathroom construction
2. To evaluate the interrelationships and interdependencies that result from the design, manufacture and construction of offsite bathrooms
3. To establish existing industry practices, in relation to IM, around the process and people factors which affect the offsite manufacture and onsite installation of offsite bathroom construction
4. To identify key problems and solutions for offsite bathroom construction

5. To develop, test and validate a conceptual model to better understand the IM of the manufacture and onsite installation of offsite bathrooms.

Table 1.1: Relationship of aim, objectives and research questions

<table>
<tr><th>Aim</th><th>Objectives</th><th>Research Questions</th></tr>
<tr><td rowspan="5">To identify and understand the interconnectivity between the main process and people factors that influence IM in relation to the offsite manufacture and onsite installation of bathrooms in construction.</td><td>To determine and critically review the process and people factors that relate to the management of interfaces, focusing on offsite bathroom construction.
(Objective 1)</td><td>What are the main process and people factors that significantly influence the IM of the manufacture and onsite installation of offsite bathrooms? (RQ1.1)</td></tr>
<tr><td>To evaluate the interrelationships and interdependencies that result from the design, manufacture and construction of offsite bathrooms. (Objective 2)</td><td>How do process and people factors affect the relationship between offsite and IM? (RQ1.2)</td></tr>
<tr><td>To establish existing industry practices, in relation to IM, around the process and people factors which affect the offsite manufacture and onsite installation of offsite bathroom construction.
(Objective 3)</td><td rowspan="3">What is the relationship between offsite construction and IM in the context of offsite bathroom installation? (RQ1)</td></tr>
<tr><td>To identify key problems and solutions for offsite bathrooms construction. (Objective 4)</td></tr>
<tr><td>To develop test and validate a conceptual model to better understand the IM of the manufacture and onsite installation of offsite bathrooms.
(Objective 5)</td></tr>
</table>

1.6 Outline Methodology

Fellows and Liu (2015) argue that research should start from a theoretical basis; the theory adopted for this research will focus on organisational theory. Naoum (2013) endorses the view that it is essential to have a thorough knowledge of what has been written about a research topic, prior to embarking on the search for data. The literature review consisted predominately of peer reviewed journal papers, conference papers, reports and books, accessed via the library at Glasgow Caledonian University (a more detailed account of the literature search is available in 4.6).

Saunders et al.'s (2016) research onion framework was used to identify options available and to justify the appropriate choice at the various stages of the methodology. Silverman (2013) argues that there is no right or wrong methodology. However, it is important that the method or methods chosen are compatible with the research objectives and questions. The philosophical stance of pragmatism was adopted, which is aligned to the mixed methods approach used to collect and analyse data.. Creswell (2014) acknowledges that more than one method is acceptable for answering research questions and objectives.

The strategy used to collect data was to identify case studies that incorporated an offsite form of bathroom construction into the project. Eight construction projects, which fell within the following five categories, were used:

1. New build student accommodation (projects A, B and C)
2. Refurbished hotels (projects D and E)
3. New build prison (project F)
4. New build office (project G)
5. Military accommodation (project H)

The case study method allowed data to be gathered. A pro forma (see appendix A) was designed to incorporate the collection of both quantitative and qualitative data related to the 16 factors. The Likert scale was used to elicit quantitative data, while additional comments from and appropriate probing of interviewees provided qualitative data. The analysis of the pilot study interviews identified the people factor of 'Leadership' as being inherent in the people factor 'the role of the project manager' thus leadership was removed, this reduced the number of factors to 15. Eighty-two 'face to face' semi-structured interviews were carried out with a range of trade and professional disciplines from the eight projects. The quantitative data were analysed using the Minitab program package, using the Wilcoxon signed rank test for non-parametric testing. The richness of the qualitative data was analysed manually by the researcher, aided by Microsoft Excel using thematic analysis to identify sub-factors relevant to the main factors.

Three supplementary questions allowed the interviewees to rank their top five factors in order of preference relative to each of the three questions. A cumulative ranking table was devised to score each of the 15 factors in ranked order. An analysis of the scores resulted in nine factors being included for full analysis and the remaining six not being studied further. The top two or three sub-factors applicable to each statement relating to the nine factors were further scrutinised, to identify emerging findings.

1.7 Contribution to Knowledge

Research into IM within the construction management community is relatively sparse. Similarly, research into offsite construction has been relatively sparse up until the past ten years, which has seen a slight increase. However, it is considered that very little research has reviewed the relationship of IM to offsite forms of bathroom construction and the main contribution offered from this thesis will be such a review. The conceptual model in Chapter 6 (Figure 6.10) relates IM to offsite bathroom construction by annotating the main process and people factors and their sub-factors that have been identified through the research process. A fuller account of the research's contribution to knowledge will be discussed in the concluding chapter.

1.8 Structure of Thesis

This thesis is organised into seven chapters. Figure 1.1 presents a diagrammatic model of the thesis, illustrating the interrelationship and flow of the chapters. A brief summary of each chapter follows.

Chapter 1 introduces the content of the thesis, starting with a rationale of the subject matter and the main areas of the research. The research questions, aim and objectives are stated, and an outline of the research methodology is presented.

Chapter 2 is the first of two literature review chapters. The main focus of this chapter is a review of traditional construction, offsite construction and IM, to determine and justify the study of the main process and people factors that are deemed to influence the IM of offsite construction, with a particular focus on offsite bathroom construction.

Chapter 3 entails a literature review of each process and people factor identified in Chapter 2, with a particular focus on their relationship to offsite construction and IM. The process factors are: procurement, design management, supply chain management, whole life costing, health and safety, sustainability, lean construction, quality and tolerance. The people factors are: communication, client and design team, role of the project manager, leadership, integration, culture and perception.

Chapter 4 discusses research methodology and justifies the various methods used. A philosophical stance of pragmatism led to a mixed method approach to collecting data from eight case study projects. Each case study was selected due to the inclusion of a form of offsite bathroom construction. An ethical approach was adopted for carrying out and analysing the semi-structured interviews. The design of the pro forma used to carry out the interviews is also discussed.

Chapter 5 presents the data analysis of 82 interviews from the case study projects which are further divided into five classifications of project types. A ranking process resulted in nine factors being included for full analysis. The quantitative data are analysed using the Wilcoxon signed rank test and the qualitative data are analysed using thematic analysis. The main findings resulting from the analysis are identified.

Chapter 6 discusses the nine factors individually, with a particular emphasis on the sub-factors applicable to each factor. The discussion relates the findings of the sub-factors and compares and contrasts them with the relevant literature, to distinguish emerging overall sub-factors relating to each individual factor. A diagrammatical conceptual model is developed to relate the nine factors and their sub-factors to the successful IM of offsite bathroom construction. A further analysis and discussion is carried out on all sub-factors identified in Chapter 5 to identify the main problem and solution themes that occur. A final summation of all 70 findings identified throughout the research is analysed and discussed to relate the findings back to the nine factors, to establish a ranked order of importance.

Chapter 7 concludes the research by revisiting the aim, objectives and research questions and offering a final critique on the significance of the research to improving the IM of offsite bathroom construction. Recommendations are also provided for further research and a personal reflection on the research journey is offered.

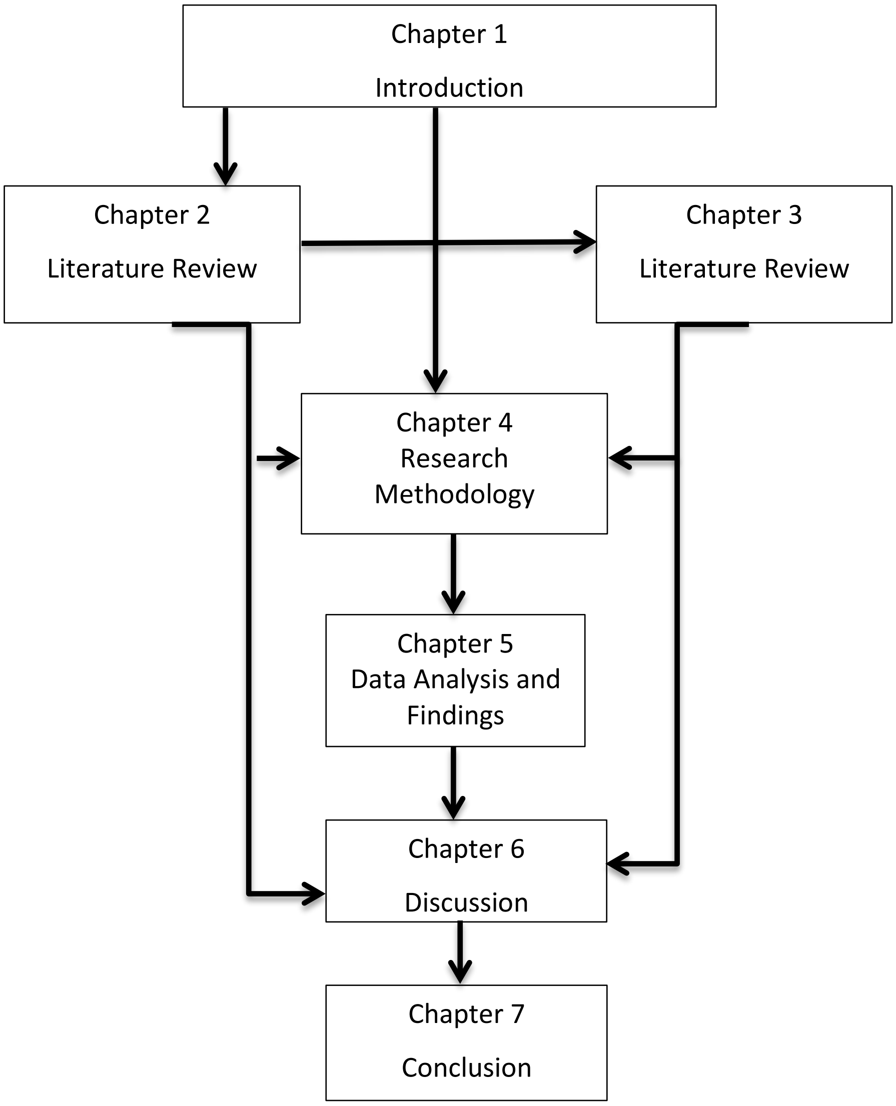

Figure 1.1: Structure of thesis

1.9 Summary

This introduction chapter has set the scene for the research that follows. The rationale and purpose of the research has been identified. The research questions, aim and objectives have been introduced. An outline of the research methodology and the contribution to knowledge has been justified. Finally, the structure of the thesis has been shown both textually and diagrammatically. The next chapter will review traditional construction, offsite construction and IM to identify process and people factors, which could be influential in the IM of offsite bathroom construction.

Chapter 2 – Literature Review: Part 1

2.1 Introduction

Chapter 1 introduced the key issues and areas of research within which this study is framed. The main focus is the relationship of interface management (IM) to offsite forms of bathroom construction, which is viewed from a holistic perspective, focusing on the organisational IM of the many processes from design through to installation on site, which if not managed adequately would have a major impact on the success of the overall process. It is considered relevant to also review traditional construction as offsite methods do not sit in isolation from traditional construction. This chapter begins the review of literature by assessing the current perception of traditional construction, to offsite forms of construction and the implications of these methods for IM.

An analysis of offsite construction follows, with a brief historical review, a review of uptake, identification of the current drivers and constraints and a specific review of offsite bathroom construction. The concept of IM in construction is analysed from a historical perspective, followed by a review of the types of interfaces. Boundary management in relation to IM is included, as are social networks, followed by project IM. Traditional construction, offsite construction (with a focus on bathroom construction) and IM are reviewed to identify the pertinent process and people factors that influence the IM of offsite bathroom construction.

2.2 Traditional Construction: Perceived View

The word 'tradition' is defined as a specific custom or practice of long standing (Oxford, 2013). 'Traditional construction' is a term used in construction management literature to define the customs and practices of the construction process that have remained unchanged for a considerable period of time. Moreover, the traditional view of building construction consists invariably of 'a process of preparing a site, bringing in materials and components, forming materials into elements such as frames, walls and roofs, assembling readymade components, installing services and then finishing ready for occupation' (Morton, 2008, p. 152). While simplistic in description, it belies the complex processes and the high labour content required to complete a project (Durdyev and Ismail, 2016). Common attributes of traditional construction are wet trades such as insitu concrete, plasterwork and paintwork and craft trades such as bricklaying, joiner work and plumbing to name but a few (Tam et al., 2007).

It is accepted that manufactured elements such as structural steelwork, pre-cast sills and lintels and timber roof trusses are components that fit within traditional construction but nevertheless include elements of offsite production (Gibb, 1999; Davidson, 2009; Goh and Loosemore, 2017). Davidson (2009) confirms that manufacturing has been prevalent in traditional post-war construction not only in the form of component parts but also as whole buildings. However, full exploitation will not occur until change takes place within the organisational process and people factors that dominate traditional construction (Soares, 2013). Andujar-Montoya et al. (2015) agree with Davidson (2009) that most of the problems associated with low productivity in traditional construction stem from the people involved in the processes. A survey by Durdyev and Ismail (2016) identified 39 constraints that hinder production of traditional construction. The main constraints include the skill and experience of the workforce, insufficient supervision and the competency of the project manager. The competency of the project manager aligns with the people factor, the role of the project manager.

While offsite construction demands a more integrated management structure, the onsite part of the process may still operate the traditional adversarial main contractor/subcontractor culture, which, if affected by the aforementioned constraints, can lead to considerable reworking of the onsite works required for the offsite installation (Durdyev and Ismail, 2016).

The *Farmer Report*, the most recent report to review UK construction, suggests that a holistic management approach is required for the whole process. It is argued that the industry is required to 'modernise or die' (Farmer, 2016); a poignant phrase used to capture the report's view of the industry. Furthermore, offsite construction is unequivocally endorsed by the report as an approach to modernise the industry. The structure of traditional construction has been captured in Figure 2.1 as lacking integration and connectivity. The comments alongside processes and people would suggest that factors such as supply chain management, lean construction, design management, communication, role of the project manager, and culture and integration are not being view by the traditionalists as factors that influence the successful outcome of a project (Andujar-Montoya et al., 2015).

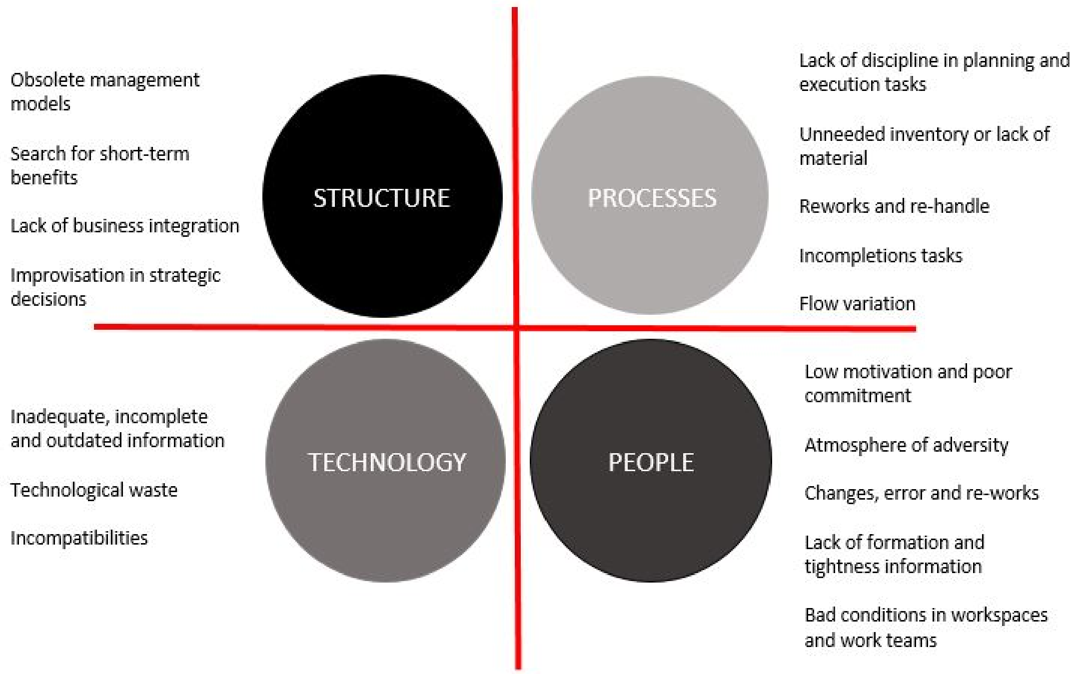

Figure 2.1: Structure of traditional construction (Andujar-Montoya et al., 2015)

2.2.1 Resistance to Change and Innovation

Construction inherently has a reputation of an industry that is slow to change and is wasteful in its use of materials and time, which results in low productivity and inefficiency onsite (Larsson et al., 2014). In a review of the British building industry since 1800, Powell (1996) argues that the construction industry has seen a considerable amount of change over the past two centuries. However, also evident is that the industry does not respond well to dramatic change; rather, very slow incremental change has proved more effective in the long term.

In his seminal book 'The *British Building Industry*', Bowley (1966) argues that a lack of co-ordination between the main stakeholders, that is, clients, architects and contractors, has been a fundamental obstacle to advancement in the industry. Despite advances in materials such as structural steel, reinforced concrete and framed construction, designers are reluctant to embrace new methods and view construction as craft-based (Goh and Loosemore, 2017). Furthermore, innovation and modern techniques are being hindered from adoption into the process, suggesting that the client and design team relationship could be a relevant factor in the uptake of offsite forms of construction.

Other obstacles to innovation, apart from the isolation of the main parties, include some procurement routes and forms of contract which place all the risk on the main contractor, and therefore contractors are less incentivised to be innovative. Dale (2007) argues that the main innovators associated with construction are in fact specialist suppliers keen to obtain a bigger market share for their products. Gann (2000) reiterates the view of Bowley (1966) that the main problem encountered by the UK construction industry is the separation of design and construction. Ozorhon and Oral (2017) argue that project complexity and the many stakeholders make innovation both difficult and essential for construction. The patterns of relationships are compared to a complicated 'mosaic' and until the interfaces and boundaries between the many pieces (organisations) can be enhanced, it will be difficult to produce an effective and picturesque mosaic. This highlights procurement and design management as process factors which have an impact on not only traditional construction but also offsite construction.

2.2.2 The Role and Relationships of Subcontractors

Green (2011) relates the employment of subcontractors back to the national building strike of 1972, which led main contractors to shift the main financial and production risks onto subcontractors. The current pattern of traditional construction relates to the main contractor dividing the project into work packages and engaging subcontractors to carry out the works, based mainly on lowest price and with little attention to the interdependence between the various subcontractors engaged on a project (Dubois and Gadde, 2002).

While the procurement route chosen for a project normally focuses on the client and main contractor relationship, Artto et al. (2008) and Abbasianjahromi et al. (2016) argue that the same importance should be placed on the procurement method used by the main contractor in the selection of subcontractors, thus re-emphasising procurement as an important process factor. Karim et al. (2006) comment that although the contractual relationship exists between the main contractor and the subcontractor, in practice the flow of work can progress from one subcontractor to another subcontractor and to another. Furthermore, if the main contractor does not communicate effectively with the subcontractor interface problems can result, emphasising the importance of communication as a factor in any form of construction.

Dainty et al. (2001) uncovered serious concern among subcontractors about the relationships between main contractors and subcontractors. A total lack of trust, scepticism and adversarial relationships are cited as being inhibitors to the improvement of relationships within the industry. This is further argued by Akintan and Morledge (2013), who consider that the interdependence between subcontractors and the main contractor in particular has a major impact on the success of a project, reiterating integration between the stakeholders as a people factor worthy of inclusion. Current construction research centres mainly on production, with little research on the impact of organisational interfaces, which could improve the main contractor and subcontractor relationship by acknowledging that subcontractors should also be included in the decision-making process (Koskela and Vrijhoef, 2001; Akintan and Morledge, 2013). However, it could be argued that an increase in offsite methods could have both a negative and positive impact on subcontractor participation in the process – that is, fewer operatives required, existing skills adapted to new skills and education about new technologies for both offsite and onsite (Goh and Loosemore, 2017).

2.2.3 The Future and Advancement of Construction

The UN (1996, cited in Flanagan, 2004) states that the urban populations in developed countries will double between 1990 and 2025, from two and a half to five billion. Furthermore, the size of the ageing population of those aged over 60 is predicted to overtake that of children between the ages of zero and 14 by 2050, thus adding to the demand for the construction of housing, schools and hospitals, etc. While clients in general may not have a detailed appreciation of the various construction methods available, it is widely accepted that clients now demand shorter construction timeframes (Morton, 2008).

Chen et al. (2007) endorse the growing view that traditional construction faces major challenges due to the growing complexity of the construction process. Morton (2008) argues that advanced materials and techniques, if assembled onsite using traditional processes, will not advance the process. The implication here is that to advance the whole process, advanced materials need to be assembled offsite (Goh and Loosemore, 2017). Khalfan and Maqsood (2014) identify the management of complex interfaces between the design, manufacture and onsite processes as a research gap worthy of more in-depth research to further the uptake of offsite methods.

Table 2.1 states the factors identified within the traditional section of this chapter. The table will be developed further in the offsite construction section.

Table 2.1: Factors identified in literature attributed to traditional construction

Factor	Authors
Supply chain management	Andujar-Montoya et al. (2015)
Lean construction	Andujar-Montoya et al. (2015)
Design management	Gann (2000) Andujar-Montoya et al. (2015)
Communication	Karim et al. (2006) Andujar-Montoya et al. (2015)
Role of the project manager	Durdyev and Ismail (2016) Andujar-Montoya et al. (2015)
Culture	Andujar-Montoya et al. (2015)
Integration	Andujar-Montoya et al. (2015)
Client and design team	Bowley (1966)
Procurement	Gann (2000) Artto et al. (2008) Abbasianjahromi et al. (2016)
Integration	Akintan and Morledge (2013)

2.3 Offsite Construction

2.3.1 Definitions

The term 'offsite construction' would appear to be self-explanatory – that is, the process is carried out away from the construction site. However, a number of terms have become synonymous with the phrase such that clarification is necessary. Terms such as prefabrication, standardisation, pre-assembly, industrialised building, system building and modular construction are often used interchangeably with the term offsite construction.

The above are not new processes to the construction industry. However, different stakeholders view them with varying degrees of acceptability. Gibb and Isack (2001, p. 46) define standardisation as 'the extensive use of processes or procedures, products or components, in which there is regularity, repetition and a record of successful practice'. CIRIA (the Construction Industry Research and Information Association) (1999, p. 27) argues that pre-assembly (literally 'to assemble before') 'refers to the manufacture and assembly of buildings or parts of buildings ahead of the time that they would traditionally be made on-site'. Gibb (1999, p. 1) defines prefabrication as 'a manufacturing process, generally taking place at a specialised facility, in which various materials are joined to form a component part of the final installation'.

Groak (1992, cited in Gibb, 2001) offers an alternative view: 'buildings are fixed to the ground which means we have to have a mobile industry', and, furthermore, 'this interest in the car analogy probably appeals to those who prefer walking around a warm, dry factory to struggling across a building site on a cold damp evening'. White (1965, cited in Gibb, 1999) argues that the term 'prefabrication' can have many interpretations, such that it can lose its exact meaning. It is considered that this could be applied to all of the aforementioned terms. This thesis adopts the following terms, which are more precise in definition:

1. Non-volumetric offsite: This term encompasses the items that do not enclose useable space, for example wall panels and roof trusses
2. Volumetric offsite: This term refers to units which enclose useable space, but in themselves do not form a complete building, for example bathroom pods
3. Modular offsite: This term describes a unit or units that form a whole building or part of a building in terms of full enclosure and structural needs, for example a complete building (Gibb, 1999, p. 8).

2.3.2 A Brief Historical Review of Offsite Construction

While this research does not profess to confirm the earliest period of offsite fabrication, Pitts and St Joseph (1985, cited in Gibb, 1999) recorded details of an example of a Roman fortress (AD 86) in Inchtuthil, Scotland, built with prefabricated elements, showing that prefabrication is by no means a new process. Other examples include prefabricated timber huts used in the Crimean War to aid the treatment of injured soldiers and the Great Exhibition of 1851 which saw the Crystal Palace structure being erected from cast iron and glass, which was subsequently dismantled and re-erected at a new location. From this period on, many other examples have been identified whereby offsite methods have been utilised.

In the 1920s, Buckminster Fuller, a renowned architect, designed a sub-assembly bathroom comprising four sections, which could be installed by two people. His motto was ‘Houses like Fords’, making reference to mass production of the Ford motor car (Argen and Wing, 2014, p. 12). The thinking at this time was that construction needed to embrace mechanisation, similar to other industries such as automotive and shipping, in order to become more efficient.

At the end of the Second World War there was an urgent need for housing and prefabrication was considered the best means of alleviating this problem. This form of housing was commonly referred to as a ‘prefab’, and received mixed reactions from occupants. A more advanced form of prefabricated construction was developed in the 1960s and 1970s, commonly referred to as ‘system’ or ‘industrialised’ building that consisted mainly of large pre-cast concrete panel construction. Two examples of industrialised or system building that went wrong included the 22-storey block of flats known as Ronan Point in London’s East End, which suffered a progressive collapse and resulted in four deaths (Atkin, 2014) and the Tracoba development in Glasgow, a French design of system building, which, due to inherent dampness problems, was demolished (Diamant, 1965).

Both examples resulted in any form of industrialised or system building being rejected as a satisfactory form of construction. Investigations into both projects identified serious interface problems, which had contributed to the collapse at Ronan Point and the dampness problems in the Tracoba flats. Winch (2003, p. 114) attributes the failures of this form of construction to the following:

1. Poor urban planning where large housing estates were created with little or no amenities, for example St Ann’s in Nottingham and Castlemilk in Glasgow
2. Poor structural integrity and thermal performance of some designs (design management)
3. Lack of management control over site production processes leading to severe quality problems in the final product (lean construction, tolerances and quality)
4. Poor maintenance of the stock.

While each of Winch’s observations is worthy of a deeper discussion, it is the consideration of this research that items two and three allude to the process factors of design management, lean construction, tolerance and quality.

2.3.3 Use and Uptake

A survey carried out to ascertain main stakeholders’ perceptions of offsite construction indicated that 73 percent of the clients and designers surveyed considered that they had a good understanding of the advantages and disadvantages of offsite methods, compared to 54 percent of contractors and 30 percent of suppliers (Goodier and Gibb, 2007). However, the general perception is that clients lack a clear understanding of the offsite process. This would suggest that the high figure for clients and designers results from designers’ influence on their clients (Gibb and Isack, 2003). Gibb and Isack (2003) argue that educating clients on the merits of the offsite construction process is crucial to its increased uptake. Furthermore, design for manufacture widely used in manufacturing industries is not seen as being an appropriate design method applicable to construction, as it is considered by designers to inhibit flair in the design process (Fox et al., 2001).

A survey by Goodier and Gibb (2007) identified cost as being of particular concern to all of the actors who participated in the survey and in particular the lack of bona fide data on cost comparisons between the two modes of delivery, which it is considered has hindered the uptake of offsite construction. Blismas et al. (2003) argue that the direct cost comparison between offsite construction and traditional is too narrow in its approach. To ascertain the true value, the inclusion of direct and indirect costs would create a more realistic comparison in the form of whole life costs (Blismas et al., 2003), emphasising it as a factor in relation to offsite and IM.

A survey carried out by Goodier and Gibb (2004) indicates that the value of the offsite sector in 2004 was in the region of £2.2 billion. This compared to the industry's overall value during the same period of £106.8 billion resulting in only a 2.1 percent share of the overall construction market. In 2014 the market share of UK offsite construction was believed to be 7 percent (GOV.UK, 2014). The total value of construction contribution to the UK economy in 2014 was £103 billion (Rhodes, 2015), suggesting that the offsite sector has seen growth to £7.21 billion, while the overall value of construction for 2014 is slightly down on the 2004 value. This suggests that the offsite sector is gaining momentum, while the industry overall is still recovering from the 2008 recession. However, these studies should be considered with a degree of scepticism due to the considerable difficulties in gathering appropriate data, both of what constitutes an offsite product and how the size of the various sectors are measured. This difficulty is acknowledged by some of the authors of such reports (e.g. Goodier & Gibb, 2004). Goulding et al. (2015) acknowledge a slight increase in the uptake but argue that overall the value of offsite construction is still small in comparison to the total value of construction.

A survey carried out in 2008 to determine the uptake of offsite methods in the housing sector found that, despite the shortage of affordable housing, the uptake was low (Pan et al., 2008b). A similar survey carried out in 2014, with a continuing shortage of affordable housing, also showed a low uptake of offsite methods (Elnaas et al., 2014). Interestingly, both surveys highlighted interface issues as a barrier to the increased use of offsite methods in house building (Pan et al., 2008b; Elnaas et al., 2014).

The *Barker Report* (2004) and the *Housing White Paper* (2017), both brought about by the UK government to review the shortage of affordable housing, recommend innovative methods such as offsite construction to aid both the shortage of housing and the skills shortage. However, Barry Holmes, executive director of the Traditional House Bureau (cited in British Research Establishment, 2004), argues against offsite construction, at least in the residential sector, expressing the view that the vast majority of the population still favours traditional brick and block construction. Holmes cites from the *Barker Report* (2004) that masonry construction is 10 percent cheaper than offsite. While the skills shortage is viewed as an argument against traditional methods, this is countered by Holmes, who takes the view that the reported skills shortage is but a scare tactic. However, Holmes' view is refuted by the findings of a Chartered Institute of Building (CIOB) survey of its members. From a sample size of 1,346, eighty-two percent (1077) claim that the skills shortage is still having an effect on the construction industry (CIOB, 2013).

Miles and Whitehouse (2013) argue that the uptake of offsite methods is not directly affected by a skills shortage in traditional construction. Moreover, it is perceived to relate to the production strategies of house builders, who prefer a more flexible approach, rather than adhering to the constraints of offsite construction (Lang et al., 2016). However, effective training for the installation of offsite units onsite and the management of the inherent interfaces are seen as important skills required of operatives and the project manager (Vokes and Brennan, 2013). Goh and Loosemore (2017) suggest that offsite production, in particular in bathroom pod manufacturing, could facilitate women, elderly and disabled people, who would normally feel excluded from traditional construction, to be employed in the offsite sector.

At a more local level, the Mtech Group, commissioned by Scottish Enterprise to review the extent of the offsite construction market in Scotland, considers that the industry needs to take a more holistic view of the process, similar to that found in the Japanese market. The results of a survey carried out by Venables et al. (2004, cited in Mtech, 2005, p. 22) on the main concerns about the uptake of offsite construction are as shown in Table 2.2, which also identifies the factors applicable.

Table 2.2: Factors influencing the Scottish offsite market

Factor	Statement
Design management	Lead time (for design and scheduling) Design limitation in providing variety
Tolerance	Matching tolerance to onsite work
Perception	Public and industry perception Certainty of future demand
Whole life costing	Cost
Lean construction	Handling and logistics

A further review of the offsite construction sector in Scotland identifies the public procurement process as a barrier to the uptake of offsite methods and calls for a more inclusive approach, whereby offsite construction could be recognised within the building standards in Scotland (Smith et al., 2013), emphasising procurement as a process factor to be included in this research.

2.3.4 Drivers and Constraints – UK Perspective

The 1998 Egan report, *Rethinking Construction*, attempts to develop offsite forms of construction, to follow the principles already in use within the manufacturing industry. Egan (1998) considers that greater use of prefabrication and standardisation than those currently in use would greatly enhance the productivity of the construction industry. It is widely accepted that cost, time and quality are the traditional drivers which operate within the construction industry (Blismas et al., 2005). However, Blismas et al. (2005) argue that when consideration is given to offsite construction, factors such as quality, whole life cost, culture, health and safety and sustainability need to be elevated to the same level of importance as time and cost for the management of the offsite process. It is also considered that the aforementioned factors could have an influence on the process and people issues that influence the relationship of IM to offsite construction.

Interview surveys with 59 leading client representatives across a wide spectrum of markets identified that, from a client's perspective, lowest whole life cost was considered the main driver applicable to all categories (Gibb and Isack, 2001). While it is perceived that cost is the main driver, it is encouraging that clients are considering whole life costing, which may lead to value for money being considered by enlightened clients as the main driver, re-emphasising it as a process factor, and thus allowing a fairer comparison between offsite construction and traditional methods.

In contrast, Blismas et al. (2005) categorised constraints under three broad headings:

- Site constraints
- Process constraints
- Procurement constraints.

A questionnaire survey to gauge the industry's perception of the constraints yielded a response rate of 25 percent (73 No), which could be considered low based on the percentage, but reasonable based on the divergence of roles and number of responses (Blismas et al., 2005). The analysis of the results indicates that process constraints dominate, with the inability to freeze design and specifications being considered the main barrier to the implementation of offsite construction, followed closely by the obligation by clients to accept the lowest cost. A common theme identified by both Gibb and Isack (2001) and Blismas et al. (2005) is the missed opportunity for contractors to influence the early stages of the design process for the possible incorporation of offsite construction, stressing the importance of design management and integration as factors which can impact on offsite construction and IM.

2.3.5 Drivers and Constraints – Non-UK Perspective

Evaluation of the uptake of offsite methods must be 'country focused' (Rahman, 2014). A questionnaire survey by Zhai et al. (2014) of 110 responses to determine the main constraints on the uptake of offsite methods in house building in China used factor analysis to determine the views of a range of professionals such as clients, designers, contractors, manufacturers and suppliers. Six main factors were established and categorised as follows:

1. Constructability implementation
2. Social climate and attitudes
3. Architectural performance
4. Costing
5. Supply chain
6. Preparatory stage.

A further analysis of the implied meaning of factor one, ‘constructability implementation’, indicates that Zhai et al. (2014) relate this factor to process factors such as tolerance and procurement and people factors such as communication and integration**.** Factor two, ‘social climate and attitudes’, relates to the people factors of client and designer scepticism, culture and perception. These stem from the government, which continues to be indifferent to offsite methods and favours traditional construction.

Factor three, ‘architectural performance’, implies the process factors of design management, which relates to the complexity of managing the design of offsite works, and quality, which relates to a perceived view of a poor quality product that would be achieved using offsite construction. Factor four, ‘costing’, infers the high capital cost of setting up the manufacturing plant versus the low cost of labour and materials, which gives a narrow cost comparison compared to the process factor of whole life costing. Factor five, ‘supply chain’, infers the integration and co-ordination between the various actors in the process, which in China lacks a cohesive approach, suggesting that supply chain management and integration are two factors worthy of inclusion in the analysis.

Finally, factor six, ‘preparatory stage’, implies that the Chinese housing market does not have a culture that considers that time spent in preparation is a benefit to the design, but rather the freedom to make random changes is seen as the norm, suggesting that design management again is a process factor central to the barriers of the offsite market in China and in general (Zhai et al., 2014). While the construction industry in China embodies a different culture to the construction industry in the western hemisphere, the rigorous approach applied to the data collection and analysis of the study makes the implied factors relevant to the industry in general.

Lu and Liska (2008) reviewed the construction industry's perception of offsite construction in the US. Their study surveyed architects, engineers and general contractors using interviews and questionnaires to determine their views on benefits and barriers to the use of offsite construction. A sample of general contractors with an annual turnover exceeding $1 million was established from the Dun & Bradstreet database of contractors, and similarly architects and engineers were identified from the American Institute of Architects. Of the surveys returned, 67 (51 percent) were architects or engineers and 64 (49 percent) were general contractors.

The architect or engineer respondents reported that almost 27 percent of their work incorporated one or more forms of offsite, while general contractors reported that almost 20 percent of their work consisted of offsite. In both cases certain types of pre-assembly dominated, such as pre-cast concrete and roof trusses, but respondents considered them to be traditional rather than offsite methods. Eastman and Sacks (2008) identified that the method of reporting the economic effect of offsite construction in the US suggests that any works which are manufactured offsite are counted as manufacturing output and not construction output. Therefore, only work which is carried out onsite is accounted for within the turnover of the construction industry, which leads to a misrepresentation of the actual value of the US offsite construction industry. In contrast, the UK construction industry includes offsite forms of construction in the total value of construction.

It would appear that Australia lags behind the UK in the use of offsite manufacturing, and this is exemplified by the small number of experienced participants that were available to take part in a survey of bathroom pods (Goh and Loosemore, 2017). A survey carried out by Blismas and Wakefield (2009) using a series of workshops in Melbourne, Perth and Brisbane identified the main barriers to be low level of knowledge, perceived higher costs and resistance to change the existing process. The offsite process and programming of offsite works were seen as constraints in Australia rather than drivers. The main driver identified is the reduced number of trades' onsite thus reducing the co-ordination of interface issues. Cost was also seen as a key driver. However, little awareness of possible cost savings is apparent when cost is viewed from the whole lifecycle perspective. Blismas and Wakefield (2009) conclude that a review of the procurement routes would possibly aid the uptake of offsite construction in the Australian construction industry. The various methods used by countries to review offsite construction suggest that procurement routes and people's perception of offsite construction are factors worthy of consideration.

The housing authority of Hong Kong has decreed it mandatory to use prefabrication on its projects; however, this same requirement does not extend to private and commercial projects (Chiang et al., 2008). A survey of the Hong Kong construction market about the uptake of offsite construction identified that more developed forms of prefabrication, such as volumetric and modular, prosper when the following are addressed:

- Full mechanisation of the construction process
- Turning construction into an assembly industry rather than site production
- Using recycled materials (Tam et al., 2007, p. 3652).

While the Hong Kong housing industry would appear to embrace prefabrication, the remainder of the construction industry in Hong Kong remains to be convinced, citing the volume of units required to make it economically viable as the main barrier to a strategy for a greater use of offsite methods (Chiang et al., 2008). While the uptake in offsite construction varies from country to country, the barriers and constraints suggest a level of commonality, which indicates that process and people factors identified in non-UK studies are worthy of inclusion in this research.

2.3.6 Facilitators

While the debate on the merits of comparing the construction industry with the car industry continues (Egan, 1998), other industries, in particular manufacturing, do apply philosophies and strategies that the construction industry could adopt or amend to further the implementation of offsite methods. Gibb (2001, p. 311) identifies various statements that resonate with some of the process and people factors identified in Table 2.3

Table 2.3: Factors aligned with the manufacturing industry

Factor	Statements
Client and design team	Mass customisation must replace mass production as the modus operandi because technology can now deliver the choice that clients demand. The customer's needs and desires must be identified and addressed; this will include the need for customisation and the offer of choice.
Whole life cost	Most customers will accept that hand-crafted one-off products, if desirable, are likely to cost more and take longer. Customers are interested in the value for money, although few can really elucidate exactly what that means.
Quality	Most customers are interested in the end product (the building or car) but rarely concerned about the process involved. The performance of the product (for as long as the customer has it) is as important as its appearance. The whole process must be focused on producing an excellent end product.
Supply chain management	The supply chain must be acknowledged and managed.
Leadership	Appropriate pre-assembly and outsourcing of components and sub-assemblies is useful, provided that the process is subservient to the delivery of the end product (the tail must not wag the dog).
Design management and tolerance	Interchangeability and surety of fit will demand close attention to interface or connection design, manufacture and assembly.

2.3.7 Offsite Methods of Bathroom Construction

Goh and Loosemore (2017) posit that traditional bathroom construction and offsite forms in particular have received little research in academia. This is surprising considering that the bathroom or wet room area of a construction project is commonly identified as the most intense area of a project in terms of the number and variety of activities and trades required to construct it. The continuum of construction methods available for the construction of bathrooms ranges from total onsite construction to total offsite manufacture, with various hybrids in between. Taylor et al. (2009) employed a case study approach to compare two methods of constructing a bathroom. One method is the use of bathroom pods and the other a pre-finished 'kit' of parts. Both forms of construction were adopted in a £28 million hotel in Edinburgh, which consisted of both new build and refurbishment elements. Several different types of pods were used in the four star hotel, in order to accommodate en-suite, disabled and higher specification bathrooms.

The pre-engineered kits came in the form of 'flat pack' panels with sanitary ware attached to them, designed for ease of assembly, and had a heavier reliance on the skills of the onsite fitter but still less so than the traditional onsite bathroom construction. Benefits include:

- Reduction in personnel onsite
- Reduction in construction programme
- Reduction in waste
- Reduction in snagging.

Similar to bathroom pods, the pre-engineered bathrooms in Edinburgh were constructed by one subcontractor who had responsibility for all trades. Although pod and kit construction reduce the level of interface between trades, it is not possible to avoid a level of physical and organisational interface between the offsite installations onsite. What is important is to recognise the variations in the types of interfaces which may, in certain situations, demand a higher level of management expertise to achieve the benefits of offsite construction (Taylor et al., 2009).

Pan et al. (2008a) reviewed the maintenance costs applicable to bathroom construction via case studies of student accommodation. A comparison is made of the maintenance cost of offsite and traditional in situ bathrooms, by reviewing four forms of bathroom construction: concrete modules (216), glass reinforced polyester (GRP) modules (84), and two different types of traditionally built in situ bathrooms

(96). A quantitative study of the maintenance records resulted in the traditionally built in situ bathrooms being classed as the most expensive to maintain, followed by the pre-cast concrete modules, resulting in the GRP module being confirmed as the cheapest to maintain. However, caution should be taken to generalise the findings, with recommendations given by Pan et al. (2008a) to carry out further research utilising other commercial building types such as offices and hotels, which this research will endeavour to execute.

2.3.8 Future Vision

Research by the British Research Establishment (BRE) (2004) endorsed offsite construction as a pragmatic approach to construction. The BRE argues that offsite construction is an appropriate method for the construction of public and commercial projects in the form of schools, hospitals and hotels, etc. The study endorsed the industry view that the time is now right for more prominent use of offsite construction; however, ten years hence and the uptake is still low, which may be attributed to the 2008 recession (Rahman, 2014). Furthermore, worthy of deeper research is the view that the industry has little knowledge of the tolerance and interface issues prevalent in offsite construction, in comparison to traditional methods such as brick and block (BRE, 2004; Rahman, 2014), highlighting tolerance as a factor worthy of inclusion in the research in relation to offsite and IM.

Mtech (2005) and Rahman (2014) recommend that academic institutions integrate and/or create new modules for offsite construction, to enlighten students about the alternative methods available in comparison to traditional methods, thus stimulating the next generation of construction professionals to make a more informed choice. This research has and will continue to contribute to fulfilling that recommendation by inclusion in a third year construction technology module at Glasgow Caledonian University.

The Mtech report highlights the need to review logistics at both local and national level, to consider the skillset of site project management, to review the implications on health and safety and fundamentally to review procurement routes with the understanding that the traditional route does not lend itself to offsite construction. While logistics is an important entity within construction, within the context of this research, logistics will be included in the theme of lean construction. Furthermore, the role of the project manager, health and safety, procurement and lean construction are considered relevant process and people factors for inclusion in this research. Moreover, Jonsson and Rudberg (2014), in a review of current literature in relation to industrialisation, reviewed 12 peer reviewed papers to determine factors that could influence the drivers and barriers to offsite construction. Included within the process factors identified were quality, health and safety, lean construction, sustainability and design management. The people factor of project manager was seen as enhancing the role due to their involvement at an earlier stage than traditionally.

Jonsson and Rudberg (2014) also reviewed three case studies. What became evident from their analysis was that the greater the level of interface between the offsite components, the greater the detrimental effect on the project, thus suggesting that interface problems are not the sole domain of traditional construction but equally require to be managed on offsite forms of construction. Also, the greater the degree of offsite used, that is, modular, the fewer interface problems should occur onsite.

Furthermore, when considering IM issues, Jansson et al. (2014) focused on the design management issues of system building in housing, and analysed two case studies, to determine the hard and soft factors that impact on the design management of interfaces. The results of the analysis acknowledge that a holistic approach is required whereby not only the physical nature of the interface is considered, but equal consideration must also be given to the human aspects of communication, collaboration and the input of the client. While the depth of the analysis may be considered inadequate to generalise the findings, the study consisted of two well-established house building companies in Sweden and the methodology consisted of both quantitative and qualitative studies to validate the findings, such that the findings from the study are worthy of consideration. Andujar-Montaya et al. (2015) argue that the construction of 'mock-ups' should be included in the contract, as a mock-up of the main sections (bathroom) has the potential to reduce impending interface issues.

Harty et al. (2007) argue that developments in material technology and methods of production have the benefit of aligning more with the offsite process. An alternative manufacturing process to the established factory being piloted by an international Swedish contractor is termed the 'modern flying factory', which sits between an established factory and onsite production. The benefits include lower capital investment costs and closer proximity to the site (Young et al., 2015), which in turn contribute to reducing the high wastage factor currently experienced by the industry.

This is reiterated by UK contractor Babcock & Wilcox, who argue that the increased use of volumetric units has fuelled the evolution of more advanced heavy-lifting cranes. The main risks identified focus on interface issues at the workplace, indicating that a lack of co-operation between the parties involved will result in a high chance of failure. Conversely, good co-operation and management will enhance the success rate. Blankinship (2008) argues that modular construction calls for a re-appraisal of current project management techniques, to ensure that best practice is followed, suggesting that the role of the project manager is central to the success of offsite construction and construction projects in general and is worthy of inclusion as a people factor in this research. Table 2.4 includes the factors identified in Table 2.1 and factors identified in the offsite section.

Table 2.4: Factors identified in the literature attributed to traditional and offsite construction

Factor	Authors
Supply chain management	Andujar-Montoya et al. (2015), Zhai et al. (2014), Gibb (2001)
Lean construction	Andujar-Montoya et al. (2015), Winch (2003), Mtech (2005), Jonsson and Rudberg (2014)
Design management	Gann (2000), Andujar-Montoya et al. (2015), Winch (2003), Mtech (2005), Gibb and Isack (2001), Blismas et al. (2005), Zhai et al. (2014), Gibb (2001), Jonsson and Rudberg (2014)
Communication	Karim et al. (2006) Andujar-Montoya et al. (2015), Zhai et al. (2014)
Role of the project manager	Durdyev and Ismail (2016). Andujar-Montoya et al. (2015), Mtech (2005), Jonsson and Rudberg (2014), Blankinship (2008)
Culture	Andujar-Mo Zhai et al. (2014), Montoya et al. (2015), Blismas et al. (2005)
Integration	Andujar-Montoya et al. (2015), Akintan and Morledge (2013), Gibb and Isack (2001), Blismas et al. (2005), Zhai et al. (2014)
Client and design team	Bowley (1966), Zhai et al. (2014), Gibb (2001)
Procurement	Gann (2000), Artto et al. (2008), Zhai et al. (2014), Blismas and Wakefield (2009), Mtech (2005), Smith et al. (2013)
Sustainability	Blismas et al. (2005), Jonsson and Rudberg (2014)
Tolerance	Winch (2003), Mtech (2005), Zhai et al. (2014), Gibb (2001), Rahman (2014)
Quality	Winch (2003), Blismas et al. (2005), Zhai et al. (2014), Gibb (2001), Jonsson and Rudberg (2014)
Whole life costing	Blismas et al. (2003), Mtech (2005), Blismas et al. (2005), Gibb and Isack (2001), Zhai et al. (2014), Gibb (2001)
Perception	Mtech (2005), Zhai et al. (2014)), Blismas and Wakefield (2009)
Health and safety	Blismas et al. (2005), Mtech (2005), Jonsson and Rudberg (2014)
Leadership	Gibb (2001)

2.4 Interface Management (IM)

2.4.1 Definitions

Wren (1967, p. 70), in an attempt to explain the term 'interface', considers that in a technical sense interface is defined as 'a surface, usually a plane surface, forming the boundary between adjacent solid spaces or immiscible liquids', thus making reference to the surface tensions that occur in a technical sense. Morris (1983) defines IM as either 'static or dynamic'. Static refers to the normal relationships which exist between the main parties in all projects throughout the life of a project, while dynamic refers to the interrelationships that develop in a project as a result of the design and production issues, which are specific to the actual project. It is the dynamic interfaces which tend to cause most problems in a project when design and production clash for various reasons, such as out of tolerance service connections between volumetric units to the onsite services, emphasising tolerance as an important process factor.

Stuckenbruck (1983, p. 40) defines IM by focusing on three categories of interface:

1. Personal interface – relates specifically to people issues and can be difficult to resolve, in particular when multiple parties are involved
2. Organisational interface – involves not only people but also process issues both internally and externally
3. System interface – referred to as physical interfaces.

Healy (1997, p. 268) defines IM in the context of project management thus: 'an interface is a boundary where an interdependence exists across that boundary and where responsibility for the interdependency changes across that boundary'. It could be argued that this definition relates to the dynamic relationship of organisational interfaces as posed by Morris (1983).

Gibb (1999) has defined IM by identifying three distinct categories of interface, which are considered of particular relevance to construction in general and offsite in particular:

1. Physical interface – as the term suggests this refers to the actual physical connection between elements or components, which form actual linkage. Physical interfaces can be related to hard interfaces. Pavitt and Gibb (2003) refer to the connection details between cladding types, that is, the connection between the roof and wall.
2. Contractual interface – relates to how the work packages have been formed from a contractual basis: that is, a contract may be broken down into a small number of major packages, thus reducing the number of interfaces. Alternatively, the decision may be to break the process down into many smaller packages, resulting in a considerable number of interfaces between the contractual parties.
3. Organisational interface – refers mainly to the soft interfaces, which affect the successful management of a project. Organisational interfaces can relate to individual and/or group relationships, which start from the inception of a project and continue throughout the life of the project.

Emmitt (2010) suggests that organisational interfaces are relatively easy to manage due to contractual arrangements. However, individual interfaces that are not based on any contractual agreement can be difficult to manage, and, moreover, they rely on the compatibility of individuals to communicate effectively and build positive working relationships thus confirming communication as an important people factor in relation to IM.

Archibald (2003, p. 331) offers the meaning of IM to be ‘the interaction of the organisational relationships between the major parties involved in a project’. Furthermore, Chen et al. (2008, p. 433) define IM as ‘the management of the boundaries between such project entities as people/participants, processes/phases, resources, contracts, costs, schedules, systems/functions and safety/risk to enable a dynamic and well-coordinated construction system’. This all-encompassing definition attempts a holistic approach to IM and emphasises the need to understand the effects of the process and people factors identified as having an influence on IM. Whilst Chen et al.'s (2008) research is a worthwhile contribution into IM in construction; it is disappointing that the processes identified relate only to design and quality, with no discussion on procurement, supply chain management or health and safety. Similarly, the people factor of communication was discussed but no reference was made to the role of the project manager, culture, perception or integration. However, it can be acknowledged that Chen et al. (2008) identify with some of the interface problems that occur from the offsite process, such as poor plant organisation, poor quality of products, production bottlenecks and a low degree of industrialisation.

Acknowledging that there is not a standard definition of IM (Shokri et al., 2016) and with the focus of this research on the relationship of IM to offsite construction, with a particular emphasis on offsite bathroom construction and the main emphasis on organisational interfaces, this researcher offers the following definition:

> **Organisational IM can be defined as an intangible entity, which requires a dynamic approach to the process and people factors that influence the interdependencies that span between organisations for the good of the project.**

2.4.2 Background

The concept of IM would appear to have little exposure in general management literature and in construction literature in particular (Morris, 1983; Chen et al., 2008). Koskela (2017) argues that construction management research should focus more on practical aspects of construction, rather than pure theoretical research that does not have a practical application to industry. It is hoped that this research will respond to Koskela's challenge.

While technical interfaces are relatively well understood due to their physical nature, Wren (1967) initially developed the concept of IM to review the relationships between two or more organisations, thus linking the issues that arise from people and processes. As in the technical sense, organisational interface is the contact point between organisations which in one sense are independent of each other, but which interact and become interdependent to achieve a common goal.

Construction literature generally describes the industry as ‘fragmented’, which has resulted in a plethora of interfaces whose effects the industry has found difficulty in quantifying (McCarney and Gibb, 2012). However, a positive outcome of fragmentation is the number of specialist subcontractors that have emerged, which would suggest that the problem lies with a lack of recognition of the interdependence between the many specialist subcontractors contracted on construction projects (Fellows and Liu, 2012). Fellows and Liu (2012) regard fragmentation as two dimensional, horizontal and vertical, where horizontal relates to the many stakeholders party to a project, and vertical denotes the various activities which require to be executed throughout the process and the actors engaged in the activity. While the horizontal fragmentation is fairly common to most industries, the vertical fragmentation over the lifecycle of a construction project is notably extensive and likely to cause people and process interface issues at the boundary of the activities (Kamara, 2013).

Gidado (1996, cited in Dubois and Gadde, 2002) attributes the complexity of construction to the many interface activities that occur onsite and the interdependency between the technology and the trades, which may not become apparent until the activity is executed, thus having a detrimental effect on the productivity and efficiency of the project. Shan and Zhang (2012) argue that approximately 70 percent of all problems on construction projects can be associated with interface issues. Dubois and Gadde (2002) advocate the concept of a ‘loosely coupled system’, to resolve the problems identified by Fellows and Liu’s (2012) vertical fragmentation, whereby there is a degree of understanding between subcontractors, which allows a degree of flexibility and contingency to resolve problems. Conversely, a ‘tightly coupled system’, which is the dominant system on individual construction projects, causes problems which influence the efficiency of the overall project.

Chen et al. (2008) consider that IM is a topic worthy of greater recognition by the construction industry. The move from one organisation executing all of the works, to the current form of sub-dividing the works into trade packages, signifies IM as a major contributor to the success of a project. Morris (1983), in a review of the lifecycle of a project, considers that the design phase plays a significant part in contributing to the many interface issues that arise in both a technical and organisational sense, again reiterating design management as an important process factor.

The Royal Institute of British Architecture’s (RIBA) plan of work has been in used since 1963 as the vehicle that details the various stages in a construction project from inception to completion. To mark the fiftieth anniversary and after a full scale review, a new eight stage plan was launched in 2013 (RIBA, 2013). While it is pleasing to see that offsite construction is now included in the plan as a possible design concept, it is disappointing to note that the current plan does not include any references to IM at the various stages, and this could be construed as a missed opportunity by RIBA and the industry in general.

Stuckenbruck (1983) further argues that project integration and project interface are similar in detail and that personnel should be allowed to transfer from stage to stage as the lifecycle of a project evolves. White and Marasini (2014) offer that personnel who move between stages are less likely to cause conflict, are more amenable to promoting a more ‘trusting’ culture and will be better integrated into the process of the project, which strengthens the argument for the involvement of construction personnel during the procurement and design process stages and endorses integration as an important people factor.

Of the 70 percent of interface problems previously mentioned by Shan and Zhang (2012), it is a generally held view that the majority that occur on projects are attributed to organisational interface problems. Healy (1997) argues that this may be due to the difficulty in succinctly quantifying or measuring the tangibility of organisational IM. Interestingly Healy's definition of IM focuses on 'boundary management', which is a term that is closely linked to IM (refer to section 2.4.4).

2.4.3 Types of Interface

The importance of IM in the construction industry is succinctly captured by Pavitt and Gibb (2003, p. 8) who concur with Shan and Zhang (2012): 'interfaces, joints and connections between different elements or sections cause more problems than most of the rest of the building'. Furthermore, the shift from the traditional form of contract to more varied management forms has seen a significant shift in the employment of labour from direct to indirect and also the formation of work breakdown structures. These structures can lead to increased interfaces issues between the various parties, therefore highlighting the need to better manage the interrelationships, which suggests the importance of the procurement route adopted (Boes and Holman, 2003). Chua and Godinot (2006, p. 68) identify four types of interface relevant to the construction process:

- Technical – the joining of various components
- Organisational – the divisions between groups or persons
- Time – the need to move from one activity to another as per the programme
- Geographical – the separation of offsite and onsite works.

The introduction of various forms of offsite construction into the construction process does not appear to totally remove the problems associated with IM. A study by Danby and Painting (2007) identifies miscommunication and a lack of knowledge of the offsite process by the onsite workforce as contributors to volumetric interface problems.

Chen et al. (2008 p. 434) offers a 'multiperspective approach' to interface issues, focusing on the following six factors: people/participants, methods/processes, resources, documentation, project management and environment. The six factors are further sub-divided to highlight actual causes which may contribute to interface activity. Within the people/participant area, causes listed relate to poor communication, and poor decision-making and co-ordination. Within methods/ processes, comment is made on the many disciplines which participate in the process, causing complications which may be generated from poor design through to actual construction problems. This approach should be applauded, as it attempts to bring to the fore the complexity of the interrelated factors and issues which in the main are hidden in the process. This emphasises the need for IM to be integrated within supply chain management. Shokri et al. (2016) argue that IM as a discipline of construction management has only recently been acknowledged and its implementation is mainly within mega-complex projects, rather than projects in general, which suggests that the industry needs to be educated in the benefits of IM to all projects. A comparison of two studies that identified the main causes of interface problems is shown in Table 2.5.

Table 2.5: Causes of interface problems

No.	Archibald (2003, p. 334–335)	Sha'ar et al. (2016, p. 9)
1	Change of responsibility – a task is passed over to another team member or organisation	Unstable client requirements
2	Results of action – a task is required to be completed before another task can begin	Lack of proper co-ordination between various disciplines of the design team
3	Management – key decisions required, which affect project interfaces	Awarding the contract to the lowest price regardless of the quality of service
4	Customer – actions required by the client which can have an effect on the management of the project	Lack of skilled and experienced human resources in the design firms
5	Information – information which has an effect on more than one task	Lack of skilled human resources at the construction site
6	Material – physical items which must be available to allow work to proceed	Delaying of due payments
7	/	Lack of specialised quality control team
8	/	Lack of professional construction management
9	/	Delaying the approval of completed tasks
10	/	Vague and deficient drawings and specifications

Interestingly, there is a degree of similarity in the findings of both studies, although the order of significance varies. Considering the time lapse, it could be construed from the comparison that the causes of interface problems remain unchanged.

Worthy of identification is the importance of the role of the project manager as implied in Archibald's (2003) study, while Sha'ar et al. (2016) identify the client and design team, quality and the role of the project manager as factors relevant to this research.

2.4.4 Boundary Management – Spanning and Objects

As has been stated previously the fragmented nature of construction projects has resulted in a multitude of subcontractors of varying degrees of specialism and configuration, which has led to the formation of various layers of boundaries (Kamara, 2013). Fellows and Liu (2012) profess that a typical project will consist of numerous boundaries; the formal boundary of each organisation, the boundary of each organisation's activity group operating on the project, the boundaries around each within-an-organisational group on the project and boundaries around informal groups, which may be formed of different organisational members, culminating in a plethora of tangible and intangible interfaces which require to be managed. While the permeability of boundaries may be achieved informally, in the main contractual obligations will result in a 'stand-off' between the affected organisations, such that 'effective communication' is central in resolving the impasse (Chow and Leiringer, 2014).

The term 'boundary spanning' has been coined to refer to a designated person or organisation tasked with bridging the affected boundary and negotiating a solution. This may involve the sharing of knowledge, which is sensitive to the stakeholder but is in the interest of the overall project (Gustavsson, 2015). It could be interpreted that boundary spanning is more akin to IM than boundary management (Di Marco et al., 2010). Ancona and Caldwell (1990) in a study of 45 teams from five high technology companies identified that those teams that performed well were more likely to engage with other teams and that the team member who engaged with the other team was likely to have some knowledge of the operation of the other team. From a construction perspective this would suggest abandoning the traditional 'silo' mentality and developing a 'bridging' mentality which encompasses a greater understanding of the characteristics and cultures that exist within interfacing organisations and networks thus promoting greater collaboration and learning though out the lifecycle of a project (Pemsel and Widen, 2011).

Star and Griesemer (1989, cited in Bresnen, 2010) developed the concept of the 'boundary object' in relation to IM. The concept of boundary objects can relate to objects that are shared or shareable between parties – they can cause conflict and they can also spark innovative practices (Carlile, 2002; Kamara, 2013). Boundary objects are both hard (design drawings/models) and soft (communication/interpretation) in nature. Wenger (1998, cited in Bresnen, 2010, p. 617) intimates that objects reside at the boundary; they apply to artefacts, documents, terms and concepts, with the objective of creating flexibility between the parties affected in order to promote improved inter-organisational collaboration. In other words, they may have a different purpose for the various parties affected but contain a common theme identified by all connected to the boundary (Bresnen, 2016).

In a construction environment this could be referred to as a 'pragmatic boundary', whereby the many organisations involved in a project accept a modicum of pragmatism in relation to the many conflicts that can occur at boundaries and interfaces, and promote a culture of integration and collaboration rather than the traditional form of conflict and dispute (Fellows and Liu, 2012). Central to promoting and executing the pragmatic boundary approach are good communication skills, which can result in a compromise of information exchange to resolve the problem. Fellows and Liu (2012, p. 656) refer to this overarching objective of the project as the 'common glue', confirming communication as an integral people factor in relation to boundaries and IM. It is often claimed that construction is all about the people who work in the sector, and social networks are suggested as an important entity in the desire to improve IM.

2.4.5 Social Networks

Pryke (2004) attributes the existing procurement methods as the main component of the interface problems that occur on construction projects. With the networks of relationships that result from the formation of work packages, social networks are offered as a concept to analyse and promote greater inter-firm relationships by focusing more on partnering arrangements, supply chain management and work/technology clusters. A 'work/technology cluster' in this context relates to a substantial section of a project whereby technical interfaces are identified within the management of the cluster and the number of boundaries are reduced compared to the current dominant method of dissecting the project into 'work packages', thus promoting better communication and fewer buildability and constructability problems (Pryke, 2012; Naoum and Egbu, 2016).

Gray (1996, cited in Pryke, 2012, p. 59) describes the creation of technology clusters:

1. Group together all contributors involved in given technology clusters
2. Bring together technical, quality and efficient solutions to support appropriate and practical design solutions
3. Create a fully integrated solution for the given system
4. Complete the system as an integrated unit
5. Create and sustain value through highly localised focus
6. Interface the system with related systems accurately and on schedule thereby transferring value without dissipation.

Item six is of particular interest to this research, as it highlights the importance of managing the interface in all its forms between systems, which is equally applicable to the management of offsite units to onsite works on many projects. Worthy of note are the process and people factors referred to in the above items: integration**,** quality and sustainability.

The objective of social networks is to determine the many node points that are formed by the organisations participating in a project and to use this information as an indicator of the levels of integration, collaboration and communication between the organisations (Smyth and Pryke, 2008). Aubry (2011) posits that networks formed at the boundary or interface can be a positive learning opportunity for all members of the network. Goh and Loosemore (2017) argue that social networks can translate to social capital. However, this is not an automatic result but rather, networks require development, learning and positioning to increase social capital.

Ruan et al. (2011) consider that due to the transient nature of construction, whereby networks are continually re-established from project to project, the application of social networks is difficult within the construction environment. Commenting on Pryke's stance on social networks, Ruan et al. (2011) consider that an essential component missing from Pryke's method is the inclusion of informal networks in the workplace, which can have a considerable influence on the efficiency of a project.

Nicolini (2002, cited in Kabiri et al., 2014) coined the phrase 'project chemistry' as a potent attribute in informal social networks; however, what is less understood is the effect of the informal networks on the formal networks. Farshchi and Brown (2011), in an attempt to apply social network analysis to a case study involving a multi-disciplinary construction organisation, found the process difficult to apply due to the continual changes in personnel. However, the informal process identified disconnected sub-groups, with the potential to cause major problems to the project, emphasising the importance of giving recognition to the existence of and value accrued from informal networks.

2.4.6 Project Interface Management

O'Connor et al. (1987, cited in Pavitt and Gibb, 2003, p. 10) state 'poor work packages can result in an excessive amount of interdependence among work packages, thus increasing the likelihood of delays'. It is incumbent on the main contractor to maximise the financial gain of a project. However, this can result in an excessive number of work packages beyond the overall interest of the project, resulting in a greater number of organisational interfaces than is necessary for the benefit of the project. This not only causes delays to the project but also results in an adverse effect on the overall success of the project. While offsite construction as an element of the process will possibly reduce the organisational interfaces, consideration should be given to the following:

- The project management issues may vary from the traditional (role of the project manager)
- Interface issues will need to be incorporated into the process at an earlier stage than traditionally (design management).

The importance of the role of the project manager in the control of project interfaces is an emerging theory in construction management (Shokri et al., 2016). Archibald (2003) argues that the main consideration of IM should be given to organisational relationships. Hence, the role of the project manager, which includes the planning, scheduling and control of a project, is representative of the role of a designated project interface manager. However, in the event that no interface manager is allocated, project managers will delegate physical and organisational interface controls to package or construction managers within their team (Shokri et al., 2016). This again emphasises the importance of communication as a people factor in the management of interfaces (Shokri et al., 2016). This is further emphasised by White and Marasini (2014) in a case study research into the management of interfaces between main contractors and subcontractors. The important findings from the research confirm that the proactive role of project managers and their teams along with face to face communication between main contractors and subcontractors are factors which will have a positive influence on resolving interface issues.

Table 2.6: Factors identified in literature attributed to traditional, offsite construction and IM

Factor	Authors
Supply chain management	Andujar-Montoya et al. (2015), Zhai et al. (2014), Gibb (2001), Chen et al. (2008)
Lean construction	Andujar-Montoya et al. (2015), Winch (2003), Mtech (2005), Jonsson and Rudberg (2014)
Design management	Gann (2000), Andujar-Montoya et al. (2015), Winch (2003), Mtech (2005), Gibb and Isack (2001), Blismas et al. (2005), Zhai et al. (2014), Gibb (2001), Jonsson and Rudberg (2014), Morris (1983), Pavitt and Gibb (2003)
Communication	Karim et al. (2006) Andujar-Montoya et al. (2015), Zhai et al. (2014), Emmitt (2010), Fellows and Liu (2012), White and Marasini (2014), Shokri et al., 2016
Role of the project manager	Durdyev and Ismail (2016). Andujar-Montoya et al. (2015), Mtech (2005), Jonsson and Rudberg (2014), Blankinship (2008), Pavitt and Gibb (2003), White and Marasini (2014), Archibald (2003), Sha'ar et al. (2016), Shokri et al., 2016
Culture	Andujar-Mo Zhai et al. (2014), Montoya et al. (2015), Blismas et al. (2005), Fellows and Liu (2012)
Integration	Andujar-Montoya et al. (2015), Akintan and Morledge (2013), Gibb and Isack (2001), Blismas et al. (2005), Zhai et al. (2014), White and Marasini (2014), Pryke (2012)
Client and design team	Bowley (1966), Zhai et al. (2014), Gibb (2001), Sha'ar et al. (2016)
Procurement	Gann (2000), Artto et al. (2008), Zhai et al. (2014), Blismas and Wakefield (2009), Mtech (2005), Chua and Godinot (2006), Pryke (2004)
Sustainability	Blismas et al. (2005), Jonsson and Rudberg (2014), Pryke (2012)
Tolerance	Winch (2003), Mtech (2005), Zhai et al. (2014), Gibb (2001), Rahman (2014), Morris (1983)
Quality	Winch (2003), Blismas et al. (2005), Zhai et al. (2014), Gibb (2001), Jonsson and Rudberg (2014), Pryke (2012), Sha'ar et al. (2016)
Whole life costing	Blismas et al. (2003), Mtech (2005), Blismas et al. (2005), Gibb and Isack (2001), Zhai et al. (2014), Gibb (2001)
Perception	Mtech (2005), Zhai et al. (2014)), Blismas and Wakefield (2009)
Health and safety	Blismas et al. (2005), Mtech (2005), Jonsson and Rudberg (2014)
Leadership	Gibb (2001)

2.5 Summary

The literature that makes reference to traditional construction has indicated that it continues to be slow to change. However, internal factors such as advances in materials and processes, and the growing involvement of stakeholders in the process, coupled with external factors such as an aging population, climate change, etc., indicate that the industry both locally and globally needs to embrace new forms of construction. The process of offsite construction and in particular offsite bathroom construction would appear to advance traditional construction. However, challenges still exist in relation to the interface management of offsite construction.

The concept of IM has received little research in the construction sector, with the continual fragmentation of the industry; IM would appear to be an area worthy of significant research. The review of IM has identified organisational interface management as the main focus for this research aligned with offsite bathroom construction as the main direction of travel for this research from a knowledge gap that exists in this area of construction management research. Table 2.7 lists the nine process and seven people factors that have been identified in the literature as possible factors that will contribute to the successful IM of offsite bathroom construction.

Table 2.7: Process and people factors

Process Factors	People Factors
Procurement	Communication
Supply chain management	The role of the project manger
Whole life costing	Leadership
Health and safety	Culture
Design management	Client and design team
Lean construction	Perception
Sustainability	Integration
Tolerance	
Quality	

Chapter 3 will review the existing literature on each of the process and people factors stated with particular reference to offsite construction and IM to identify any pertinent sub-themes that may have an impact on the installation of offsite bathrooms.

Chapter 3 – Literature Review: Part 2

3.1 Introduction

Chapter 2 justified the inclusion of nine process and seven people factors in this research. Each factor will be reviewed separately under their appropriate process or people factor heading. Their importance will be reviewed within the literature applicable with the main focus on the factors' relationship to interface management (IM) and offsite construction to gain a more in-depth understanding of each factor's contribution.

It was anticipated that there would be a level of interrelationship between the factors, both from a process and people perspective. However, while an increase in offsite construction literature is evident, literature applicable to IM in construction remains sparse.

3.2 Process Factors

The *Oxford English Dictionary* (2013, p. 811) defines process as 'a series of actions or steps to achieve a particular end'. The *Project Management Body of Knowledge* (2013, p. 47) determines that 'a process is a set of interrelated actions and activities performed to achieve a pre-specified result'. Anantatmula (2008) argues that many projects are managed with no formal processes, whereas formal processes have the potential to improve risk and increase the maturity of the management of the project in particular when offsite construction is involved.

3.2.1 The Influence of Construction Procurement

The Department of Business Innovation and Skills (2012, cited in Ruparathna and Hewage, 2015) define construction procurement as the 'process of identification, selection and commissioning of the inputs required to construct a project'. While the definition is succinct and clearly defines procurement as a process and implies a systems approach to its execution, it is disappointing that the definition makes no reference to the stakeholders involved in the construction process. Hughes et al. (2015, p. 12) offer a more detailed definition of construction procurement as:

> The strategic processes of funding, organising, managing and decision making in a construction project (or programme) at all stages of development, including the creation, management and fulfilment of contracts for construction work, consultancy and advice throughout the supply chain networks that collectively achieve construction output.

The latter definition is more relevant to the complexity of construction projects. It is also encouraging that recognition is given to the importance of stakeholder influence in the supply chain.

Traditional lump sum/fixed price was the sole procurement method used by the construction sector up until the mid-twentieth century. From the 1960s, construction management and design and build started to emerge as alternatives, followed by numerous hybrid versions. As clients have become more experienced they have demanded more efficient ways of procuring their projects (Oyegoke et al., 2009; Morledge and Smith, 2013). However, Lam and Wong (2009) and David and Dornan (2008, cited in Naoum and Egbu, 2016) both confirm that traditional procurement remains the dominant procurement route in the UK. Morledge and Smith (2013) argue that construction procurement is in a state of flux. With construction projects becoming more complex, construction procurement needs to change accordingly to promote innovative forms of offsite construction (Naoum and Egbu, 2016).

Walker and Rowlinson (2008) posit that clients and design teams do not give sufficient cognisance to the importance of deciding the procurement route. Rather, their decision is simply based on lowest cost, with no in-depth analysis of the modern processes that could be included to enhance the success of the project (Naoum and Egbu, 2016). Oyegoke et al. (2009, p. 340) argue that the chosen procurement route and subsequent conditions of contract will have a major influence on 'how production will take place'. Construction as has been previously stated is generally considered an adversarial environment. However, the use of offsite methods has stimulated the debate on the importance of the choice of procurement, and it is vitally important that actors central to the process are all 'on the same side of the fence' and engage in open communication, emphasising the importance of the client's choice of procurement (Nadim and Goulding, 2011, p. 85; Blismas and Wakefield, 2009; Pekuri et al., 2014).

A study of the top 100 UK house builders carried out by Pan et al. (2008b) identified 18 barriers to the uptake of offsite methods; surprisingly, the influence of the procurement route was not included in the list. However, it was identified in the study that 57 percent of respondents still prefer to use traditional procurement, with non-traditional routes, such as partnering at seven percent and design and build at five percent, scoring very low (Pan et al., 2008b, p. 63). A survey carried out by Tam et al. (2007) identified design and build as the preferred procurement route when incorporating offsite construction into the design, followed by strategic partnering, management contracting and traditional in order of preference. The study also cites communication between the main parties as a very important people factor.

Pasquire and Connolly (2003) argue that the chosen procurement route will determine the design process adopted for the project, which in turn will influence the methods of construction selected. In traditional procurement, the design is aligned to the Royal Institute of British Architects' plan of work (RIBA, 2013). Stage five is the construction stage at which the main contractor and subcontractors are introduced into the process. Problems may occur when the design requires the input of specialist subcontractors, as the traditional procurement route does not allow the subcontractor to participate during the design stages, as they will not yet have been awarded a contract. However, design and build contractors recognise the value of including the specialist subcontractor and manufacturer during the early design stages, in particular where offsite construction is involved in the design (Gil et al., 2001; Larsson et al., 2014).

A case study to better understand the management of offsite construction identified a partnering approach to the procurement route was best suited, as it also enhanced the management of complex interfaces (Doran and Giannakis, 2011). Goulding et al. (2012) and Araujo et al. (2017) do not stipulate partnering as the only procurement method for offsite construction, but emphasise the importance of choosing the 'best fit' procurement route when engaging with the offsite process. Furthermore, a procurement route that does not embrace collaboration between stakeholders will make both physical and organisational interfaces more difficult to manage. Pan et al. (2008b) identified 'complex interfacing between systems' as a major barrier to the uptake of offsite methods.

A review of a build-operate-transfer (BOT) procurement route highlighted the complexity of the multiple participants, the vast array of project elements and the interactions between the different parties (Chan et al., 2005). This led to the recognition that IM has an important role to play in the operation of the project to aid success. However, it is recognised that while IM techniques have been applied in other industries, for example aerospace, car and information systems, little evidence exists to demonstrate similar techniques being utilised in construction (Kumaraswamy et al., 2004; Chan et al., 2005). A survey of practitioners with experience of the BOT form of procurement resulted in the formation of a conceptual model of IM for BOT projects. Although Figure 3.1 appear simple, it signposts the need to acknowledge the importance of IM and the more complex process of identifying, simplifying, prioritising and managing interface factors in a cyclical manner, to aid the success of the project. Furthermore, its use should not be restricted to BOT projects, as its principles can be applied to any project that promotes an integrated approach.

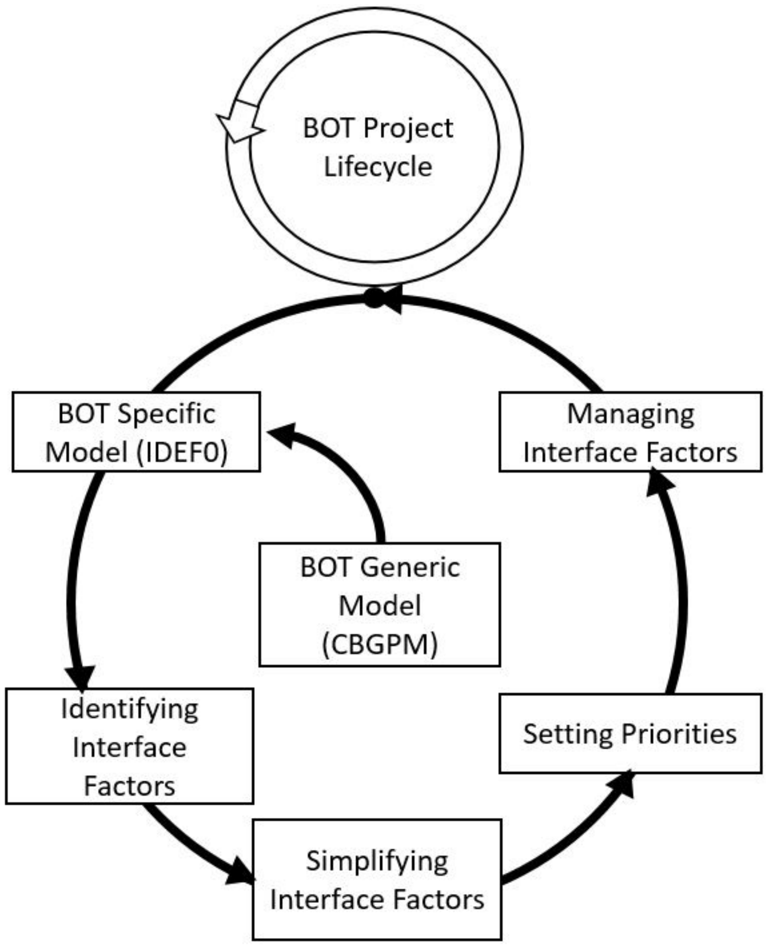

Figure 3.1: BOT generic model (Chan et al., 2005)

Larsson et al. (2014) suggest that the client should specify the minimum of detail to allow the contractor the opportunity to innovate and introduce offsite methods where they are considered beneficial during the early design stage of the project. Jaganathan et al. (2013) argue that designers (that is, architects) that are inexperienced in the manufacturing process should not lead the design of offsite units and that the incumbent procurement route should allow the manufacturer early access to avoid onsite interface problems marring the process. While it is suggested that the procurement route has a major influence on the design process and subsequently the management of design, Mohammad et al. (2014) argue that the procurement route also has a significant influence on the level of integration adopted within the supply chain, suggesting that a lack of trust between supply chain members is endemic regardless of the procurement route. Goulding et al. (2012) argue that a root and branch review of procurement is required to promote a greater level of co-operation and collaboration between stakeholders that will allow offsite methods to be considered on a par with traditional methods. It is further argued that a 'paradigm shift' from the current procurement routes is required to give equal consideration to both offsite and traditional construction. Recognition should also be given to the higher level of precision and tolerance required at the interface of offsite and onsite works when deciding on the procurement route (Blismas and Wakefield, 2009; Nadim and Goulding, 2011).

A comprehensive review of construction procurement practices carried out by Ruparathna and Hewage (2015) states that interest is now moving towards 'green procurement', which looks to incorporate environmentally friendly materials and services into the tender documentation, thus clarifying clients' approach to reducing the environmental impact of their projects on the environment (Uttam et al., 2012). A report compiled by Price Waterhouse Coopers (2009, cited in Ruparathna and Hewage, 2015) predicts that green procurement has the potential to cut carbon dioxide emissions by 70 percent and reduce lifecycle costs by 10 percent, which would suggest that green procurement has the potential to promote innovative forms of construction such as offsite construction (Testa et al., 2012).

3.2.2 The Importance of Design Management

The complexity of construction projects has in turn resulted in a complicated design process. The process of design involves physical solutions, which are achieved by human interaction, whereby each of the actors involved will have their own interpretations and perceptions as to what constitutes the best design. However, it is a generally held view that the management of the design process within construction lags behind other industries such that deficiencies in the design process contribute to poor productivity and quality onsite (Knotten et al., 2015). Furthermore, the skillset of design managers is in question as to whether they possess the required technical and human skills to carry out the role effectively (Tzortzopoulos and Cooper, 2007).

The design process starts with a briefing between the client and the architect. The importance of the briefing process should not be underemphasised. The primary function of the design team is to identify, understand, articulate, define and manage the client's requirements (El-Reifi et al., 2014). However, Knotten et al. (2015, p. 122) argue that the briefing stage should be 'creative, iterative and innovative', suggesting that the opportunity should be used to abandon the status quo and liberate the design. However, if the client's fundamental requirements are not identified in the briefing process and not achieved, it can lead to a project being viewed as a failure by the client, regardless of the cost, time and quality outcome.

Traditionally, the design phase and the construction phase were seen as separate operations, each able to function independently, with design the domain of the architect and construction the province of the project manager (Ahadzie et al., 2014). The management of the many designers, and client and contractor representatives that are involved in the design process requires the design manager to understand and adopt a positive approach to integration and collaboration, never more so than when understanding the relationship between the client and design team (Knotten et al., 2015; Karna and Junnonen, 2017).

Research has identified the importance of the 'design-construction interface' and the need for both the design team and construction team to have a greater understanding of each other's specialism (Mitchell et al., 2011; Ahadzie et al., 2014). Furthermore, Alarcon and Mardones (1998) highlight the lack of communication and co-ordination between designers, which directly affects the design interface. It is suggested that this may be attributed to a lack of knowledge in areas related to buildability and constructability by designers and a lack of input by the various specialists involved in the project (Karna and Junnonen, 2017). Lam and Wong (2009) argue that the abstract concept of buildability/constructability is not given adequate recognition as a contributor to a quality design. However, its effect can have a negative influence on the time, cost, quality and safety outcomes of the project (Naoum and Egbu, 2016).

An ethnographic study carried out to review an integrated design approach to timber offsite construction identified onsite assembly problems resulting from dimensional variations that had not been envisaged in the design process. Figure 3.2 suggests that onsite assembly is not prominent in the design team agenda, which in this study resulted in remedial works being carried out onsite due to the interface problems with the offsite/onsite structure (Jaganathan et al., 2013; Arashpour et al., 2017).

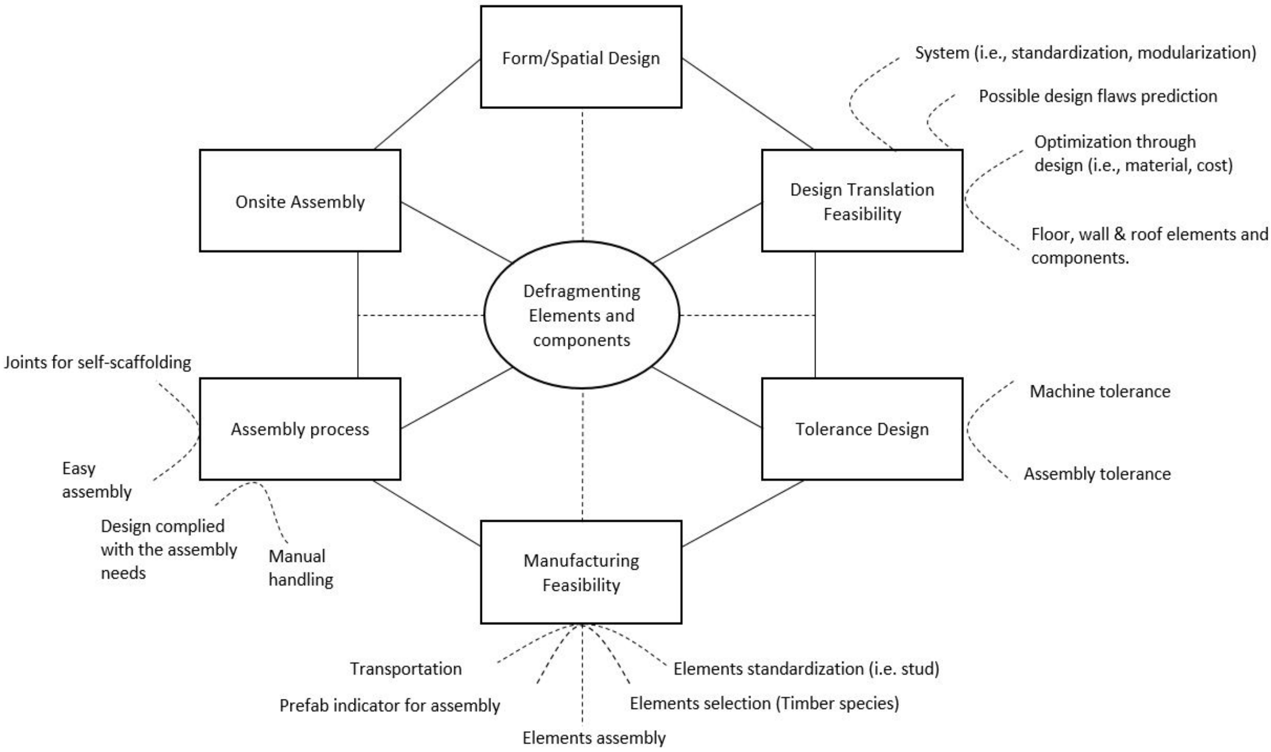

Figure 3.2: Integrated design lifecycle (Jaganathan et al., 2013)

A study of four projects associated with the same construction company by Alarcon and Mardones (1998) using a qualitative research approach with observations and interviews, identified that 40 to 50 percent of design time is taken up by design changes and that a considerable amount of time is wasted during the flow of design information. This compromises relationships between the main stakeholders thus emphasising the call for the design manager to plan and co-ordinate the design process effectively (Mitchell et al., 2011). The study also concluded that the design process displayed a lack of co-ordination among the specialists involved in the process and that the designers displayed a lack of construction knowledge.

Pasquire and Connolly (2003) and Mitchell et al. (2011) argue for closer integration and co-ordination among designers to assist in overcoming the continuous problems associated with the interface between the design and construction of components. Isaac et al. (2014) propose a 'modularisation design' approach whereby the modular component is designed to incorporate interface connections that in the original design would have been installed by a different subcontractor, thus alleviating the potential interface problems. Greater freedom should be given to manufacturers to contribute directly to the design process, thus improving communication, and buildability and constructability issues.

Chua et al. (2003) propose a 'process-parameter-interface model' (Figure 3.3) to aid the management of the design process. The model has been developed to encourage transparency in communication and collaboration. The component parts of the model include the interface, which encourages specialist designers to share essential design information with other specialists. The other component parts of the model include the engine, which promotes collaboration between the various parties and the design dictionary, which acts as a vehicle for accumulating information from other designers. All designers can access the dictionary to gain a better appreciation of other design functions. While in practice the model may not be considered a new approach to the design process, its value can be attributed to highlighting the importance of transparency and the sharing of information between specialist designers, which in turn can have a positive effect on the interface issues when reviewing the design process.

A review of two case studies in India by Senthilkumar and Koshy (2008) to investigate the management of interface issues associated with the design stage identified a lack of information as the main factor in the interface problems. While the paper lacks a robust methodology and does not identify any new system to manage design interface issues applicable to complex projects, it serves to highlight that most interface issues start from the design process. This therefore makes design IM an important factor when considering either offsite or onsite construction.

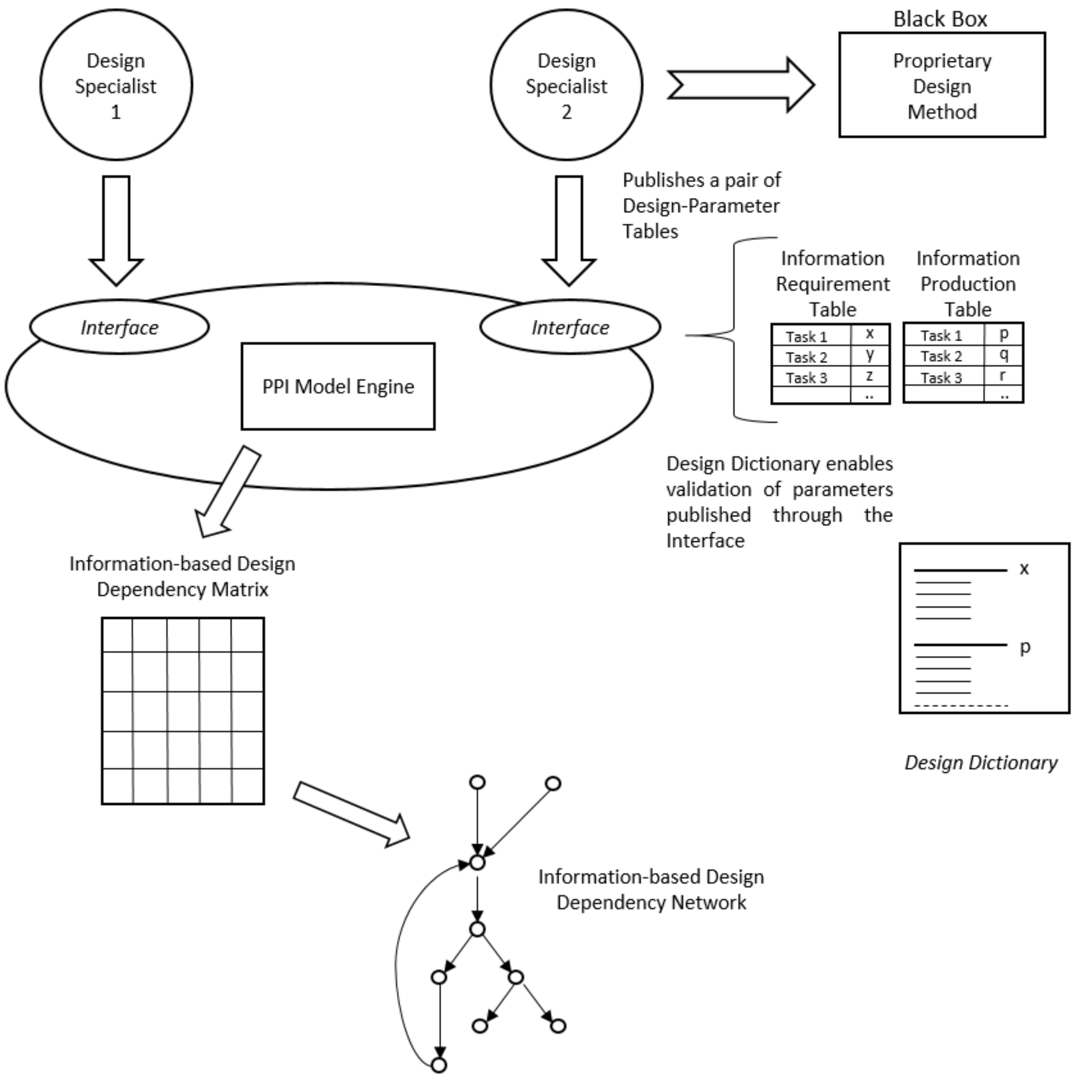

Figure 3.3: Process-parameter-interface model (Chua et al., 2003)

In their paper to identify the dominant drivers and constraints that influence offsite construction in Australia, Blismas and Wakefield (2009) do not identify design management as a driver or constraint. However, they acknowledge that the traditional design process is not compatible with offsite methods nor is the knowledge of offsite and IM prevalent in traditional design. This may be attributed to the need for the client and design team to freeze design much earlier than is required in traditional approaches.

A Swedish study by Engstrom and Hedgren (2012) to understand clients' acceptance of offsite construction identified that, in general, clients are more inclined to stick with the status quo and are reluctant to make decisions that will introduce innovative processes to their construction project. The main exception identified was when the procurement route was design and build (D&B) which allowed the D&B contractor to make innovative decisions. The results of the study indicate that both experienced and inexperienced clients are not informed of all the relevant information on offsite methods and are more likely to be informed of the barriers and constraints by the design team (Engstrom and Hedgren, 2012). A study of four EU countries analysed qualitative data from 54 interviews and concurred that, when all relevant actors at the design stage have access to the relevant information at the same time, the design management and resulting physical interfaces benefit from a more collaborative and integrated approach, which should also permeate the supply chain (Nadim and Goulding, 2011). Mitchell et al. (2011) argue that the flow of design information from specialists would benefit from a procurement route that allows early engagement of specialists. Pulaski and Horman (2005) posit that when contractors are allowed to provide information at the design stage it has a positive effect on buildability and constructability issues and the overall performance of the design

3.2.3 A Modern Approach to Construction Supply Chain Management

Supply chain management (SCM) is a term that was coined in the manufacturing industry in the 1960s, but its use did not resonate in construction until the 1980s. Green (2011) argues that the adoption of the popular term by the construction industry was mainly to legitimise the increased use of subcontractors rather than improve the construction process through a more modern management approach. However, it is also acknowledged that main contractors are slowly realising the benefits of a proactive approach to enhance the co-operation and collaboration with subcontractors and suppliers for the benefit of the project, thus making an incremental step in the pursuit of a pragmatic approach to construction SCM (Annan, 2012).

Numerous definitions of SCM abound in management literature. However, definitions relating to construction SCM are sparse. Akintoye et al. (2000, cited in Tong, 2011, p. 69) offer the following definition:

> Construction SCM may be regarded as the process of strategic management of information flow, activities, tasks and processes, involving various networks of organisations and linkages (upstream and downstream) involved in the delivery of quality construction products and services through the firms and to the customer, in an efficient manner.

The definition acknowledges the two levels of flow, upstream and downstream. However, it is suggested that little cognisance is given to the interfaces and interdependencies which exist between the numerous parties, and that practice has been shown to be the main problem area of inefficient construction supply chains.

Construction SCM in the context of this research is seen as a process in an industry which is process driven. Vrijhoef and Koskela (2000) argue that the main characteristic of the construction supply chain is that all materials are delivered to the site. The typical supply chain is temporary and fragmented and is set up for one new project, with little chance of repetition. Figure 3.4 suggests the four roles that emanate from the characteristics identified. Roles one and two relate to the traditional method of managing the supply chain activities onsite, role three relates to utilising the supply chain offsite and finally role four advocates improvement in production by integrating the supply chain such that offsite and onsite production can co-exist.

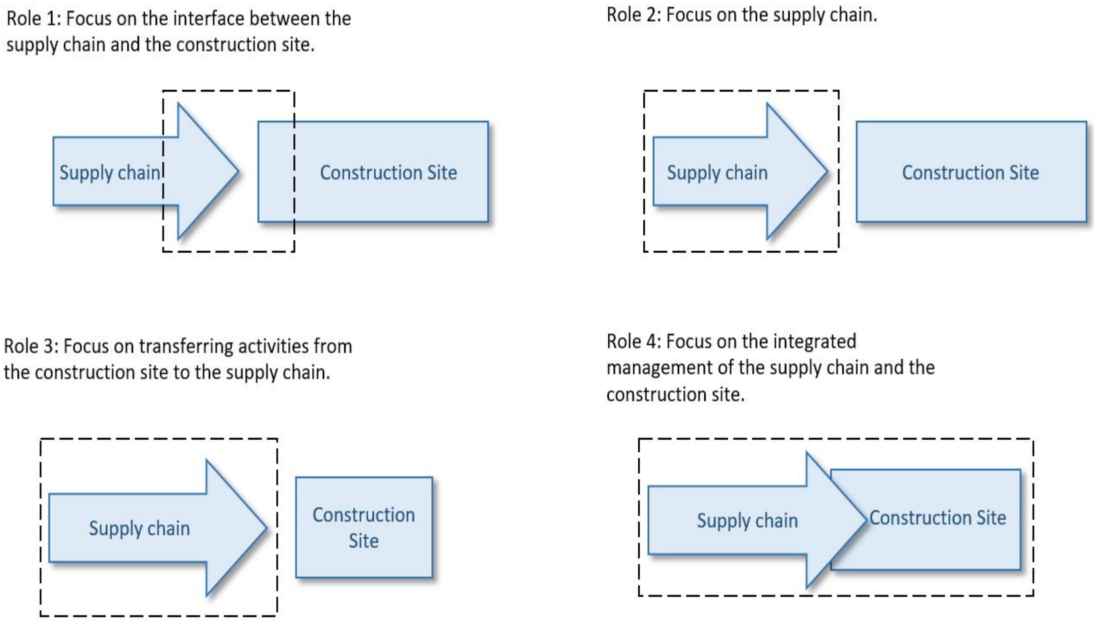

Figure 3.4: The four roles of supply chain management in construction (Vrijhoef and Koskela, 2000)

Construction SCM has many facets. It is the organisational interrelationships that exist, for example the end user and client interface, client and design team interface, main contractor and subcontractor interface, production and organising interface, and organising and handing over interface, that will have major influence on the success of the supply chain (Behera et al., 2015). Al-Hammad (2000) states that the literature mainly focuses on the relationship between two parties whereas, in a practical sense, a decision directed at one organisation will have a ripple effect and cascade to numerous organisations involved in the process. Peat and McCrea (2009) suggest that, although construction SCM is termed a process, recognition must be given to the human relationships that emerge between the parties. Wolstenholme et al. (2009) argue that the construction industry has slowly awoken to the importance of people issues in relation to its processes, such that the people factor of integration is seen as an important factor, never more so than in the integration of the supply chain.

Behera et al. (2015) argue that large construction organisations are now embracing manufacturers' approach to SCM by the inclusion of 'lean construction' in their processes. However, Tennent and Fernie (2014) consider it unhelpful to the uptake of construction SCM to make the direct comparison with the management of manufacturers' SCM. Thunberg et al. (2017) assert that the construction sector does not have a knowledgeable understanding of how best to adapt its traditional structure to gain the maximum benefits from SCM. Furthermore, a new approach by large construction organisations to include specialist contractors and suppliers earlier in the process may facilitate the integration of 'offsite manufacturers' thereby better integrating the construction supply chain (Peat and McCrae, 2009; Mostafa and Chileshe, 2016).

Al-Hammad (2000), in a review of literature and interviewing construction professionals, identified 19 interface problems common to the main supply chain members. These were categorised under four general headings: financial, contract and specification, environmental and miscellaneous interface problems. Interestingly, contained within the latter section are issues common to the industry in general: poor communication, delays in decision-making by the client, lack of management supervision, poor quality of work and poor planning and scheduling. Good planning is incumbent on the main contractor when managing supply chain members, while poor planning has been identified as a major contributor to extensive delays, which have occurred in many of the complex projects executed in the UK (CIOB, 2008). The CIOB (2008) report calls for the design team to be more involved in the 'time-management strategy'. This integrated approach should be welcomed by the industry. Conversely, contractors' contributions at the design stages would benefit the process in general, but particularly the offsite process.

Tenant et al. (2012) argue that the client is the key decision maker as to whether the project will be built using traditional methods or whether offsite units will be incorporated. The adoption of offsite units will have the effect of altering the balance of power within the supply chain and consequently the organisational interfaces between members, such that many of the smaller subcontractors within the traditional supply chain (plumbers, electricians, joiners, etc.) will be replaced by a specialist manufacturer. Main contractors may find this unnerving and high risk due to the scarcity of such manufacturers. Therefore, risk-averse clients, designers and main contractors may prefer to maintain the status quo of traditional supply chains (Wolstenholme et al., 2009; Tennant et al., 2012).

Pan et al. (2008b) identify the immaturity of construction SCM as hindering the uptake of offsite construction by the late inclusion of manufacturers in the process. As mentioned previously in Section 3.2.2, complex interfacing when incorporating offsite bathrooms onsite would appear to be a barrier to the formation of an offsite-focused construction supply chain that can compete equally with the traditional-focused supply chain. Therefore, the challenge to the offsite sector is to demonstrate the benefit of integrating suppliers and manufacturers along with clients, designers and main contractors at the inception of the supply chain in order to educate the other members of the supply chain (Doran and Giannakis, 2011).

3.2.4 The Argument for Whole Life Costing

For the purpose of this research whole life costing (WLC) and lifecycle costing (LCC) are used interchangeably, although some researchers in the field, for example Meng and Hardshaw (2013), would attest to subtle differences in definition. However, a full discussion of this is out with the scope of this research. Higham et al. (2015) assert that LCC is well understood by the main stakeholders that make up the construction process, adding that its prevalence is due in part to the divergence of the procurement routes available. However, its practical application does not appear to match its understanding. Wolstenholme (2009) emphasises the need for the industry to have a better appreciation of value in comparison to lowest cost, which is still the dominant decision maker in the award of a contract. The creation of value is dependent on the WLC of a project, whereby decisions made at the design stage can have a major impact on the value and WLC (Wolstenholme, 2009).

An analysis of the LCC of housing stock in the UK identified that approximately 35 percent relates to construction cost, 50 percent to usage costs and 15 percent to the end of life associated costs (Rosa et al., 2014). Rosa et al. (2014) affirm the importance of incorporating sustainability at the design stage of house construction, in particular the energy usage which contributes to the largest impact on cost in use and is predicted to rise in the coming years. The high level of energy cost in the built environment in general is reiterated by Zeller at el. (2013), who also advocates that clients should give consideration to the LCC rather than just the initial costs. Kamali and Hewage (2016) assert that energy savings in modular offsite construction indicate a lower WLC compared to traditional construction. However, until the appropriate data are available this is an educated assumption.

Questionnaire surveys carried out by Olubodun et al. (2010) and Opoku (2013) to appraise the use of LCC in the construction industry identified the following barriers to its widespread use: lack of understanding of the application and technique, the absence of a standardised method of application, the complexity of the process and the lack of motivation by clients. A more recent survey carried out by Higham et al. (2015) concurred that LCC is rarely used in construction, identifying industrial and commercial projects as highly unlikely to use it, with the health sector most likely of all to use LCC, although it is still rarely used and only if instigated by the client, suggesting a short term strategy by the industry at large.

Public sector projects, in particular private finance initiative (PFI) and public–private partnership (PPP) projects would appear to embrace the philosophy of WLC more than any other sector. This could be attributed in part to the long term responsibility placed on the contractor (Olubodun et al., 2010). Meng and Hardshaw (2013) agree that PFI and PPP projects are the dominant users of WLC, but suggest that there is still a lack of awareness of the benefits of their application by the industry at large. A study carried out by Swaffield and McDonald (2008) would appear to contradict in part the findings of Olubodun et al. (2010) when considering the practical application of LCC on PFI projects. Swaffield and McDonald (2008) state that its use is intermittent, since when the quantity surveyors are very busy or budget allocations are tight, they are less likely to implement LCC, but rather will adopt the default position of lowest price thus compromising the facilities management of the project and ultimately the profit margin.

A quantitative survey by Nadim and Goulding (2010) to gauge the construction industry's views on aspects of offsite construction identified that a very small number of participants (four percent) considered that using offsite construction improved the use of LCC or added value to the project. A later study by Nadim and Goulding (2011) identified cost as a significant barrier to the uptake of offsite production methods, arguing for a lifecycle approach to make realistic comparisons between optional methods, whereby direct and indirect costs are factored into the framework.

Nadim and Goulding (2011) suggest that physical and organisational interfaces require to be considered during the design phase when considering offsite solutions, due to the considerable costs that can result. Hamid et al. (2012) argue that there is a strong link between offsite manufacturing and green procurement to further the implementation of WLC in that green procurement promotes a more sustainable approach to the whole construction process by calculating the cradle to grave cost in tandem with the design. Pan et al. (2007) suggest that the more offsite construction methods are used, the more predictable the LCC will be. With particular reference to offsite bathrooms, Pan and Gibb (2009) identified a higher initial cost and a lower maintenance cost associated with offsite bathrooms in comparison to onsite, indicating a lower WLC for offsite bathroom construction. Blismas and Wakefield (2009) argue that when offsite methods are used, the management of the interfaces is given more consideration, which in turn contributes to lower WLC. However, evidence would suggest that the process of WLC remains sporadic, with little appetite within the industry to engage wholly with the process. Furthermore, with construction clients fixated by lowest price, the cost comparison between offsite and traditional construction will always be skewed in favour of the latter (Wolstenholme et al., 2009).

3.2.5 Health and Safety: the Need to Square the Triangle

It is often documented in construction management literature that the 'construction worker' is our most valued resource and therefore the health and safety (H&S) of the workforce should be the industry's top priority (Hinze et al., 2013). However, before the start of the twenty-first century, H&S was viewed as a 'bolt on' considered only when an accident occurred onsite.

Various reports and forums and the introduction of the Construction (Design and Management) Regulations 1994 (CDM), revised in 2007 and updated in 2015, aided a more integrated approach to H&S in the UK (Rawlinson and Farrell, 2010). The process of H&S has now been upgraded to the same level of importance as time, cost and quality by many clients and most main contractors. Hare and Cameron (2012) argue that the integration of H&S into the iron triangle model, which comprises cost, time and quality, is accredited with not only improving H&S but also contributing to improvement in the three dominant factors, thus arguing for parity for H&S.

US researchers Toole and Gambatese (2008) propose a similar process to CDM, 'construction hazards prevention through design', whereby engineers and architects give due consideration to the effect of their design on H&S during the construction stage with the objective of reducing potential accidents. Toole and Gambatese (2008) argue that the adoption of this process will encourage architects and engineers to design in the use of offsite methods of construction, more so than the CDM 2015 regulations which require the designer to carry out a risk assessment of their design, with minimal focus on the actual construction processes as a means of reducing onsite hazards.

Many major construction organisations now understand the importance of an exemplary H&S record as a marketing tool for winning work from potential clients. Experienced clients also comprehend the damage that can be done to their reputation when a major accident occurs onsite (Wolstenholme et al., 2009). However, the construction industry still remains one of the most dangerous industries to work in with 43 fatalities compared to 27 in the manufacturing industry for the period 2015/16. While 43 and 27 fatalities are both unacceptable, it does demonstrate manufacturing as a safer, more controlled environment in comparison to onsite construction (HSE, 2016).

Manu et al. (2014) argue that the client, design team and main contractor, if contracted at the pre-construction stages, can have an indirect influence on the H&S outcome of the project. Construction project features such as the chosen procurement route, the method of construction, project duration, complexity of design and level of sub-contracting can have a causal influence on the accident rate of a project. The organisational ability of the project manager can be seen as an important skill in the effective management of a project and, in particular, the effective management of complexity, to minimise congestion and thus improve H&S onsite (Chileshe and Dzisi, 2012). Strong leadership is required from the construction project manager to promote a culture of integrating H&S into all stages of the lifecycle of a project, not just the construction phase. Equally, the project manager should endeavour to build good relationships between stakeholders by nurturing open communication to promote a 'lessons learned' environment as opposed to the traditional blame culture, which is prevalent in today's construction environment (Kines et al., 2010; Smallwood and Venter, 2012). Kines et al. (2010) argue that H&S communication is dominated by bureaucracy in the form of paper trails and that greater emphasis should be placed on how best to get the safety message across to the workforce, either through verbal, written, pictorial or a combination of all three forms of communication. Also of equal importance is a positive example of safety behaviour from line management to the workforce (Sherratt et al., 2012).

A recent study to compare the accident rates between traditional and various offsite construction methods confirmed offsite as the safest method. However, it should be acknowledged that the study was based on a single case study comparison of each method, which can be classified as a small sample.

Furthermore, the reduced time onsite was considered a major contributing factor in reducing accident rates onsite, strengthening the argument to manufacture as much of the work offsite as possible (Rubio-Romero et al., 2014). A study of housebuilders' use of offsite methods, which included offsite bathrooms, confirmed that H&S was deemed an important benefit due to the volume of work executed within a factory environment (Pan et al., 2008b; Arif and Egbu, 2010; Kamali and Hewage, 2016). Moreover, the use of offsite methods improved onsite H&S, not just by the reduced volume of work, but by the operatives being trained in the installation of the offsite components (Shahzad et al., 2015). Furthermore, it could be argued that the use of offsite methods which gives due consideration to the practical interface problems of incorporating offsite units onsite can contribute to the general H&S of the workforce onsite (Nadim and Goulding, 2011; Kamali and Hewage, 2016). Kelly and Berger (2006) highlight the importance of IM in relation to improving H&S processes, by affirming that successful communication is the key to managing the interface problems that result in incidents or accidents occurring onsite.

Goh et al. (2012) claim that the construction industry has seen a slight cultural shift away from automatically blaming the victim to considering the process and the safety management system in place, thus reviewing the causes and effects that led to an accident or incident. Kelly and Berger (2006) cite an incident that occurred in an oil refinery, whereby due to a lack of communication between the process and maintenance crews an explosion occurred resulting in two operatives losing their lives, confirming the need to be mindful not only of physical interfaces but also of organisational IM. Ulang et al. (2009) concur with the importance of the people factor of communication and add the need to complement communication with the people factor of integration not only during the construction phase but equally during the design phase, thus improving the IM and H&S outcomes of the project in equal measures. Furthermore, Cameron and Hare (2008) argue that a project that integrates the management of H&S with project planning is more likely to be proactive in highlighting buildability and constructability problems, which in turn will uncover potential interface problems both physical and organisational, which can lead to a more practical and safe outcome.

3.2.6 The Compatibility of Sustainability to Offsite Construction

Sustainability has seen an explosion of literature within the construction management field over the past ten to 20 years. Construction accounts for 50 percent of UK carbon emissions, 50 percent of water consumption, 35 percent of landfill waste and 13 percent of raw materials used in the UK. Furthermore, construction stakeholders have been implicated and blamed as 'destroyers' of the environment due to the misuse of the above resources and methods of construction (Matar et al., 2008; Akaditi and Fadiya, 2013; Sfakianaki, 2015). Du Plessis defines sustainable construction as:

> A holistic process in which the principles of sustainable development are applied to the comprehensive construction cycle, from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their possible final deconstruction and management of the resultant waste (Du Plessis, 2002, cited in Matar et al., 2008).

While the definition captures the influence of the construction process over the lifecycle of a project, it falls short of not making reference to the impact of current practices on future generations (Sfakianaki, 2015). Kamari and Hewage (2016) argue that over the lifecycle of modular construction sustainable impact is reduced, not least in the energy used and pollution created onsite.

The UK government's *Construction 2025: strategy* document includes sustainability as one of its set of five initiatives to develop a world class industry for the future. The objective of the sustainable factor is to develop a low-carbon construction industry than can meet the demands of a green sustainable global economy, which is forecast to grow at a rate of 4.3 percent per annum until 2025 (Gov UK, 2013). Akadiri and Fadiya (2013) carried out a questionnaire survey of construction professionals to determine the industry's perception of the main factors that contribute to sustainable construction practices. The findings from the analysis of the 91 survey questionnaires suggest that government regulations are the most influential factor in the uptake of sustainable practices, followed by the influence of top management. A strong correlation was identified between government pressure and top management influence within major construction enterprises. A further study by Osmani (2014) concurred with the Akadiri and Fadiya (2013) findings but added that a high proportion of the construction supply chains are small to medium organisations not willing to make a cultural shift from traditional practices. This would suggest that the majority are not influenced by government initiatives or top management. Furthermore, it could be argued that the current mindset of construction professionals is stagnant with ever increasing targets being forced upon them (Thomson and El-Haram, 2011).

While tools exist to measure the environmental impact at the construction stage, they do not give recommendations for sustainable practice during the design stage (Yunus and Yang, 2014). Moreover, to improve the uptake of sustainable construction action plans and assessment, tools are required which give guidance on best practice and measure the progress being made over the lifecycle of the project, rather than relying on anecdotal evidence (Thomson et al., 2008; Thomson and El-Haram, 2011; Marjaba and Chidiac, 2016). Matar et al. (2008) introduce a framework entitled ‘operational context space’ where the concept comprises three dimensions:

1. Project lifecycle phases (each phase will contribute to sustainable construction)
2. Project execution entities (clarification of which professionals fall within the boundary of a particular work entity)
3. Sustainability performance parameters (the measurement of 18 parameters).

A significant benefit of operational context space relates to its ability to measure not only qualitative but also quantitative data, thus providing an assessment the industry practitioners can benchmark. Yunus and Yang (2014) suggest that a more holistic approach is required, whereby an integrated approach over the lifecycle of the project takes cognisance of the environmental, social and economic dimensions at each stage by involvement of professionals (clients, designers, contractors and manufacturers) that have a view on sustainable practice. Kamali and Hewage (2017) offer a performance criterion to measure the 'triple bottom line' of environmental, social and economic categories. The results of their questionnaire survey confirmed that industry professionals consider that economic criteria are the main influence on sustainability, followed by social then environmental factors. Worthy of note is that of the 33 sustainability indicators identified in the survey, the top ranked indicator was from the social category 'workforce health and safety', confirming the increased gravitas of the social dimension within the triple bottom line.

Matar et al. (2008) suggest the barriers to the uptake of sustainable construction include:

- A lack of interest from a high percentage of professionals
- The lack of training or education in sustainable design and construction
- High initial costs of sustainable building alternatives
- The lack of a framework that gives guidance on practices that comply with sustainable construction.

Robichaud and Anantatmula (2011) argue that the high cost of implementing sustainable construction is the main barrier and that a paradigm shift from traditional project management is required to make sustainable construction more acceptable to clients' budgets. Moreover, sustainability can be influenced by design decisions, material selection, waste recycling and energy use (Sfakianaki, 2015). Figure 3.5 identifies the fundamental steps required to implement sustainable project management. Most striking are the need to consider the end product at the beginning of the design and the integration of the team from the design stage, not solely at the construction stage (Matar et al., 2008).

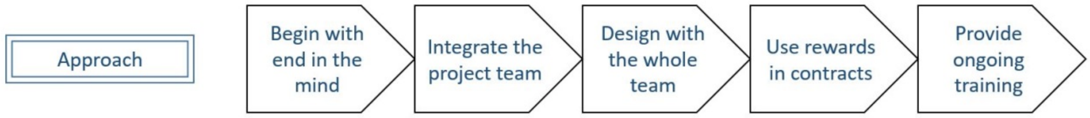

Figure 3.5: Sustainable project management (Robichaud and Anantatmula, 2011)

Reduction in material waste is considered one of the main benefits of offsite construction to sustainable construction (Hamid et al., 2012; Yunus and Yang, 2014; Kamali and Hewage, 2017). Hamid et al. (2012) offer some additional benefits:

- Controlled production environment – better workmanship
- Offsite manufacturing and building materials – materials that are formed into composite components (offsite bathrooms)
- Offsite manufacture and logistics – a logistics plan that is reduced to one-third in comparison to the total transportation for the onsite project.

Lu and Yuan (2013) dispute offsite logistics as a positive contributor to sustainable construction, implying that in most cases transportation is increased and therefore has a negative impact on the environment through increased carbon emissions while also increasing the cost of transportation. It could be argued that sustainable project management that gives consideration to sustainability at the design stage, or even earlier at the concept stage, and integrates the main actors during design is more amenable to the use of offsite forms of construction as alternatives to traditional. Therefore, this provides a paradigm shift in the thinking and decision-making that may improve the efficiency and sustainability of construction in the future (Sfakianaki, 2015).

No reference to any direct relationship between sustainable construction and IM was found in the literature. However, the use of offsite components indirectly implies a level of IM, which as reviewed above contributes to sustainable construction.

3.2.7 The Influence of Lean Construction

The Toyota production system, more commonly referred to as 'the Toyota Way' is widely accredited with being at the vanguard of the promotion of lean production, whereby the philosophies of 'continuous improvement' and 'respect for people' are at the centre of its approach (Gao and Low, 2012). Liker (2004) has adapted the principles of the Toyota Way to create a model based on the four 'p's of philosophy, process, people and partner, and problem solving to give the 4P model (see Figure 3.6). Central to the 4P model is the role of process and people, which advocates and encourages the process of standardisation of materials and components, while developing new skills for the individual trades and teams involved. In a construction sense, this could be interpreted as promoting innovation in the current processes and people by endorsing offsite forms of construction and promoting the upskilling of construction workers to a multi-skilled status (Mostafa et al., 2016).

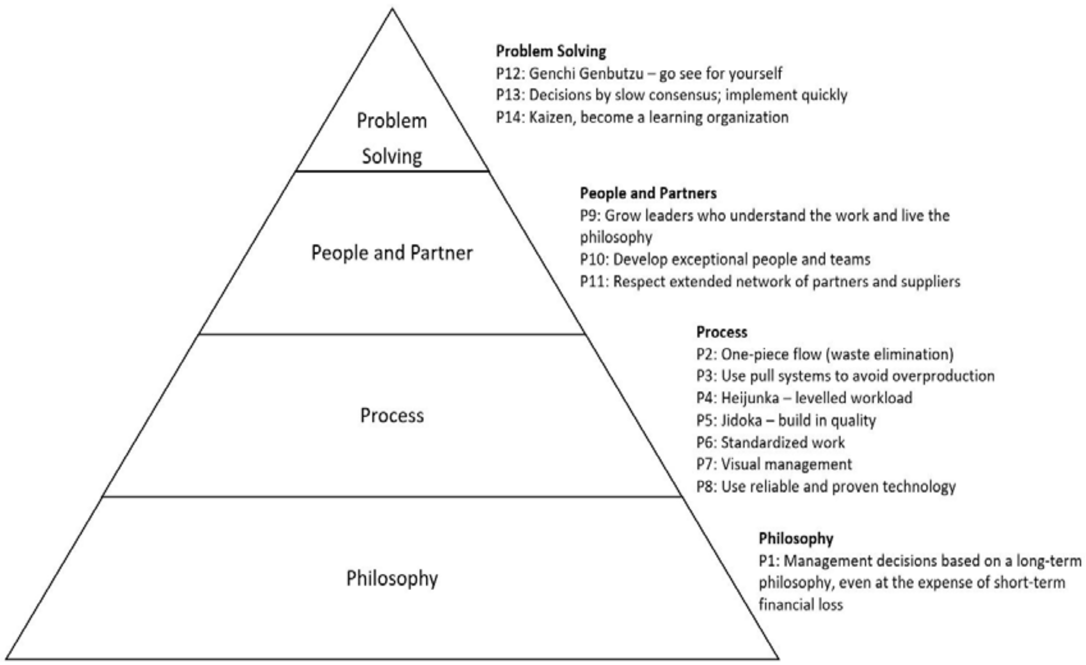

Figure 3.6: 4P model of the Toyota Way (Liker, 2004)

The term 'lean construction' was introduced to the construction industry circa the 1990s, and while there has been a wealth of literature written on the topic, confusion still exists among practitioners as to the full meaning of the term. The common view is of a process to reduce labour and material waste (Alves et al., 2012). Pasquire (2012) acknowledges that construction differs from manufacturing, but advocates that the lean production principles of 'just in time' and 'no waste' should be viewed as a long term strategy for construction. Furthermore, Zimina and Pasquire (2011) suggest that there is some evidence of lean thinking and construction being embedded in the larger construction organisations. Chesworth et al. (2011) suggest that the current approach to the implementation of lean thinking in construction is based on a deductive methodology, whereby the focus is on tools, when in fact an inductive approach that recognises that tools and systems will not bring about change without endorsement from the workforce tasked with their implementation is needed and this will require a cultural change from all members of the project team (Schaufelberger and Holm, 2017).

Jorgensen and Emmitt (2009) argue that concepts and systems that originate from other industries do not easily transfer directly to construction, such that no clear definition exists for lean construction, other than definitions which relate to lean manufacturing that have been used to define lean construction. Furthermore, the premise of being 'leaner' implies downsizing and outsourcing, activities the construction industry has been active in since the 1970s. Outsourcing has resulted in multiple organisations being involved in a construction project, each with their own agenda and interpretation of what constitutes lean construction, resulting in a fashionable term being peddled with little or no benefit to construction (Green and May, 2005). Simonsen et al. (2014) question the validity of lean construction as a long term strategy for construction and imply that it is fast becoming considered a 'fad', whereby the hype dissipates over time.

Traditional construction has difficulty implementing lean thinking. However, offsite construction products manufactured in a factory environment are considered bedfellows with the lean thinking philosophy of lean production, such that wastage is reduced, site safety is improved, quality is enhanced, sustainable construction is increased and the overall project time is improved (Senaratne et al., 2010). A questionnaire survey within two offsite factories to measure the uptake of lean principles based on the 4P model identified that all four factors require to be implemented concurrently to gain continuous improvement. A further finding from the analysis highlighted a management approach whereby both a top-down and bottom-up approach were required to engage both management and operatives to strive for a more efficient outcome (Meiling et al., 2012). Pasquire and Connolly (2002) postulate that greater use of offsite construction, whereby lean thinking is used in the factory, will have a positive influence on the uptake of lean construction for onsite works. However, it is recognised that clients and consultants continue to resist offsite forms of construction, which would suggest that the uptake of lean construction is dependent on the uptake of offsite construction. Miles and Ballard (2002) argue that to benefit from the application of lean construction requires lean thinking to be embedded into the design process, never more so than in its application at the design/construction interface of offsite components.

Low et al. (2015) state that lean construction advocates the early involvement of contractors at the design stage, such that incorporating their knowledge of the construction process alleviates buildability issues that can cause material and time waste. However, early contractor involvement is not specific to lean construction; rather, it is regarded as good project management practice, which can improve relationships between the design team and the contractors and also allow better management and sharing of the risk (Rahman and Alhassan, 2012).

A case study of the preassembly of mechanical installations for heating, ventilation and air conditioning identified the benefits of using multi-skilled labour in reducing the overall time required for the project and the importance of not isolating the offsite works from the onsite installation. Furthermore, the importance of project managing the interfaces, which for many organisations may require a cultural change to their current management style, was highlighted (Pasquire and Connolly, 2002). While the industry is divided on the merits of lean construction, there are many who profess to it being no more than good project management (Green, 2011).

3.2.8 The Aspiration for a Uniform Quality Standard

Quality is a subjective word that can be perceived differently by designers and practitioners. No succinct definition of quality in construction dominates; however, various phrases such as ‘meeting the customer’s expectations’, ‘reducing rework and defects’, ‘repeat business’ and ‘conforming to ISO 9000’ (ISO 9000 being a set of international standards on quality management and assurance) capture the essence of the quality debate in construction. These insights notwithstanding, achieving quality in practice appears to be complex (Jha and Iyer, 2006; Hoonakker et al., 2010).

Evans and Williams (1993, cited in McGeorge and Zou, 2013) offer seven factors used to determine a high level of quality: performance, reliability, conformance, durability, serviceability, aesthetics and perceived quality. Furthermore, Gavin (1987, cited in Arnheiter and Harren, 2006) identifies with the same seven factors but adds an eighth: ‘features’, which can enhance the use of the product. Furthermore, Altayeb and Alhasanat (2014, p. 880) argue that the following eight factors will contribute to achieving the quality required by a client: leadership, quality management, resource management, process management, customer satisfaction, training and education, continuous improvement and communication. The eight factors are not listed in order of importance, but it is gratifying to have leadership identified and also the need for training and education to contribute to improving quality in construction. Further analysis would suggest that the two sets of factors are not in conflict with each other, and rather the latter set relates to the management of quality, while the formed signifies the practices required to achieve quality.

Total quality management (TQM), which has its roots in the manufacturing industry, is seen by some industry professionals and academics as the way forward for the construction industry to improve its efficiency (Delgado-Hernandez and Aspinwall, 2008). However, consideration should be given to the difficulty of implementing systems from other industries into construction. This was identified by Jorgenson and Emmitt (2009) in the previous section in relation to lean construction and supported by Sullivan (2011), who also argues that TQM has the same difficulty of acceptance in the construction sector due to its uniqueness and the culture that resides in the industry.

Project management of construction projects, as has been mentioned previously, is dominated by cost, time and quality (Leong et al., 2014). Jha and Iyer (2006) argue that cost and time are generally considered of primary importance with quality to a lesser extent. While considerable literature exists on quality in construction, few offer any framework that the industry in general could use to improve quality standards in construction (Delgado-Hernandez and Aspinwall, 2008; Aichouni et al., 2014). Delgado-Hernandez and Aspinwall (2008) utilised case study research on seven construction organisations mainly in the form of interviews to determine their approach to quality management, taking into account their adherence to the international management standards set by the International Organization for Standardisation (ISO). A number of the companies were accredited for ISO 9001 quality assurance, while other were not and some considered the benefits of integrating quality management with safety (ISO 18001) and environmental management (ISO 14001) as a means to improve their product and service quality. The main findings from the study suggest that all organisations recognise the importance of continuous improvement. However, senior management need to demonstrate an understanding of the client's quality expectations and to communicate the importance of this to site staff, whom in turn need to advise all actors involved of the quality required thus enhancing the possibility of project success (Mane and Patil, 2015).

A framework to achieve quality in construction is offered by Delgado-Hernandez and Aspinwall (2010). This is founded on all stakeholders giving recognition to the cultural differences between the parties to improve methods in the design and build phases, adopting a two way form of communication to formulate a quality policy that incorporates environmental and H&S factors. Hoonakker et al. (2010) and Aichouni et al. (2014) concur with Delgado-Hernandez and Aspinwall (2010) that the main barrier to achieving acceptable quality on construction projects comes from the inherent organisational culture of the construction industry.

Most studies carried out to determine the relationship of site safety to the quality achieved have relied on qualitative data. Wanberg et al. (2013) gathered quantitative data from 32 projects, confirming the general findings of the previous studies which were that a strong correlation exists between injury rates and rework, suggesting that a project with poor quality standards is likely to experience a high injury rate. Oakland and Aldridge (1995, cited in Hoonkker et al., 2010) state that 'if ever an industry needed to take up the concept of TQM it is the construction industry'. Aichouni et al. (2014) argue that greater awareness and training of management and operatives would help to dissipate the current culture. AlMaian et al. (2015) argue that the root cause of rework should be given greater consideration in training programmes, with the aim of reducing or eliminating this cause. Hoonakker et al. (2010) claim that the poor quality achieved is due to a lack of standardised methods and the multitude of stakeholders involved.

Offsite construction has been identified as a method of construction which offers a standardised approach and has significantly reduced the number of stakeholders involved in the manufacturing process (Nadim and Goulding, 2009). The offsite factory environment compared to the onsite environment is considered an important attribute in the improved quality of construction (Mostafa et al., 2016). A case study comparing two offsite projects to six onsite projects confirmed a lower defects rate from the offsite projects, and, moreover, a high proportion of the defects accrued against the offsite projects resulted from the onsite works carried out to incorporate the modules (Johnsson and Meiling, 2009).

Arif and Egbu (2010) argue that the offsite environment allows for better quality control, a greater level of consistency and ultimately fewer defects. However, it is imperative that the main contractor visits the facility during the selection process and maintains a monitoring brief of the manufacturing process, to ensure quality standards are met (AlMaian et al., 2015). A comparative study of a refurbished (traditional) and new build (offsite) school, with the main objective of assessing the environmental impact of both methods, confirmed that not only was the offsite method environmentally better, but also the quality of build was superior, such that the end users attributed the offsite method and quality as factors that contributed in improving their educational achievement (Piroozfar et al., 2012).

Karim et al. (2006) argue that good management of the many interfaces is also imperative in reducing defects, and the reduced number of subcontractor interfaces accrued within the offsite process also makes this process beneficial. The interface between the offsite product and onsite installation is generally perceived as a phase that can cause quality problems, which was a finding in Johnsson and Meiling's (2009) case study. Johnsson and Meiling (2009) advocate the use of experienced operatives with knowledge of the systems to incorporate modular or volumetric products onsite.

Mitchell et al. (2011) argue that the interface between the design and construction phases will impact on the quality of construction, suggesting that strong management is required to ensure the correct information is available to the contractor timeously, allowing them to achieve the quality required by the client. Khosrowshahi (2015) claims that the quality of the briefing process is the starting point, not the design stage as argued by Mitchell et al. (2011), to ensure the desired quality is ultimately achieved. Keerthanaa and Shanmugapriya (2017) argue that a lack of quality control offsite and onsite can result in interface problems, adding that IM is an evolving practice that construction needs to acknowledge.

Leung et al. (2008) offer a web based monitoring system, which could be configured with a wireless internet connection to enhance communication between the actors who have the expertise to resolve the interface problems and subsequent defects at the earliest stage, thus avoiding potential delays and increased costs. A study by Pan and Gibb (2009) to compare the maintenance costs of offsite and insitu bathroom construction confirmed that the quality of the final product was significant in determining the level and cost of maintenance. Their study confirmed that the quality of workmanship was superior in the offsite bathrooms. However, it is essential that quality materials and products are used in offsite bathrooms to maintain the quality over the lifespan of the bathroom. Furthermore, it is widely accepted that tolerances are tighter when components are manufactured in a factory, thus improving quality (Hoonakker et al., 2010).

3.2.9 Tolerance

Tolerance is a word that fits within both the process and people factor profiles. However, in the context of this research, the focus is on the process (hard) factor, while still acknowledging the importance of the people (soft) factor applicable to tolerance. The *Oxford English Dictionary* (2013) defines tolerance as 'an allowable amount of variation of a measurement'. Gorse et al. (2012, p. 448) develop the definition in their dictionary of construction terms as follows:

> The discrepancy allowed between an exact location or fit and one that deviates slightly, but is still acceptable and functions. When setting out, cutting, manufacturing and fitting, it is normal to attempt to obtain total accuracy but, in practice, the process often results in slight variations. As long as the variation is within the acceptable tolerance, then functionality will still be achieved.

Both definitions acknowledge that most of the materials used within the construction process have slight deviations in size and therefore the pragmatic approach is to allow a degree of tolerance, which is governed by the appropriate British (European) standards for both dimensions and workmanship (Sherratt, 2015).

The degree of tolerance and the accepted quality should be embedded in all stages of the construction process, but the end product is important not only to the client but also to the end user, as the finished appearance becomes visible (Talebi et al., 2016). A study carried out by Soetanto et al. (2006) to identify the perceived views of clients, engineers, architects and contractors on the main criteria required to be considered during the design process identified that, apart from engineers, the other members did not consider tolerance an important criterion at the design stage. Landin and Kampe (2007) argue that tolerances should be monitored from the design through the various construction stages and not just with a focus on the end product. Moreover, designers give little attention to buildability during the design process, which can result in tolerance issues occurring at operational level (Lam and Wong, 2009).

A study within the Australian housing industry, to gauge end users' perceptions of tolerance in relation to an acceptable quality standard of onsite ceramic floor tiling in bathrooms, using a sample size of 50 new build houses, produced 402 sets of data on the variations of joint widths. The data were analysed using Weber's law, a branch of psychophysics, which measures the quantitative perceptions of change in relation to given stimulus, to determine the level of variation that consumers are willing to accept. The results confirmed that end users were willing to accept up to 70 percent variance in the joint widths before they would lodge a complaint (Forsythe, 2006). This study helps to clarify that onsite tolerances that are 'pleasing to the eye' are becoming more acceptable, in comparison to regional building standards as a measure of acceptable quality (Kolarevic, 2014). A concept used in the service industry to gauge customers' reactions to variations in degrees of tolerance is termed the 'zone of tolerance', and its particular value relates to high value purchases. With construction clients possibly making their most expensive purchase, a zone of tolerance would appear applicable to construction (Stodnick and Marley, 2013).

Defects are viewed as a constant problem within the construction process. However, little research has focused on 'construction tolerances' as being a cause of defects. Construction tolerances relate to a variety of differing trades that combine individual tolerances, resulting in an overall defect. Pavitt and Gibb (2003) highlight the importance of communicating the various interfaces between differing trades in order to ensure the end product can avoid the tolerance defects and achieve the required quality. A study by Jingmond and Agren (2015) identified 'unclear tolerance management' as a problem in managing multiple tolerances. One significant area identified was the interface between the different materials, components and volumetric units that can make up the project. The findings from the study suggest that the profile of unclear tolerance management should be raised for resolution at management level and not solely at operational level. Furthermore, designers may be unaware that their specified tolerances are physically impossible to achieve under site conditions and that it is the site personnel who resolve the tolerance issues (Rooke et al., 2007; Talebi et al., 2016). Conversely, Seymour et al. (1997) argue that inefficient supervision, poor workmanship and ineffective control measures are the main causes of tolerance non-compliance onsite. Some 20 years later, Talebi et al. (2016) argue that tolerance management has not advanced within construction.

Tolerances constantly achieved within a manufacturing environment are unlikely to meet the same level of consistency onsite, highlighting the complexity of interface tolerance between offsite manufactured components and their incorporation onsite (Seymour et al., 1997; Shahtaheri et al., 2017). A case study of a housing project in Sweden focused on the integration of offsite components onsite and found that a level of adjustment was required to achieve acceptable tolerances. This mirrored Seymour et al.'s findings that the precision of tolerance achieved offsite is not matched onsite, further highlighting the need for a higher level of communication between offsite and onsite personnel to promote 'tolerance thinking' on how to achieve the required tolerance when incorporating a precision built component into onsite works built to a lower level of precision (Landin and Kampe, 2007; Thuesen and Hvam, 2011; Talebi et al., 2016).

Blismas and Wakefield (2009) argue that onsite trades need training on the precision of offsite components and the importance of the tolerance level at the interface of offsite component and onsite preparation to avoid defect problems.

Nadim and Goulding (2011) concur with Blismas and Wakefield but add that while training is important on the technical aspects of tolerance, it is of equal importance to consider the softer issues of communication, culture and integration. Pan and Gibb (2009) and Shahtaheri et al. (2017) argue that volumetric (offsite bathrooms) and modular construction that fall outside the acceptable tolerance levels are more problematic to resolve and less forgiving in comparison to traditional construction. In other words, the degree of acceptable tolerance in relation to volumetric and modular must be achieved both offsite and onsite.

3.3 People Factors

The importance of the preceding process factors has been analysed in the literature review; however, without the input of an array of people factors, their importance would be greatly diminished. The seven people factors identified in Chapter 2 will now be reviewed. Furthermore, it is acknowledged that many other human factors will influence the nine process factors in this research, to varying degrees. However, in the interest of brevity the focus will be on the seven identified as most influential to the IM of offsite forms of bathroom construction.

3.3.1 Communication

Communication is defined as ‘the action of communicating’ while communicating is defined as ‘to share or exchange information or ideas’ (Oxford, 2013). Emmitt and Gorse (2007, p. 3) offer a more comprehensive alternative: ‘communication is the sharing of meaning to reach a mutual understanding and to gain a response’. Both definitions relate to a basic human action that would suggest that communication in its various forms should be instinctive for humans to carry out effectively. Furthermore, little in-depth research has been carried out into construction communication which may be attributed to communication being considered a ‘soft’ people factor that does not directly contribute to the construction process. However, it underpins all the ‘hard’ processes that are essential to the management of the construction process (Dainty et al., 2006). Furthermore, recognition is required for two forms of communication, 'internal and external', which should be viewed with equal importance to avoid problems (Thunberg et al., 2017).

The construction process is complex and temporal, and involves many multidisciplinary actors whose interactions are perceived as adversarial with poor interaction between parties, resulting in a difficult environment in which to promote effective and efficient communication (Emmitt and Gorse, 2007; Emmitt, 2010). Martin et al. (2014) argue that projects that are well organised will reduce the barriers to clear and concise forms of communication.

Aligned with effective communication is interpersonal trust, which resonates from good relationships between the various parties. Conversely, the risk of trust being misaligned will undoubtedly cause a strain on relationships and consequently affect the level of open communication between the parties. The latter situation is more prevalent in a construction context than the former (Ceric, 2014). Adriaanse and Voordijk (2005) suggest that interorganisational communication is affected by three factors: the contract, the terms of reference and the interests of the parties. The contract will detail the project requirements; however, changes are inevitable and this will lead to further tranches of information. The terms of reference identify the various parties, that is, the client, design team, contractors, subcontractors and manufacturers, each with their own way of thinking, operating and communicating. The interests of the parties will inevitably be directed towards themselves: the client will want a quality project for the lowest possible costs and the contractor will wish to gain as much profit as possible. These are all factors that endanger open trusting communication (Adriaanse and Voordijk, 2005; Emmitt and Gorse, 2007).

Construction has become a process of outsourcing, at both the design and the construction phases. Architects will outsource parts of the design to either UK or international designers because they consider it more cost effective. The construction phase is divided up into packages, which allow numerous subcontractors and/or sub-subcontractors to execute the works, thus creating a construction team that has varying communication skills, both verbally and in terms of information communication technology (Emmitt and Gorse, 2007; Senaratne and Ruwanpura, 2016). Otter and Emmitt (2007) posit that to achieve effective communication at the design stage requires a strong competent team leader and willingness between the parties to use information communication technology that is compatible to all. Xie et al. (2010) argue further that, to achieve effective communication, six variables should be considered and monitored: accuracy, timeliness, procedures, understanding, barriers and completeness. A case study of a new shopping centre, procured under design and build and embracing partnership practices between the main stakeholders, identified that while partnering relationships do improve communication some variables still impede it, such as clients who make changes by taking advantage of the partnering agreement. Similarly, late involvement of the main contractor and/or specialist subcontractors who fail to impart their knowledge during the design stage often results in late design changes (Xie et al., 2010).

Figure 3.7 succinctly shows the communication mediums that may be used in various locations at varying time zones. Cultural differences need to be factored into the communication mediums. It is the project leader that is central to instigating a culture of trust, good interpersonal skills and speedy procedures for resolution of any areas of conflict (Ochieng and Price, 2010).

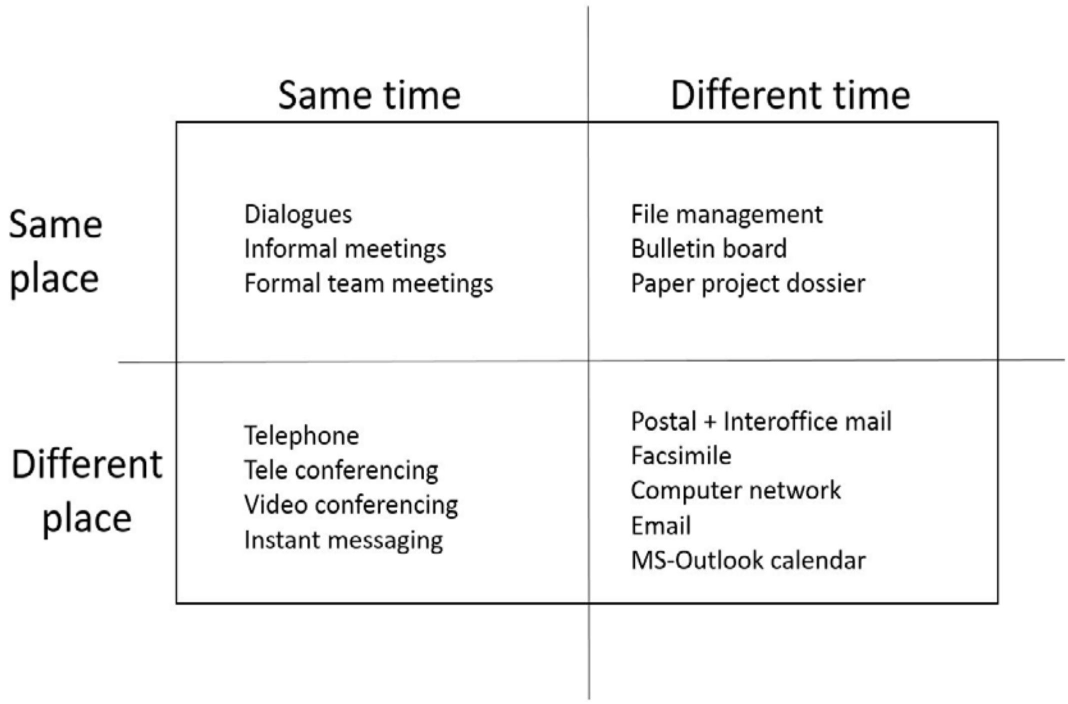

Figure 3.7: Time/place communication (Otter and Emmitt, 2007)

The top management team in a construction sense refers to the leaders of the clients, design teams and main contractors. A qualitative study of seven international companies, based on one top management interviewee from each organisation, identified the major challenge of communicating between boundaries of organisations, where some team members did not adhere to the team objective of open communication. Moreover, it was identified that informal communication has a worthwhile part to play in the strategy of business success (Hedman and Valo, 2015). While seven interviews would seem to be a small sample, considering the seniority of the interviewees, the findings are worthy contributions to the research into communication.

All construction projects are made up of many stakeholders, some of whom are directly involved in the construction process and others who are positively or negatively affected by the outcome of the project. The chosen procurement route can determine the structure and formal routes of communication between the principal actors involved in a project (Hughes et al., 2015). Furthermore, the resulting relationships will invoke the principal-agent theory, whereby one party will be better informed than the other and both parties will be motivated by self-interest, thus causing challenges to open communication between the parties (Ceric, 2014). However, informal structures will be formed, which will lead to informal communication between groups of actors that will have a significant influence on the project (De Blois et al., 2011). Communication between the client and the architect is paramount for any project, never more so than at the briefing stage.

A study comprising interviews with 18 architects confirmed that architects do not consider that briefing documentation communicates adequately the client's requirements and therefore recommend face to face communication to explore not only the quantitative requirements but also the qualitative issues of culture, attitude and desires of the client (Bogers et al., 2008). While the recommendations should improve the briefing process, Bogers et al.'s (2008) study would have benefited from inclusion of interviews with clients, to achieve a more balanced result.

Chua and Godinot (2006) attempt to show that better communication between all actors involved in the process would result in improved IM. They offer a model (Figure 3.8) which is split into three distinct areas: IM strategy, common IM issues and remedial action. Each area is further split into the five strategy headings, with communication central to the overall strategy. What is evident from the model is that inadequate forms of communication can contribute to interface problems while effective communication combined with co-operation and co-ordination between parties can play an important part in avoiding or resolving interface problems. In particular, the 'grey areas' that prevail in construction projects are an example of items that are normally annotated on working drawings as 'by others'. This implies incomplete design through a lack of communication. Al-Mousli and El-Sayegh (2016) concur that the lack of communication at the design/construction interface contributes to most problems in construction projects.

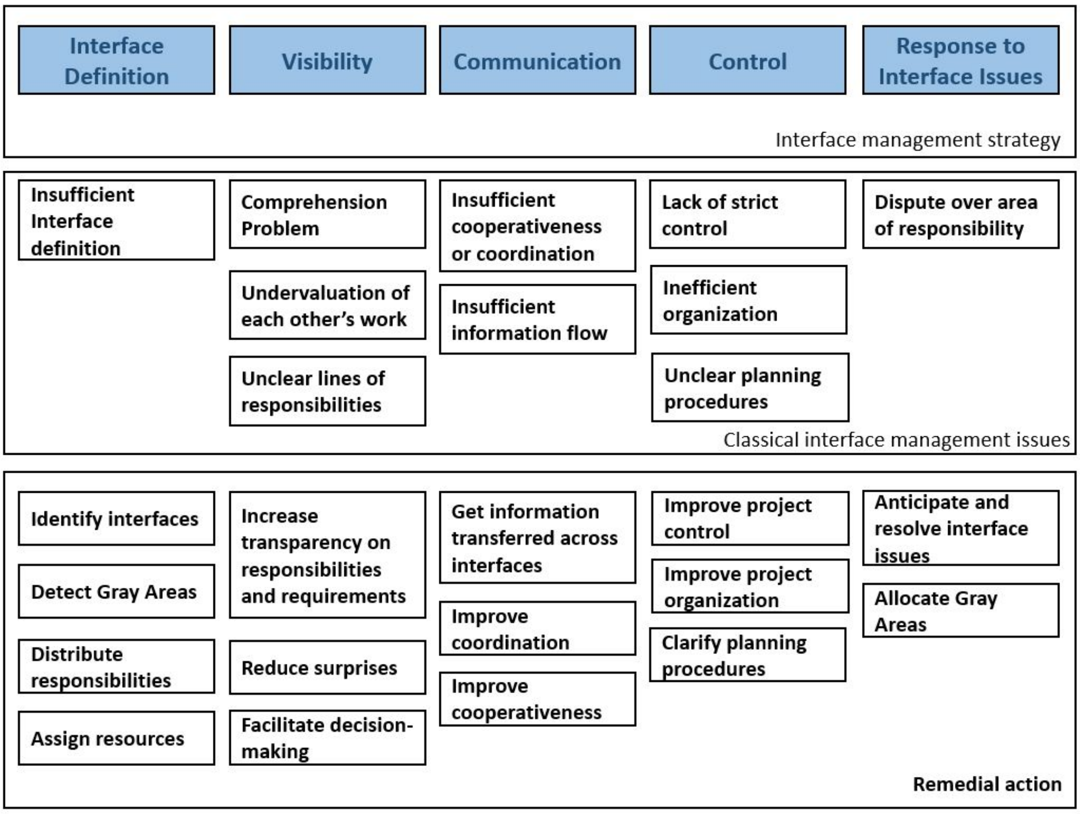

Figure 3.8: Functional aspects for interface management (Chua and Godinot, 2006)

Shokri et al. (2016) agree that communication has a major influence on IM in construction, adding that by applying a systematic IM practice the detrimental effects of miscommunication can be reduced. Lin (2013) argues that IM is not generally accepted as a management tool by the construction industry and therefore the positive influence of IM on communication is being missed and a valuable tool that can contribute to reducing design problems and rework is lying dormant. While electronic communications systems are now commonplace within construction, unless cognisance is given to IM, the advantages of the system will not be captured and the problems which relate to miscommunication and IM will persist (Lin, 2013).

Offsite construction requires open communication with manufacturers during the design stage. Johnsson and Meiling (2009) argue that poor communication at the design stage will lead to defects in offsite construction, in none more so than bathroom construction. A survey carried out by Pan et al. (2007) to review house builders' perspectives on the use of various forms of offsite construction identified problems with IM, the current procurement routes and people's perceptions as barriers to the uptake. However, it was overwhelmingly agreed by the participants that better forms of communication were required, in particular with offsite bathroom construction where there appears to be a willingness within the sector to increase the uptake. A further study of a leading house builder identified that a lack of communication from the design team on the benefits of using various forms of offsite construction inhibits its utilisation (Pan et al., 2012). A study of the European construction industry on the uptake of offsite construction identified the interface of information and the ability to communicate information in real time to all parties as essential factors, thus confirming that soft factors are equally if not more important than hard factors in promoting offsite forms of bathroom construction (Nadim and Goulding, 2011). Luo et al. (2017) posit that the uptake of volumetric (offsite bathrooms) will require architects to adapt more to the language of the manufacturer and accept their changing role, in order to stay relevant in a changing industry. Goulding et al. (2015) argue that training is required to upskill assemblers and installers of offsite products in the language necessary to understand the offsite, onsite and offsite/onsite interfaces that encapsulate the whole process, with the objective of installing a quality product.

3.3.2 Client and Design Team

Experienced clients have become more knowledgeable about the construction process and are more inclined to get involved with the design team during the design stage. However, inexperienced clients are more dependent on the design team to provide the design solutions to their brief. Regardless of whether the client is experienced or inexperienced the flow of design information needs to be managed efficiently and effectively (Gray and Hughes, 2001). Studies carried out by Cheng et al. (2006) and Karna and Junnonem (2017) identified that client satisfaction with the design team is fundamentally based on the overall quality of service, technical accuracy, quality of people and effective communication. A further study confirmed mutual respect, tolerance, trade-off, communication and clarity of interfaces as the dominant themes in the client and design team working relationship (De Blois et al., 2011).

De Blois et al. (2011) argue that, in practice, informal communication can play a fundamental role in the project dynamics that contributes to the client being satisfied with the design team. The role and involvement of the client can vary from project to project; however, regardless of project type, the client must give clear and unambiguous instructions during the inception stage in the form of the project brief, and thereafter the procurement route and level of experience will dictate the client's involvement for the remainder of the project (Emmitt and Ruikar, 2013). Furthermore, it is highly unlikely, with the level of uncertainty and inexperience of clients, that they will stipulate the use of offsite bathroom construction. Moreover, with the design team acting on behalf of the inexperienced client they are more inclined to specify traditional construction than to opt for a novel approach (Levander et al., 2011; Isaac et al., 2014).

A good and trusting relationship between the client and design team is important, never more so that during the briefing and design stage. Furthermore, it is equally important that the design manager builds a similar relationship between the client and design team, to effectively manage the design (Knotten et al., 2015).

While much research has been carried out into teamwork in construction, little has focused on the design team, which could be termed a sub-team of the main construction team. Pectas and Putlar (2006, cited in Senaratne and Gunawardane, 2015) advocate that effective management of the design team is crucial to achieving the quality, cost effectiveness and timely completion of a project. The consultants that make up the design team are generally chosen for their ability to carry out a 'functional role', with little regard given to their team role and soft skills during the selection process (Senaratne and Gunawardane, 2015).

A study of 128 construction design team members identified six variables in order of importance which contribute to team development: management commitment and support, satisfaction, setting clear objectives and criteria for their achievement by team members, personnel involvement, asking for external help, and communication in construction design teams (Tabassi et al., 2014, p. 944). With most design teams formed for one-off projects, it is detrimental to the industry not to instil a team spirit within design teams, and, furthermore, while the six variables are significant, the variable of leadership should also be included. By default, in the building sector, architects will generally assume the leadership role; further analysis may determine that they are not the best actors to lead the design team to a positive outcome, confirming that the configuration of the design team should not be based solely on functionality but that group composition and personal traits be given due consideration (Stewart, 2006).

While experienced clients may be aware of offsite practices, they may also hold traditional views on the construction process and therefore be reluctant to give support to proposals from the main contractor to implement offsite methods (Jaillon et al., 2009; Luo et al., 2017). Inexperienced clients rely on the design team to specify the construction strategy and similarly the design team may be averse to adopting offsite forms of bathroom construction, citing complex interfacing between the offsite bathroom and the onsite structure (Arif and Egbu, 2010). A quantitative survey of 36 large construction companies to gauge their perception of the uptake of offsite methods confirmed that the largest response was undecided (37 percent) on whether offsite methods would give greater satisfaction to clients over traditional methods. Moreover, a higher proportion agreed (17 percent) compared to those disagreeing (11 percent), suggesting that greater investment is necessary to inform clients and the design team of the benefits and to alleviate their fears of using offsite methods. A number of the undecided respondents offered 'complicating interfacing' and lack of a skilled workforce to integrate offsite within onsite construction (Nadim and Goulding, 2010).

Taylor (2010) argues that the UK has an organisation in place to inform clients and designers on all aspects of offsite construction, namely ‘Buildoffsite’. He also argues that when clients gain a better understanding of the efficiency and quality of build from offsite it may overtake traditional methods as the favoured choice of clients. However, it is also considered that architects will be a tougher ‘nut to crack’ due to the architect not being in total control of the design. Davidson (2009) argues that to innovate through offsite construction will demand early integration of the client into the project team and utilising the client’s expertise and knowledge, in particular about the expectations of the end users. End users are particularly interested in the maintenance of their project. Bathrooms are considered to be the area most affected by maintenance within most projects. A comparative study of offsite and insitu bathrooms confirmed that, to achieve clients’ and end users’ expectations on the maintenance of bathrooms in particular, offsite forms require the design team to give due consideration to the maintenance aspects and not rely on the manufacturer alone to design a maintenance-free bathroom (Pan and Gibb, 2009).

The project briefing process is undoubtedly an important client/design team interface, during which the client’s requirements are communicated to the design team. It is not unusual for ambiguities to surface as a result of the process, which result in problems manifesting during the design and construction phases. Khosrowshahi (2015) suggests that the design teams should consider adopting a system used in the software industry entitled ‘system analysis and design methodology’. It is out with the scope of this research to detail the specification and operational details of this system, but results from the software industry suggest that automation has enhanced their briefing process and similarities between the industries would suggest that it could be adopted for the construction briefing process.

De Blois et al. (2011) and Tjell and Bosh-Sijtsema (2015) argue that no matter which method is used to interface between the client and design team the physical presence of the client and face to face communication should always be a part of the process, in the form of an integrated design team, which should include rather than isolate the client from the process. The benefits are that the client has a better appreciation of the design process and relationships between all parties are enhanced, which may be beneficial during difficult periods. Tenant and Fernie (2012) suggest that, rather than the client being marginalised within the construction team, they should lead the 'clan' form of supply chain. A clan is defined by Ouchi (1981, cited in Tenant and Fernie, 2012, p. 1) as 'an intimate association of people engaged in economic activity', the main characteristics of which are integration, trust and community of practice, characteristics which would reduce interface problems and allow clients to be better informed of options alternative to traditional construction (offsite construction) and less dependent on the design team as the sole provider of process information.

3.3.3 Role of the Project Manager

Historically, the role of the project manager (PM) in construction was defined as delivering a project on time, within budget and to the quality specified, otherwise known as the 'iron triangle' (Burke, 2013; Fewings, 2013). The modern PM is still required to deliver a trade-off of time, cost and quality, with added dimensions of project safety, environment and sustainability, and client and end user satisfaction (Walker, 2015; Koops et al., 2016). Burke (2013) argues that to achieve all of the aforementioned factors to the satisfaction of a client requires the PM to possess a considerable set of skills and abilities, such as management and leadership skills, stakeholder management, scope management, procurement management, communication, quality and risk management, problem solving and decision-making. The *Project Management Body of Knowledge* (2013, p. 18) suggests that the modern PM requires a mixture of 'technical, interpersonal and conceptual skills, such as leadership, team building, motivation, communication, influencing, decision making, political and cultural awareness, negotiation, trust building, coaching and conflict management'.

Hwang and Ng (2013) identify social skills, decision-making, problem solving, an ability to recognise opportunities and management of change to be key personal attributes required of a PM in the twenty-first century. Tong (2011) argues that, in the main, the required skills are acquired through experiential learning in the form of on the job experience and observations. It is not uncommon for PMs to find themselves in the role by default, having been promoted from their original profession.

Savelsbergh et al. (2016) agree that PMs learn on the job and that informal training is the norm for inexperienced PMs. Harris et al. (2013) argue that a good education and high level of training is required to develop a potential PM, which would suggest that potential candidates now require a university degree, therefore excluding experienced tradespersons with no formal qualifications. Ramazani and Jergeas (2015) argue that the current framework used by universities to educate students in the competencies of the PM's role is lacking in what is actually required of a competent PM. They argue for greater emphasis on developing critical thinking to deal with complex projects, and developing softer skills such as interpersonal skills in tandem with the required technical skills to prepare potential PMs to engage in real life projects. These are all skills that are better experienced in practice under the guidance of practising PMs rather than the current fixation of instilling only the theoretical education of project management in students. Figure 3.9 captures the main themes that practitioners of the study consider will contribute to mitigating the gaps in the performance of PMs, by focusing on the selection of the right individual and providing them with the education and continuous training required to develop competent PMs.

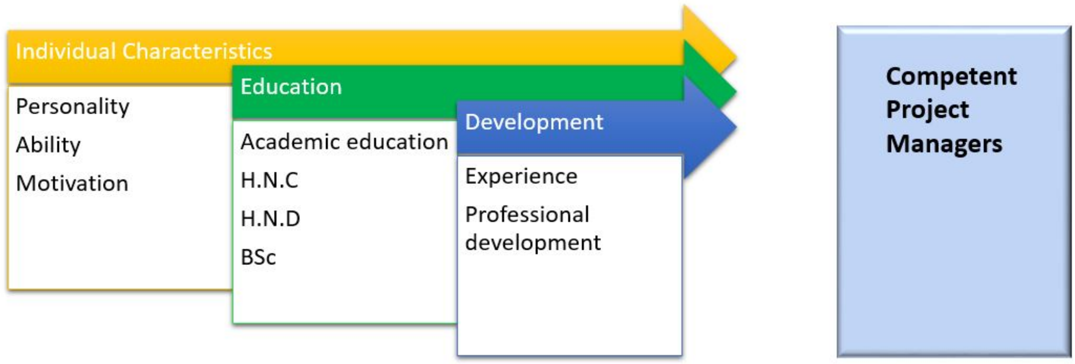

Figure 3.9: Requirements for competent project managers (adapted from Ramazani and Jergeas, 2015)

Sommerville et al. (2010) add that age and experience contribute to the PM's ability to carry out the role, arguing that no definitive route exists to nurture potential PMs and that the role will vary according to the scope of the project, which could suggest that the skills and abilities that PMs require for a traditional project may vary when they have to manage a project which is predominately offsite construction. The PM must be not only technically competent (hard skills) but also people-oriented (soft skills). Fisher (2011) identified six people skills required of a successful PM: understanding behavioural characteristics, leading others, influencing others, authentic behaviour, conflict management and cultural awareness.

The diverse range of multidiscipline professional and trade organisations that contribute to a project, each with their own allegiance to their specialist employer, makes for a skilful PM with the ability to integrate these many parts into a unit that works cohesively towards the project objectives (Winch, 2010; Pinto and Winch, 2016). Jha and Iyer (2006) concur that, on major complex projects, PMs do not need to have technical ability as their dominant skill, but rather the ability to communicate effectively with all stakeholders is more important. However, a survey by Sommerville et al. (2010) to gauge the frequency of 32 possible roles of experienced PMs identified that technical roles dominated over management roles, suggesting that the main function of a PM is to resolve technical issues. However, it could be argued that soft skills are an added function to complement the technical ability of the modern PM. Furthermore, the PM is responsible for managing the many contractual and non-contractual interfaces and boundaries that exist within construction projects that require a mix of hard and soft skills to be resolved (Emmitt, 2010).

A questionnaire survey to identify the main factors that affect the performance of construction PMs identified ineffective traditional methods and practices, long working hours and lack of administrative support as obstacles to the effectiveness of the PM (Powl and Skitmore, 2005). A similar study carried out by Low and Quek (2006) to identify environmental factors that can impede the PM’s performance also identified long working hours as a main factor. The top three attributes of a PM identified by a quantitative study of UK construction organisations are strong leadership and motivation, committed and decisive decision-making and high standards of ethics and integrity (Chileshe, 2010).

While the performance of the PM is difficult to ascertain at the beginning of a project, Cheng et al. (2005) argue that the behavioural competencies required of a PM can be identified. While the job-related competencies will vary depending on the project type, there are a number that can be considered as standard. The behavioural competencies, which underpin job competencies, are deemed to be generic and therefore invaluable in the selection of competent PMs. A mixed method study utilising focus groups from leading UK construction organisations by Cheng et al. (2005) identified behavioural competencies which will aid the selection and training of effective PMs. The 12 competencies are: achievement orientation, initiative, information seeking, focus on client’s needs, impact and influence, directness, teamwork and co-operation, team leadership, analytical thinking, conceptual thinking, self-control and flexibility. While communication can be inferred from a number of the competencies, it is surprising that it was not specifically listed.

The influence of the construction PM on the uptake of offsite bathroom construction is dependent on the procurement route and form of contract. Should the procurement route promote early contractor involvement, the PM has the opportunity to promote the inclusion of offsite bathrooms as an alternative to traditionally built bathrooms. The PM may argue that offsite methods of construction should be maximised, giving superior quality control over traditional methods as a valid reason for due consideration (Harris et al., 2013). Goulding et al. (2012) argue that it is important for the PM to be objective when promoting the case for offsite, and this means giving due consideration to negative as well as positive issues. A negative issue may relate to the management of the interfaces when configuring the offsite and onsite construction. To replicate the interface issues, Goulding et al. (2012) recommend the use of a 'virtual reality' mock-up, which would allow the main stakeholders to experience and reflect on potential problems and solutions before they occur onsite.

While design and construction largely remain separate, the role of the construction PM has gained professional status, such that clients are now more inclined to seek advice not only from the design team but also from the contractor's PM (Winch, 2010). Winch (2010) and Arashpour et al. (2016) argue that PMs must take a holistic and systems view of the overall process when recommending offsite methods in lieu of traditional construction, which suggests that not all PMs will have the necessary skillset, education and sense-making abilities to promote the use and management of an offsite construction process. The design process is widely acknowledged as the stage at which offsite methods require to be incorporated into the process.

Haller et al. (2015) posit that construction PMs are not educated in tools that would support their decision to favour offsite over traditional, which concurs with Winch's view that PMs directly involved in the design and build of offsite methods need to be educated to a higher level to effectively influence the design and construction compared to more traditional methods. The incorporation of offsite methods has been generally considered as a project or production level decision. Lessing et al. (2015) argue that such decisions are more strategic and organisationally based, which would suggest that PMs experienced in traditional construction methods may not be schooled to make the necessary informed strategic decision on the incorporation and management of offsite components.

While PMs may or may not be influential in the design of offsite bathrooms on a project, they will be integral in dealing with the many organisational and practical interfaces that arise (Harris et al., 2013). Ideally during the pre-construction stage the PM will be influential in implementing the project management tool of work breakdown structures, which will determine the configuration of the work packages into deliverable, manageable and independent parts that make up the project during the construction phase (Burke, 2013). Each work package creates a boundary or interface with another work package or packages, which must be managed (Chua and Godinot, 2006). Emmitt (2010) refers to the term 'interdisciplinary working' where more than two work packages are affected by the interface, which requires collective knowledge from many disciplines to resolve the issue.

An interface manager would appear to be the obvious choice of personnel to manage the interface between work packages. However, in practice this remains one of the dominant roles which falls within the remit of the PM (Fellows and Liu, 2012). Nevertheless, Archibald (2003) endorses the role of the PM in the control of project IM, citing ineffective planning and control as contributing to the conflict which dominates construction projects. The PM is in essence the project interface manager, who must 'plan, schedule and control the project interfaces in close cooperation with the contributing functional project leaders' (Archibald, 2003, p 311). Project IM, when applied in practice, is similar in approach to systems analysis. Inputs are converted to outputs and communication can have a significant effect in reducing the organisational interface problems and stimulating a more effective conversion process. This can result in an output which matches the expectations of all stakeholders (Morris, 2013).

A case study approach to determine the implications of IM on offsite construction confirmed that the PM has an important role in resolving poor co-operation that can occur between the work packages, both offsite and onsite (Luo et al., 2015; Shahzad et al., 2015). To resolve the problem of poor co-operation, the PM needs to develop a collaborative approach that builds relationships and fosters interdependencies (Arashpour et al., 2017). Gustavsson (2015) refers to this concept as 'boundary spanning', linking the many tools that PMs have at their disposal to influence better co-operation and collaboration between the parties. Brion et al. (2012) concur with Gustavsson and argue that boundary spanning is a crucial role of the PM, confirming that soft skills are an integral attribute in a PM in ensuring that the many subcontractors are focused on the primary objectives of the project. A mixed method study by Danby and Painting (2007) to explore the interface issues with volumetric construction identified that the onsite contractors and offsite manufacturers lack a common understanding of the interfaces between their respective operations, endorsing the soft skill of communication as a pre-requisite for an effective PM to manage the interfaces that occur within offsite construction, in particular offsite bathroom construction. Emmitt (2010) and Arashpour (2017) argue that a primary role of the PM should be to manage the interface of individuals and organisations connected to the project.

3.3.4 Leadership

A review of literature on success factors by Turner and Muller (2005) gives very little credence to leadership as a contributing factor to project success, whereas leadership in organisations is considered influential and has been the subject of considerable research over the past 60 years by scholars such as Adair, Belbin, Fiedler, Tannenbaum and Schmidt, and Vroom and Yetton, who have offered various theories on approaches, styles, behaviours and traits of leadership (Mullins, 2016). For the purpose of this research leadership is focused mainly on decision-making and the parameters within which the style of leadership exists. In simple terms the parameters will vary between the extremes of authoritarian and democratic with various styles of leadership in between such as dictatorial, bureaucratic, consultative, charismatic and inspirational (Mullins, 2016, p. 331).

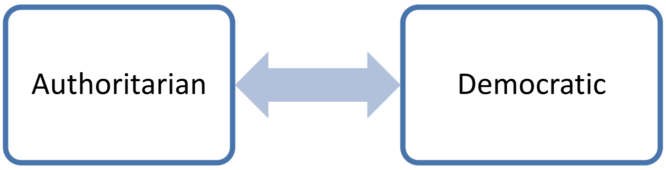

Figure 3.10: Extremes of leadership (adapted from Mullins, 2016)

Leadership in construction is intrinsically a people factor, mainly attributed to the PM although not exclusively, as all functional managers of the project team are encouraged to display leadership skills in their particular domain. However, it is the PM who is tasked with getting the best performance from the team, which generally means leading by example and being flexible with their style of leadership (Walker, 2015). Situational leadership theory fits well with the process of construction. Senaratne and Samaraweera (2015) argue that the style of leadership must change depending on the stage of the project and/or what the situations demand to get the best outcome. However, it is important that the leader assesses not only the situation but also the competence and commitment of the team members, which will have a bearing on the appropriate style (Burke, 2013). An example of his could be the PM’s lead in the recommendation of the use of offsite bathrooms as an alternative to traditional methods, demonstrating visionary leadership to the client and design team.

Given the amount and quality of published research on leadership, Muller and Turner (2010) suggest that organisations should adopt the practice of ‘profiling’ when selecting a project leader for a particular project. From a review of existing research, 15 competencies were identified and sub-divided into three groups: intellectual, managerial and emotional. Four hundred completed questionnaires were analysed. The findings suggest that leaders of construction projects require intelligence which is high in critical thinking, management skills high in developing others, emotional skills high in influence, motivation and conscientiousness (Muller and Turner, 2010). A further study on the influence of emotional intelligence on construction PMs' leadership, from a sample of 68 construction professionals, would suggest that the non-confrontational approach requires the leader to demonstrate emotional sensitivity and expressiveness in communicating with other members of the team to attain the 'leader-follower chemistry' that will influence project success (Pryke et al., 2015).

Through a quantitative study, Jha and Iyer (2006) found that the leadership of the PM is a critical positive attribute in achieving quality compliance. Conversely, a PM with a negative attitude to quality is unlikely to motivate other project participants to be quality compliant. Sommerville et al. (2010) argue that the PM not only manages the project team, but is also required to demonstrate leadership, to gain the trust of team members, through motivation, co-ordination and maintaining morale.

While leadership in this section has related mainly to the PM, it could be argued that minimal leadership has been shown by construction owners, clients and the government to increase the uptake of offsite construction (Nadim and Goulding, 2009). Elnaas et al. (2014) argue that committed leadership at senior management level is required by the construction industry to engage with clients and the design team at the design stage to influence the uptake of offsite methods. A mixed method study to gauge the effect of employee empowerment on productivity within offsite factory environments identified the importance of leadership as a contributing factor. People-oriented leadership was considered more influential in comparison to authoritarian leadership in creating a teamwork spirit that empowered employees to increase productivity. While the research consisted of a relatively small sample of 23 managers and foremen from two offsite factories and therefore the results should not be considered as a generalisation of the industry, it is still worth reiterating the importance of people-oriented leadership on offsite construction in comparison to authoritarian approaches (Alazzaz and Whyte, 2015).

Leadership is an important aspect of organisational IM, never more so than at the interface between senior management level (strategic) and project management level (implementation). If the PM advocates the use of offsite construction, but senior management does not consider it part of its strategic plan, then conflict will occur between the two. A level of collaboration and trust is required on either side when an innovative process is being proposed, and rather than senior management being dismissive of non-traditional processes, leadership is required from senior management to analyse the proposal and make an informed decision (Raes et al., 2011). Arif and Egbu (2010) argue that not only is a cultural shift required to move from traditional to offsite forms of construction but that strong leadership is also required. Pour-Rahimian et al. (2014) agree and add that education has a part to play in making use of virtual reality tools, which can inform construction students of the interface issues that pertain to offsite construction. Exposure to traditional site visits complemented with virtual reality scenarios will also enhance the students' decision-making abilities, which in turn will encourage the development of leadership skills when a novel solution is required.

Currently construction educational courses are centred on management skills; however, with increasing project complexity, equal emphasis must be placed on leadership skills, to adequately equip the construction leaders of the future (Obonyo, 2011). An important aspect of leadership in relation to the interface of offsite and onsite components is safety management. Kelly and Berger (2006) posit that effective communication, which is 'key' to the safety controls required when incorporating offsite components onsite, must be instigated by strong and effective leaders, who lead by example and demonstrate effective communication in all matters in relation to the management of the interface between offsite and onsite construction.

3.3.5 Integration

Fragmentation is repeatedly interpreted as a by-word for construction. With design executed separately from production, the theme of integration has emerged as an important people factor in the quest to integrate the project team and improve the construction process (Fewings, 2013). Jorgensen and Emmitt (2009) argue that with an increased uptake of design and build and management procurement routes, a greater level of integration between actors is required to improve relationships and ultimately production.

Central to SCM is the people factor of integration, which in essence requires a holistic view of supply chains, such that members cross the traditional boundaries of inter-related organisations without the need to adhere to traditional protocols, but this strategy may not be acceptable to all members of the supply chain. Furthermore, members that adopt an integrated approach, which requires a review of current practices, will expect to gain a positive advantage otherwise they will revert to their traditional silo approach (Power, 2005; Dave et al., 2016). Power (2005, p. 253) offers the basic attributes required of organisations to integrate with fellow members as 'co-operation, collaboration, information sharing, trust, partnerships, shared technology, and a shift from managing individual process to the management of integrated chains of processes', traits that construction organisations find difficult to adhere to and achieve.

Supply chains in construction tend to focus on the contractual relationship between the main contractor and their subcontractors, with the client and design team on the periphery. Briscoe and Dainty (2005) argue that to foster integration requires the inclusion of the client and design team, with the client showing leadership. Three case studies, involving nine different projects, resulted in 100 semi-structured interviews being carried out, to gain a better understanding of what is required to achieve more effective construction supply chain integration and identified the following:

- Effective communication throughout the supply chain
- Clients to communicate with all levels of the supply chain including subcontractors
- Trust to be developed between all actors in the supply chain

- Main contractor and subcontractors to gain knowledge of the client’s processes, to achieve the required quality
- Collaboration and co-operation to be fostered between all parties, which need not be formed on a contractual basis, when involved in a single project but fostered loosely to promote long term alliances (Briscoe and Dainty, 2005, p. 324).

While the above may appear achievable, it is difficult to comprehend clients constantly and openly communicating with subcontractors and suppliers and conversely main contractors accepting that clients converse with the subcontractors and suppliers. Where no contractual obligation exists within the procurement strategy, it is more likely that the above impediments will be resolved on an informal basis.

Koolwijk et al. (2015) argue that the level of integration in construction is difficult to measure. However, they offer a framework devised by Eriksson (2015) based on four criteria: strength of integration (attitude), scope of integration (number), duration of integration (time) and depth of integration (span of hierarchical levels). While the criteria are all interconnected and relevant to onsite works, this approach could also be of value in identifying the appropriate time and depth of involvement that offsite manufacturers should have within the construction supply chain. An equally appropriate practical method to enhance the integration of offsite construction components is to establish ‘technology clusters’ by grouping the relevant designers, manufacturers and contractors into a multi-faceted sub-organisation of the main organisation, thus promoting a greater level of integration, with the aim of resolving potential buildability and interface problems when the offsite units are installed onsite (Al-Bizri and Gray, 2010; Annan, 2012).

A study by Khalfan and McDermott (2006) suggests that to increase the level of integration in construction requires a shift away from traditional procurement to more innovative methods of procurement (PFI, partnering, project alliances, etc.)

and/or framework agreements that promote long term relationships and work. The latter procurement method would be difficult to achieve due to the one-off nature of projects. However, Al-Bizri and Gray (2010) argue that the formation of technology clusters is not dependent on the procurement route, although management forms are the preferred method. Dave et al. (2016) add that for technology clusters to work, the members would need to endorse the free flow integration of information between members and not enforce any obstructive conditions.

A study of supply chain relationships in the offsite construction sector, based on three case studies and qualitative analysis, identified a lack of integration between the parties as a major hindrance in the uptake and success of projects with elements of offsite construction (Mohammad et al., 2014). Mohammed et al. (2014) attribute the challenges of integration between the many professions to people related elements, such as lack of trust, different cultures, mindset, blame culture, selfish interests, poor communication and poor leadership. While all the elements are important, it could be argued that priority must be given to improving the people factors of communication and leadership which play a major part in promoting integration within construction. Furthermore, although three case studies could be considered a small sample, the findings in relation to integration highlight its importance among stakeholders involved in offsite forms of construction, never more so than in alleviating possible interface problems.

3.3.6 Culture

The *Oxford English Dictionary* (2013) defines culture as 'the art, customs, ideas and social behaviour of a nation, people or group', which demonstrates the width of interpretation and the difficulty of providing a universal meaning for the word 'culture'. Hofstede (2001, cited in Fellows and Liu, 2013, p. 402) offers a more concise definition: 'the collective programming of the mind that distinguishes the members of one group or category of people from another', which can be interpreted as the different cultures that exist within different industry sectors, and also the different cultures that reside within specific industries. Fewings (2013) suggests that culture is a word that is randomly used within organisations but poorly understood. Within the scope of this research culture will relate mainly to organisational and project culture and its influence on stakeholders within the construction industry. Of the many definitions applied to culture, possibly the best fit applicable to construction organisations is 'the way we do things around here' (Deal and Kennedy, 1982, cited in Walker, 2011, p. 178). Therefore culture can be construed as both an enabler and a constraint: an enabler in that employees are aware of the ethos of the organisation (how we do things), which will be influenced by the leadership of the PM, and a constraint in that change will be difficult to instigate (a move from traditional to offsite methods) (Zuo et al., 2012).

The culture within the construction environment is generally perceived as adversarial. This perception stems from traditional procurement, whereby design and construction are separated. A mixed method interview and questionnaire survey of 144 equally divided consultants and contractors was analysed using a 'competing value framework' originally devised by Cameron and Quinn (1999, cited in Giritli et al., 2013). The framework is a matrix structure covering flexibility and discretion versus stability and control, and integration and internal focus versus differentiation and external focus. The framework is used to measure the perception of respondents about the cultural aspects of various attributes of the organisation to determine the best fit from the four cultural types shown in Figure 3.11. The results of the survey clearly identified a significant difference in the organisational culture of the consultants and contractors, with the consultants being more 'clan' oriented while the contractors are more 'market' oriented (Rameezdeen and Gunarathna, 2012). A later study of 108 construction managers from various contractors using the same method of analysis identified a leaning towards 'hierarchy', which could suggest that project culture is influenced by the country within which the project is located (Nukic and Huemann, 2016).

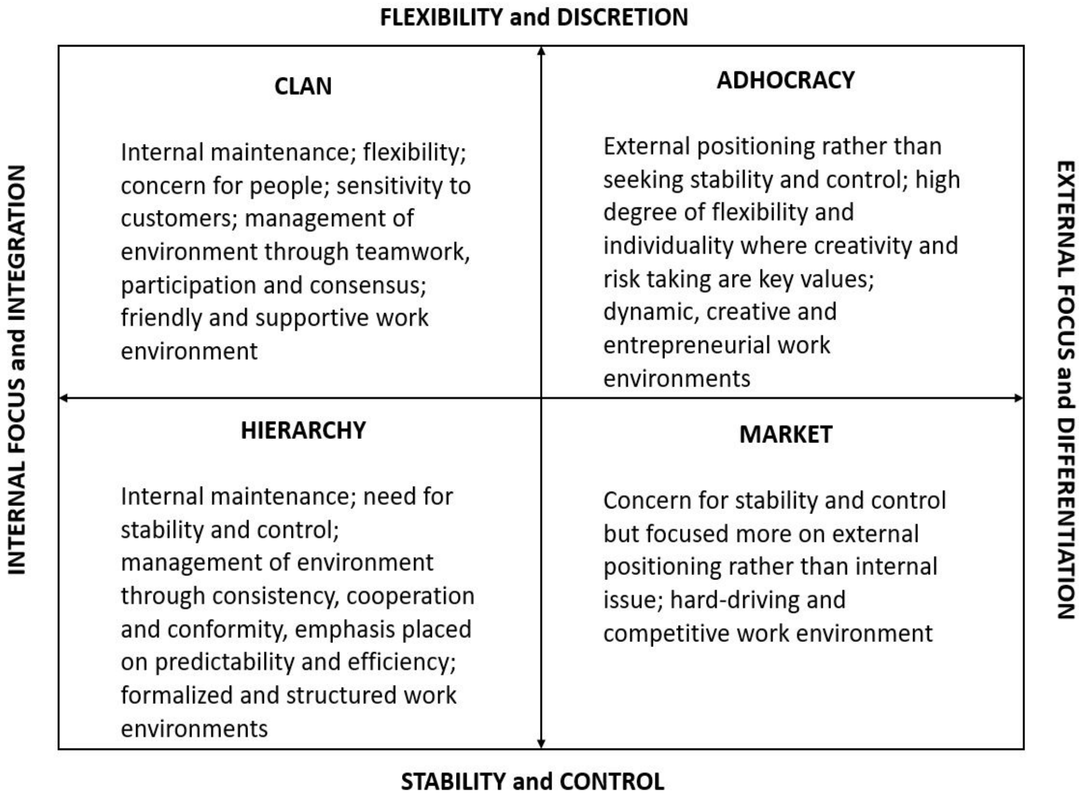

Figure 3.11: Competing value cultural frameworks (Giritli et al., 2013)

Fellows and Liu (2016) argue that leadership and culture are closely linked, arguing that it is the leader or owner of the organisation that will determine the explicit culture of the organisation. Giritli et al. (2013) argue that once the culture of the organisation has been established, the leadership style will be formed by the culture of the organisation. Moreover, the implicit culture will be formed by the management of the organisation and this is likely to be the dominant culture at project level. Ideally the explicit and implicit cultures should be in harmony to avoid a mismatch and conflicts of interest (Cheung et al., 2011). The construction industry is often viewed as an industry with a unique project culture that does not align with the organisational culture of other industries, for example manufacturing. However, it could be argued that construction organisations operate within two cultures, one at head office (explicit) and one at project level (implicit), while manufacturing operates solely within a company based culture (explicit) (Walker, 2011). Smyth (2015) argues that greater recognition is required within construction to manage the interface that exists between the explicit and implicit cultures rather than being dismissive of its intangible existence, thus recognising the relationship that exists between the two and allowing a level of independence that is required at project level to deal with unforeseen problems.

Cheung et al. (2012) suggest that the inherent culture within construction organisations is a major impediment to the good performance of the construction industry and that construction organisations need to adopt a wider business-oriented model that is more resilient to innovation and change. Project culture is generally considered to be ‘task-oriented’ (get the job done), due to the nature of the construction process (Zuo et al., 2012). However, with each project made up of a variety of clients, design teams, main contractor, subcontractors and suppliers it could be argued that each project will develop its own culture, with the PM having a strong influence on the project culture (Fewings, 2013). Green (2011) argues that to single out ‘cultural change’, for example from ‘market’ to ‘clan’, as a panacea for improvement in production of the construction industry is naive and unrealistic. Furthermore, there are many process and people factors that need to work together to aid the performance of construction, with culture being one but not necessarily the most important.

In-depth research into the influence of culture in the construction industry is still in its infancy (Walker, 2011; Fellows and Liu, 2013). While many theories exist relating to culture, a potential theory of organisational culture in construction would need to be based on empirical evidence and to have a practical base to influence the industry (Willar et al., 2016). Pan et al. (2008b) argue that construction has a risk-averse culture that has been a factor in the slow uptake of offsite methods within the house building sector. Nadim and Goulding (2011) argue that the risk averse culture stems from ‘protectionism and conservatism’ within the industry. The main obstacle that must be overcome is people’s culture of ‘resistance to change’, and augmenting overcoming this with a learning culture would have a positive impact. Construction organisations that move from traditional construction to offsite construction will experience a cultural change at both organisational and project level. The change will stem from offsite works being more of a process in comparison to traditional brick and stick construction (Johnsson and Meiling, 2009; Goh and Loosemore, 2017).

Tennant and Fernie (2013) advocate that moving onsite activities offsite could have a positive effect on the culture of the resulting supply chain, particularly in highlighting to all members of the supply chain the interface issues that result from onsite and offsite works, as manufacturers are more accustomed to engaging with organisational learning. A mixed method study identified that there is a positive correlation between a culture of employee empowerment and productivity in an offsite factory environment, that is, provided the factory operates along the manufacturing ethos and does not replicate the onsite environment with a roof covering to shelter from inclement weather (Alazzaz and Whyte, 2015). Chalker and Loosemore (2016) advocate that the culture that permeates the traditional construction industry is one of mistrust between main contractor and subcontractors, whereas the offsite sector culture in general promotes a greater level of trust between the main contractor and manufacturer resulting in improved communication and ultimately better productivity.

However, the management of the cultural interfaces that occur at the boundary of the many enterprises involved in offsite methods of construction should not be underestimated nor their importance misunderstood, in particular when international cultures are involved, which can lead to conflict and disputes (Fellows and Liu, 2013). Furthermore, a study of the UK construction industry by Ankrah and Langford (2005, cited in Nukic and Huemann, 2016) revealed that cultural differences at the interface of organisations are a main contributor to poor performance and that offsite work was not exempt. Conversely, a unified project culture can have a very positive impact on the outcome of a project when using both onsite and offsite construction, which is not the perception of construction held by many stakeholders (Zuo et al., 2012).

3.3.7 Perception

Perception is defined as ‘a way of understanding or interpreting something’ (Oxford, 2013). The ‘perceptual process’ is a complex psychological process, which attempts to explain how our individual perceptions are formed but is not well understood in organisational management and is out with the scope of this research (Mullins, 2016). Moreover, the importance of perception as an influential people factor should not be underestimated, in particular its effect on the preceding factors. Every individual has the human trait of perception, and how we perceive is strongly based on our environment, individual needs, cultural upbringing, life experiences, the present situation and our emotional state, which suggests that to change someone’s perception of a process or method would be extremely difficult (Walker, 2011).

The construction industry is generally perceived by external stakeholders as a macho industry, populated by contractors who cannot be trusted (Walker, 2011). Trust and how trust is perceived is important for the productivity achieved on any construction project. A survey of construction professionals to identify the main factors that they perceived were important to engender trust identified face to face communication and timely response to requests for information as influential in building trust between parties in the construction process. Although the survey had a low response rate of 16.5 percent, the significance of direct communication between parties, as an alternative to electronic communication, should not be understated (Zuppa et al., 2016). Internal stakeholders also perceive fellow professionals in a stereotypical way; for example, quantity surveyors are perceived as cost-centric and as control freaks (Walker, 2011).

Lim and Mohamed (1999, cited in Toor and Ogunlana, 2010) argue that there are two levels of perceived success: the macro-level relates to the end users’ perceptions as to whether the project has fulfilled their expectations and the micro level consists of the parties directly involved in the construction process, that is, client, design team, main contractor and subcontractors. Their perception is fundamentally linked to cost, time and quality. Toor and Ogunlana (2010) carried out a questionnaire survey, to gauge the micro level of stakeholders' perceptions as to what factors constitute project success. The survey generated an extremely high response rate of 95 percent. The findings suggest that while cost, time and quality are deemed measures of project success, on their own they do not provide the full picture. Factors contained in the project strategy should also be included, for example safety performance, sustainability, energy efficiency and maintainability. A comparative study by Lai and Lam (2010) had 324 responses, compared to 76 in Toor and Ogunlana's study, and the quantitative analysis indicated a slight deviation in the order of importance, to time, cost, environmental, quality, safety and effectiveness of the construction process, confirming safety and sustainability (environment) as factors that stakeholders now consider contribute to project success, and these are all factors that can be achieved better by using offsite in lieu of traditional construction.

Stakeholder perception of offsite construction in housing is still influenced by the post-war failed attempts at prefabrication and industrial building, such that potential homebuyers would rather purchase a traditional home with the many defects that are endemic in traditional construction than embrace the innovative technology now producing offsite construction, to a consistent quality (Pan et al., 2007; Kamali and Hewage, 2016). Human perception is a powerful factor such that it is not only home buyers that have a negative view of offsite methods, it also resides in many architects, developers and clients (Pan et al., 2007; Gosling et al., 2016). An international study carried out by Gosling et al. (2016) to identify the various perceptions among the many stakeholders concluded that to dissipate the negative perception of modular in particular and offsite in general requires a greater level of unity between the design team and the operations management team. This more unified approach will also benefit the identification and management of interfaces. Moreover, where repetition is dominant, offsite bathroom construction has now become the preferred choice for clients investing in hotels and student accommodation, which can only give heart for modular and volumetric construction (Alazzaz and Whyte, 2014).

A questionnaire survey by Boothman et al. (2014) to ascertain both construction professionals' and educationalists' perceptions on the use of offsite construction of school buildings identified interesting findings. Forty-two percent confirmed that both sets of stakeholders preferred the bespoke design and traditional construction methods. However, when the client has an understanding of offsite methods, they are more readily amenable to offsite construction, citing reduction of defects as a contributing factor. Furthermore, potential clients of offsite construction need to be better informed of the benefits and constraints, to enable them to have a more informed perception of offsite construction (Boothman et al., 2014). Nadim and Goulding (2010) add that architects in general have a negative perception and are reluctant to inform clients of the benefits of offsite methods, preferring to remain in the traditional camp.

A study of house builders in the UK identified a negative perception by potential buyers of offsite techniques being used to construct modern homes. Interfacing problems between offsite and traditional construction were perceived by the house builders as a significant complex barrier to the uptake of offsite methods in house building (Pan et al., 2008b). However, Arif and Egbu (2010) argue that housing clients' perceptions of a benefit of the use of offsite construction is that there are fewer interfaces between trades and that the interfaces are better managed when offsite methods are included. The difference in opinions on the use of offsite construction and the management of resulting interfaces would suggest that additional training and education is required to have a positive influence on stakeholders' perceptions of the management of interfaces and offsite construction (Pour-Rahimian et al., 2014).

3.4 Summary

The nine process and seven people factors have been analysed individually in the form of a literature review. The aim of the literature review was to determine each factor's relationship to offsite construction in general, and offsite bathrooms and IM in particular. As previously stated, literature directly related to IM in construction and IM of offsite forms of bathroom construction is scant in peer reviewed publications. However, some literature relating to the factors have eluded to IM indirectly.

Although the 16 factors were reviewed individually, the interrelationship between various factors has become evident, for example quality and tolerance. Furthermore, the interrelationship does not solely reside between groups of process or people factors but equally resides between individual process and people factors, confirming the importance of the interaction of process and people factors to the IM of offsite forms of bathroom construction.

The next chapter will justify the methodology and methods used to gather and analyse primary data, which will be discussed in a later chapter with the literature in this chapter and the preceding Chapter 2.

Chapter 4 – Research Methodology

4.1 Introduction

The previous two chapters reviewed the literature on traditional construction, interface management and offsite construction, in order to determine the process and people factors that influence the relationship of interface management to offsite forms of bathroom construction. This chapter will explain and justify the methodology and methods adopted to further the research.

The format for the research followed Saunders et al.'s (2016) 'research onion' approach (see Figure 4.1), which provides alternative approaches for each 'layer' of the research process.

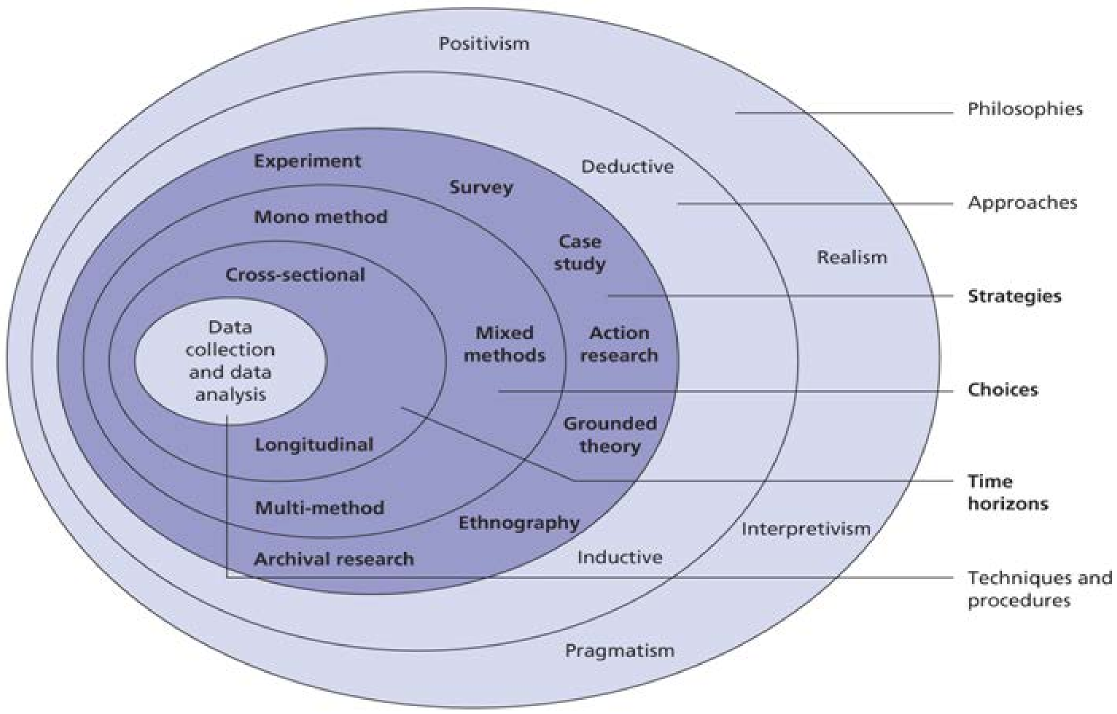

Figure 4.1: Research Onion Saunders et al. (2016)

A pragmatism paradigm was used, which is compatible with a case study strategy incorporating a mixed methods approach to collecting quantitative and qualitative data. The quantitative data were analysed with the use of the computer software Minitab, while the qualitative data were analysed manually with the aid of the Microsoft Excel package. Thematic analysis of the qualitative data culminated in the emergence of important sub-factors and themes.

4.2 The Meaning of Research Methodology

Research is defined by the Oxford English Dictionary (2013) as 'the systematic study of sources in order to establish facts and reach new conclusions'. In the context of this research a systematic study was carried out to determine facts, figures and relationships in order to draw conclusions and make recommendations. Methodology is defined as 'a system of methods used in an area of study' (Oxford, 2013) which for this research is the combination of techniques used to enquire into the relationship between offsite bathroom construction and interface management (Easterby-Smith et al., 2008). In essence, research methodology refers to the overall approach to the collection and analysis of data derived from a review of theory and literature. The theory applicable to this research has been determined as 'Organisational Theory' detailed in 4.3. Silverman (2013) argues that there is no 'correct' or 'incorrect' research methodology, only the methodology that is most appropriate for the particular research topic, which is guided by the aims, objectives and research questions.

4.3 Organisational Theory

Greenwood and Miller (2010 p 78) define organisational theory as 'an understanding of how to organise people and processes by organisational design, in order to collectively accomplish desired ends'. Jones (2001, p8) defines organisational theory as 'the study of how organisations function and how they affect and are affected by the environment in which they operate'. Both definitions capture the complexity and diversity of organisational theory. Furthermore, Tennant and Fernie (2014) argue that organisational theory is the bedrock theory for most construction management research that relates to people and process issues. . The theoretical approach used for this research is founded on 'Organisational Theory', due to organisational interface management being a major focus used to research the relationship of interface management to offsite bathroom construction. Moreover, organisational theory covers such a wide spectrum of management theories and concepts that it is prudent to include specific theories that can focus on particular areas of the research. System theory, contingency theory and actor-network theory have been identified as theories that can contribute within the organisational theory framework of this research. (Luhman and Cunliffe, 2013; Aubrey, 2011). .

Systems theory views organisations as a combination of technical and social systems, whereby a variety of process and people inputs are converted to outputs in the form of goods and/or stakeholder satisfaction (Mullins, 2016). System theory in the context of this research has been used as the lens to view the construction process, based on an open system approach, whereby feedback is incumbent on the system to advance the process from traditional to offsite (Luhman and Cunliffe, 2013). Contingency theory takes a more flexible approach and recognises that organisations differentiate in systems and structure and that environmental influence can vary (Mullins, 2016). The introduction of offsite bathrooms as an alternative to traditional bathroom construction can be seen as a deviation from the norm. The contingency approach looks to tailor the design to match the uncertainties of the new offsite method, with particular reference to the many interfaces affecting the process (Jones, 2001). Actor-network theory relates to how people interact in organisations, when exposed to varying ideas and processes, it looks at how the network stays in place or disassociates itself to form new networks (Harty, 2008). In the context of this research actor-networks relate to both internal and external stakeholders. It views the shift in dynamics when the main contractor and manufacturer are introduced into the process at an early stage to benefit the offsite bathroom process by ensuring that all stakeholders have the best interest of the project over self-interest (Luhman and Cunliffe, 2013).

Organisational theory with the aid of system, contingency and actor-network theories provides a framework for addressing the complex organisational relationships that interface each other, by making sense of what members of the organisations don’t necessarily see and don’t know, by addressing the linkages of the various processes that provide a successful output (Weick, 2016). In this research ‘sensemaking’ is applied to the data analysis to identify the sub-factors that contribute to the pertinent factors identified (Weick, et al. 2005).

While most literature separate ‘theory’ and ‘method’ as two independent entities, this research supports the view of Van Maanen et al. (2007) that the interaction between theory and method is beneficial in strengthening the findings from the research. Yin (2014) argues that the chosen theory is the building block for shaping the strategy to identify the research methods adopted. The case study strategy was considered appropriate to complement organisational theory that encompasses system, contingency and actor-network theories and the analysis of both quantitative and qualitative data for this research.

Organisational theory and the associated theories mentioned promotes the views of varying disciplines, both internally and externally to reconcile a methodology, which allows findings from an array of viewpoints to further research (Weick, 1999). This research will analyse the responses of clients, designers, main contractors, sub-contractors and manufacturers, to determine the main process and people factors that will have a positive influence on the interface management of offsite bathroom construction.

With more interest from clients to the uptake of offsite bathroom construction. Management are required to cope with an array of organisational problems. As has been mentioned previously organisational theory has been used as the foundation stone in the development of a conceptual model, to better understand the successful interface management of offsite bathroom construction, as shown in Fig 6.10.

4.4 Philosophical Background and Adoption

Easterby-Smith et al. (2008) offer three reasons why it is important for a researcher to have an understanding of the philosophical issues associated with research:

1. It can assist in choosing the research design.
2. The knowledge that the chosen design will work gives confidence.
3. It can aid the researcher in adopting a new form of design.

Creswell (2014) confirms this view by adding further that, when deciding on the actual research method or methods, it is incumbent upon the researcher to have an understanding of their philosophical stance. The terms ontology, epistemology and axiology are used to determine the philosophical standpoint or approach that the intended researcher will adopt.

Ontology, in its simplest terms, is a branch of study concerned with the nature and relationships of being, or things which exist, and deals importantly with the nature of reality and humanity (Easterby-Smith et al., 2008). Saunders et al. (2016) posit that ontology can be viewed from two perspectives: ‘objectivism’ and ‘subjectivism’. Objectivism views reality from an external position with no concern for the relationship between actors. Subjectivism takes the opposing view that the perceptions and interrelationships of actors are in a state of constant change, such that the subject matter requires in-depth research to uncover reality. It should be acknowledged that objectivism and subjectivism are not in competition, as both contribute to developing knowledge. However, the ontological stance for this research is in line with the subjectivism approach, as this researcher embarked on interviewing construction professionals, who have a degree of understanding of the reality of the construction industry from different professional perspectives.

Epistemology is narrowly defined as the study of knowledge. In a more practical sense, epistemology is about how we know what we know, and the limits or validity of the various ways of knowing. In the past, epistemology was mainly linked to scientific knowledge; however, the development of various methodologies, particularly in the field of construction management research, has given rise to epistemology being considered as also reflective in nature. Easterby-Smith et al. (2008, p. 60) succinctly define epistemology as a '*general set of assumptions about the best way of inquiring into the nature of the world*'.

Axiology refers to the role of values and ethics within the research process. The values and ethical code that the researcher embeds in the research process can have a substantial bearing on the validity of the research (Saunders et al., 2016). The extensive practical and theoretical experience of this researcher influenced the judgement on how best to carry out the various stages of the research. The axiology skills of this researcher were influential in identifying and probing the 82 interviewees from whom data were collected. Furthermore, an axiology code was adopted in the interpretation of the qualitative data, which contributed to research findings that are of value to the construction management community.

4.4.1 Philosophical Paradigms

A paradigm is a 'theoretical framework' that is the stance from which an event is viewed (Fellows and Liu, 2015, p. 18). The approach implied by the paradigm has an effect on the thinking, interpretation and analysis adopted to understand and discover the outcome of the event. It gives direction to how the research should be carried out and how the results should be interpreted.

Social positivism originated from the thinking of the French philosopher Auguste Comte (1798–1857), and in essence it deals with empirical evidence i.e. facts and figures. It leans towards the view that only true knowledge is measurable and that research used in the social sciences should fall within the parameters of scientific research therefore aligning itself with quantitative research methods, whereby the figures applied to a particular theory generate a consistent response. Positivism does not confer with subjectivity, whereby reflection and/or intuition are considered worthy components of research methods (Fellows and Liu, 2015). Easterby-Smith et al. (2008, p. 58) offer eight terms which can be associated with the positivism paradigm:

1. *Independence*: the observer should be independent from what is being observed
2. *Value-freedom*: the choice of what and how to study is determined by objective criteria
3. *Causality*: causal explanations and fundamental laws that explain regularity in human behaviour are identified
4. *Hypothesis and deduction*: fundamental laws are hypothesised allowing the deduction of what kinds of observations demonstrate the truth or falsity of the hypotheses
5. *Operationalisation*: a concept design that allows facts to be measured quantitatively is adopted
6. *Reductionism*: problems are reduced to the smallest possible elements
7. *Generalisation*: a sample of sufficient size is used to make generalisations about the wider human and social community
8. *Cross-sectional analysis*: assumptions are made by drawing comparisons across samples.

It could be asserted from the above that the hypothesis approach is central to the social positivism paradigm; however, the fundamental premise of the hypothesis must be able to withstand the test of quantitative analysis.

Philosophical paradigms that are viewed as having a direct opposite stance to positivism are interpretivism, phenomenology and social constructionism (Fellows and Liu, 2015; Amaratunga et al., 2002; Saunders et al., 2016). A common thread that influences these three philosophies is the aim of the paradigms to engage the researcher in an empathetic way with the social actors of the research, to make sense of the problem by the collection of qualitative data, which allows the various participants to express perceptions and beliefs. It is also acknowledged that the three paradigms have their own nuances. However, it is out with the scope of this chapter to review the plethora of paradigms that are available to researchers within the project and construction management discipline; rather, the objective is to gain an appreciation and justify the chosen framework.

While each of the three paradigms mentioned could equally be chosen as a suitable paradigm stance where qualitative data are the dominant method used to acquire knowledge, the research onion in Figure 4.1 illustrates the many layers that need to be considered when designing the research methodology. A review of the four philosophies offered by Saunders et al. (2016) concluded that the pragmatism paradigm was more suited to this research than the positivism, realism or interpretivism. Pragmatism was founded by the American philosopher Charles Peirce and advanced by the work of Jones, Dewey, Murphy, Paton and Rory (Creswell, 2014). The pragmatism paradigm's claims on knowledge come from real-time actions and situations. The pragmatist views positivism (quantitative data) as complementary to interpretivism (qualitative data). Furthermore, the pragmatist paradigm aligns with mixed methods of data collection and analysis, when it is deemed in the best interests of the research. Moreover, recognition is given that more than one philosophical stance or approach is acceptable for answering the research questions and objectives that drive the research (Creswell 2014).

4.5 Research Design

Reviewing the philosophical assumptions and stance allows a more knowledgeable approach to be used to review the many stages and alternative methods that are available to design the appropriate research methods. Creswell (2014) views research design as spanning the many stages that start with a research problem and end with the analysis of the data collected. Alternatively, Fellows and Liu (2015) define research design as the route the researcher adopts to answer the research objectives. Bryman (2012) concurs with Fellows and Liu and adds that, at each stage of the design, care must be taken to adopt the appropriate methods that contribute to the framework adopted to answer the research questions and objectives. This researcher affirms that the research onion offered by Saunders et al. (2016) provides a layered approach, with alternatives within each layer to allow the researcher to formulate a credible and robust research design suited to the task in hand.

In keeping with the research onion approach, the philosophy adopted is pragmatism, which is not committed to one system of reality. Moreover, it embraces a holistic approach of adopting a multiple-philosophy stance in the interests of the research. Pragmatism is commonly used in mixed method studies, and focuses on the 'what' and 'how' of the research problem. This approach fits more with the inductive approach (qualitative), but not to the total exclusion of the deductive approach (quantitative). The inductive approach suits when the main source of data is textual and the analysis produces findings, which can then be theorised (Saunders et al., 2016). The methodological choice is mixed methods (refer to section 4.5.3) and the data gathered is a combination of quantitative and qualitative, with the latter the dominant source and the former complementary. Jogulu and Pansiri (2011) argue that doctoral studies that relate to management research should embark on mixed methods research that advocates both inductive and deductive logic and integrates statistical and thematic data through triangulation of the data sets to ensure greater reliability and validity of the findings, in comparison to either single method.

The strategy used to gather the data comprised of a case study approach. This approach was considered compatible with the objectives of the study (Yin, 2014). The eight case studies chosen (refer to table 4.4) all incorporated methods of offsite bathroom construction. The time horizon used to collect the data from the case studies required a cross-sectional rather than longitudinal approach. Visits to the case studies consisted of two to five visits to carry out pre-arranged interviews with members of the project team.

4.6 Research Methods

Fundamental to research design are the research methods used for the collection and analysis of data. The research community look to either quantitative or qualitative as the method to be used; however, interest is increasing in the adoption of a third option – mixed methods (Easterby-Smith et al., 2008).

4.6.1 Quantitative Methods

The positivism paradigm leans towards the quantitative research method. When applied to social research it is objective in nature, and the variables which form the research are measured by numbers and analysed statistically. Furthermore, quantitative data are not termed as 'fuzzy' data; rather, they is considered hard, reliable and measurable (Naoum, 2013). The quantitative method will normally be used when the research requires the measurement of data, to advance previous laws or theories. Horna (1994, cited in Amaratunga et al., 2002) comments that deduction and the formation of social facts are required to measure human behaviour. Quantitative research is characterised by the use of observations and the fact that the researcher is not emotionally involved in the process to determine the results and increase knowledge. Common methods used to accumulate data include interviews, questionnaires, tests and measurements, and observations. In all the methods mentioned the questions asked are of a 'closed nature' such that a factual response is recorded as data (Easterby-Smith et al., 2008). Amaratunga et al. (2002, p. 22) suggest that quantitative research has particular strengths when applied within the field of built environment as follows:

- Comparison and replication of data are allowable
- The observer is independent of the subject
- Analysis of the subject is objective rather than subjective
- Reliability and validity are considered more reliable
- There is strength in measuring descriptive aspects of built environment

- The formulation of hypotheses is considered compatible with the quantitative method
- Reducing the whole into the smallest possible elements helps to search for causal explanations and fundamental laws.

When deciding on the analysis method or methods to be used in the analysis of quantitative data, consideration should be given to the appropriate scale of measurement (Bryman, 2012).

4.6.2 Qualitative Methods

The interpretivism paradigm links with the qualitative research method, which is subjective in nature (Naoum, 2013). Amaratunga et al. (2002) observe that qualitative data provide a rich form of discourse as it relates to people, objects and situations; it seeks to gain insight and meaning. Qualitative research is considered with events which occur naturally – it is real life and consequently is complex in nature and may be unstructured in form. It allows people's perceptions, assumptions and prejudgements to be analysed. Qualitative research is perceived by some members of the research community to be an easier method to analyse than quantitative research; however, in reality it is as demanding, if not more. It is time-consuming, when carried out correctly, to interpret the spoken word of participants (Fellows and Liu, 2015). Halfpenny (1979, cited in Silverman, 2011) offers a comparison between quantitative and qualitative methods:

Table 4.1: Claimed Features of Qualitative and Quantitative Methods (Halfpenny, cited in Silverman, 2011, p. 5)

Qualitative	**Quantitative**
Soft	Hard
Flexible	Fixed
Subjective	Objective
Political	Value-free
Case study	Survey
Speculative	Hypothesis testing
Grounded	Abstract

Qualitative research generally follows the interview technique for the gathering of data, with the aim of establishing possible patterns and relationships that exist within the categories being researched (Farrell, 2011). The format of the interview falls within the semi-structured category, with pre-determined questions. Farrell (2011) advocates the use of probing to elicit greater insight from the interviewee, and the responses from the interviewee following gentle probing form the qualitative data.

4.6.3 Mixed Methods

The mixed method approach makes use of both quantitative and qualitative research methods. The two methods are not used independently of each other; rather, they are used together to complement each other's strengths and weaknesses, thus improving the validity of the research (Creswell, 2014). Table 4.2 identifies the strengths and weaknesses of using the mixed methods approach.

Table 4.2: Strengths and Weaknesses of Mixed Methods Approach (Opoku et al., 2016)

Strengths	Weaknesses
Provides strong evidence for conclusions	More expensive and time consuming
Increases the ability to generalise the result	Researchers need to understand fully how to use multiple methods and approaches
Produces more complete knowledge necessary to inform theory and practise	Difficult when used in a single study
Answers a broader range of research questions	Can be difficult for a single researcher especially when the two approaches are used concurrently
Uses the strength of one method to overcome the weaknesses of another method	

A review of the weaknesses confirmed that the actual time and expense of collecting the data would not have been any greater had the collection proceeded for qualitative data only. Furthermore, while one case study can be considered a weakness, eight case studies were viewed as a strength. Overall, this researcher considers that the strengths of the mixed methods strategy outweigh its weaknesses confirming it as the best fit for the research undertaken.

Fellows and Liu (2015) identify 'triangulation' as a benefit of mixed methods whereby the research process is deemed stronger by the bridging effect of the two methods working in harmony with each other. Figure 4.2 demonstrates the power of combining the two methods and reflecting on previous research to gain insight into phenomena, which in turn will assist in developing new knowledge and theories.

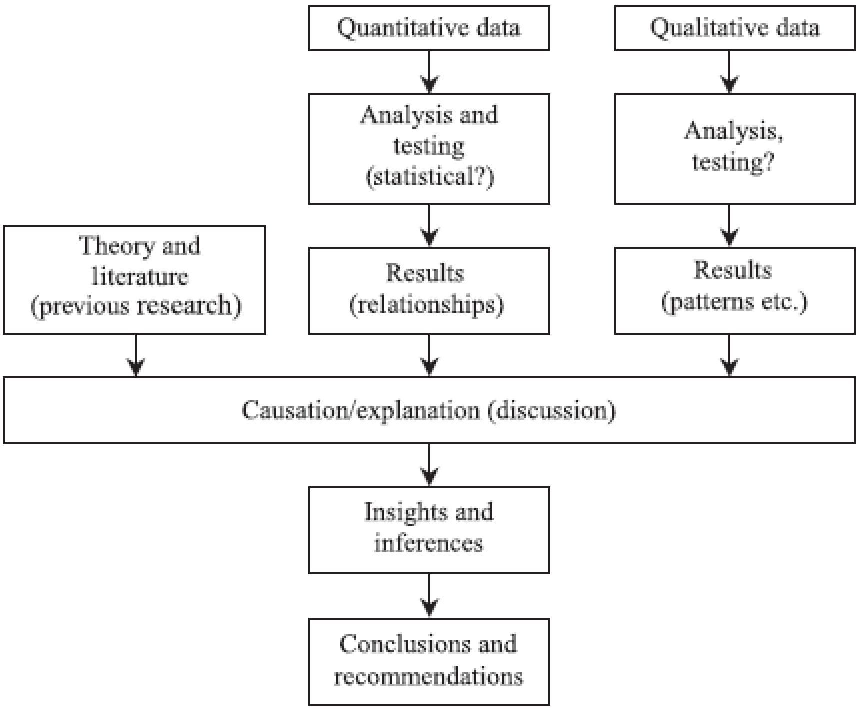

Figure 4.2: Triangulation of Quantitative and Qualitative Data (Fellows and Liu, 2015, p. 10)

The objective was to determine the appropriate method or methods to implement the research having reviewed the main opposing philosophical and paradigm aspects which dominate social science research. Flick (2014) describes two alternative approaches in making the choice:

1. Discard the methods which do not appear compatible with the research topic
2. Match the research method with the aim and objectives, such that the data contributes to the resolution of the research questions.

This researcher adopted option two. Central to the main themes of this research are people and process issues, and it is therefore considered that the main body of the research lies within the pragmatism philosophy, while the research method is predominantly qualitative analysis; however, a review of mixed methods of research led to the decision that the research method would ultimately be a mixture of quantitative and qualitative methods.

4.7 Research Process Adopted

The research process starts with a review of literature and theory. The initial review of literature assists the researcher in establishing the possible research question applicable to the study. Naoum (2013) suggests that a comprehensive review of existing literature aids the researcher in gaining an up to date appreciation of the main theories, laws and concepts which relate to the research topic.

The literature review comprises of two important parts. The search for appropriate literature and the syntheses of the literature reviewed. The initial search for literature applicable to the three main headings of traditional construction, offsite construction and interface management was carried out using the 'Discover' portal via the library web site of Glasgow Caledonian University. The search identified Emerald, Proquest, Science Direct, ARCOM and Google scholar as data bases conversant in construction management literature. From the data bases, journals such as Construction Management and Economics, Engineering Construction and Architectural Management, International Journal of Project Management etc, provided peer reviewed literature that was synthesised to identify the main process and people factors that influence the interface management of offsite bathroom construction.

A further literature search was carried out, using the above process to relate each of the factors identified to offsite (bathroom) construction and interface management. The synthesis of the literature identified potential barriers, constraints and benefits derived from the factor to the interface management of offsite bathroom construction.

Figure 4.3 in the form of a flow chart details the approaches to deliver the objectives, the various stages of the research process and their interrelationships.

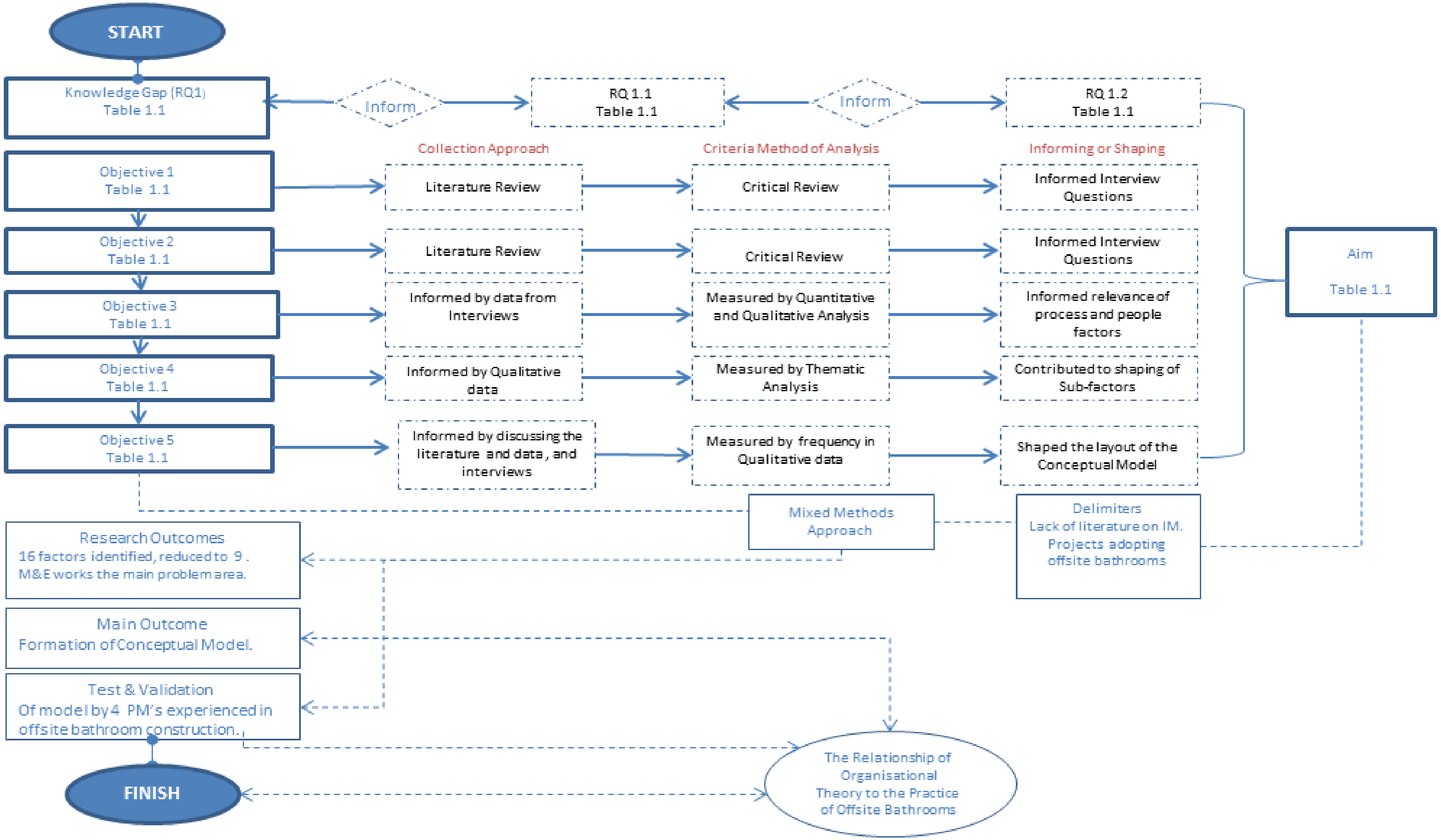

Figure 4.3: Research Flow Chart

4.8 Design of the Interview Proforma

The pro forma (refer to appendix A) was designed to facilitate semi-structured interviews and also to enable this researcher to capture quantitative and qualitative data. Section A consists of a series of general questions, for example interviewee name, company name, current project, age range, experience in the construction industry, experience of offsite construction and experience of offsite bathroom construction. The researcher assured the interviewees that anonymity would be respected. However, in the interests of creating a good rapport with the interviewee, it was considered appropriate to address them by their first name during the interview. Section B contains two questions which relate to interface management and offsite construction and utilises a five point Likert scale (see section 4.10.1), which was also used in sections C and D, followed by probing for additional comments.

The questions in section C relate to the nine process factors. Section D focuses on the six people factors (Ref to section 4.11 for explanation on reduction to 15 factors). The questions asked followed a similar pattern for each factor. Part 'a' of each statement explores the significance of the factor to interface management, while part 'b' gauges the influence of the factor on offsite or onsite bathroom construction. A third part question (part 'c') was introduced for design management, lean construction, tolerance and perception; however, the pattern remains the same. Section E contains three scenarios from which the interviewees were asked to rank the factors. Section F is a supplementary question which aimed to identify the main interface problems in relation to offsite bathroom construction.

4.9 Measurement Scales and Adoption

Leedy and Ormrod (2005) identify four scales of measurement: nominal, ordinal, interval and ratio. Each scale has its own characteristics and is listed in a hierarchy of levels of measurement, which determine the statistical analysis that can be used to analyse the data (O'Leary, 2010).

4.9.1 Nominal

Nominal originates from the Latin word *nomen* meaning 'name'. Therefore, a name has to be assigned to a person, place or thing for it to be measured nominally. For example, a group of children can be categorised into sub-groups of either male or female. A further example could be dividing the group of children by colour of hair (Leedy and Ormrod, 2005). Nominal data are limited in the statistical use of analysing data; however, its use can normally be implemented to tally responses (O'Leary, 2010). The data gathered for section A of the pro forma was measured using the nominal scale, thus clarifying distribution.

4.9.2 Ordinal

Ordinal measurement is used to measure data that has been configured to have a number of values that can be ordered by rank. It implies that statements being measured can be greater than or less than each other (Leedy and Ormrod, 2005). The numbers in ordinal data are used to categorise the various options. It is argued that the scales between the designations do not allow measurement of the difference and therefore no arithmetic calculations can be done on the classification; however, the median or half-way point can be calculated (Rowntree, 2000). The Likert scale (see section 4.10.1) is commonly used in research to gather data (O'Leary, 2010). A five point Likert scale was used to gather data for this thesis and, therefore, the resulting data were classified as ordinal.

4.9.3 Interval

Interval measurement not only orders the data, but also uses measurable units between the designations. Furthermore, it does not have an absolute zero; the zero point has been established arbitrarily. For example, temperature scales measure below zero. Interval scales allow statistical analyses that are not possible when the data are nominal or ordinal (Leedy and Ormrod, 2005).

4.9.4 Ratio

The main characteristics of the ratio scale are equal measurement units and an absolute zero. For example, if we measure the length of a table top we measure from one end to the other – there is no other measurement that relates to that table top – and we can proceed and measure many more table tops and use the measurement to compare measurements in the form of ratios. The ratio scale allows many forms of mathematical analysis to be carried out (Leedy and Ormond, 2005).

4.10 Interviews

Interviews can be carried out face to face, by telephone or by electronic means, for example Skype or Facetime. Important traits of the interviewer are the art of asking the questions and the art of listening, to allow the interviewee the freedom to express opinions and beliefs (O'Leary, 2010). Naoum (2013) identified the three most common forms of interviews to collect data:

- Structured
- Semi-structured
- Unstructured.

4.10.1 Structured Interview

In a structured interview, the interviewer executes a questionnaire-type interview, such that the questions are closed, the order of questions is pre-determined and the interviewer is inflexible to any change (Fellows and Liu, 2015). However, Naoum (2013) argues that the standardised approach of the structured interview provides data that is easily comparable. Fellows and Liu (2015) add that the inflexibility of the structured approach prevents the interviewer from probing for additional detail.

4.10.2 Unstructured Interview

The unstructured interview is the polar opposite to the structured interview. Naoum (2013) defines the unstructured interview as open-ended. The interviewer presents a general set of ideas to the interviewee, who has the opportunity to express his or her opinions in a random response (Fellows and Liu, 2015). Bryman (2012) states that this form of interview relies on social interaction between the parties to elicit data. The interviewee has more control of the proceedings than the interviewer such that it is not unusual for a quantity of the conversation to veer from the actual research objective, which can be compounded by the number of interviews carried out (Bryman, 2012). Fellows and Liu (2015) posit that the unstructured interview can result in a rich source of qualitative data, which can introduce new and applicable factors to the research. However, it is also acknowledged that it can be a time-consuming and complex set of data to analyse.

4.10.3 Semi-Structured Interview

As the term suggests, semi-structured is somewhat halfway between the two extremes of structured and unstructured. This form of interview can be administered via a proforma that allows some probing on a list of topic areas. It utilises a combination of ‘open’ and ‘closed’ questions, to acquire both quantitative and qualitative data (Fellows and Liu, 2015). The semi-structured interview approach assumes the ability of the interviewer to ‘probe’ the interviewee for additional information. This works best when both parties have a level of knowledge of the topic under review. Flick (2014) argues that the semi-structured interview is a form of ‘episodic’ interview designed to complement the interviewees’ experience and knowledge of the subject matter, to gain narrative from personal experiences and situations that the interviewee may have encountered. It is also advantageous to the process if the interviewer has a level of knowledge of the subject area allowing him or her to capture relevant data (Flick, 2014). The narrative data from semi-structured interviews can be analysed using thematic coding. Semi-structured interviews focus on a more specific group of interviewees, rather than the general population, and it can be concluded that the richness of data collected by this form of interview makes for comprehensive analysis.

Semi-structured interviews are favoured by many researchers in the construction management community, due to their capacity to access rich data. This allows researchers to provide real findings to real world problems (Dainty, 2008).

A review of the three forms of interviewing allowed this researcher to accept the semi-structured method as best-suited to collect data that would enhance the aim and objectives of the thesis.

4.10.4 Interview Bias

While the interviewer's experience could be seen as promoting bias. The interviewer acknowledged this and conducted the interviews with neutrality. (Dainty,2008). Qualitative data in particular can be subject to bias from both parties (Fellows and Liu, 2015). Creswell (2014) adds that to avoid bias the researcher should reflect on the narrative, and on how his or her past experiences have influenced the findings, through background, gender or culture.

4.11 Interview Process

This researcher made arrangements with the contacts of 12 projects and organised an initial site visit to ascertain the suitability of the project as a case study for the research. Purposive sampling was adopted as the sampling strategy due to this approach being more relevant to contributing to the research questions (Bryman, 2012). Following the initial visits, contact was made with the project managers of the eight projects chosen to gain approval and schedule interviews with team members (refer to Table 5.1). The 82 interviews were carried out face to face as semi-structured interviews, either on site or in the interviewees' main place of work, using the pro forma questionnaire. It was considered that the interviewees' normal work surroundings would maximise the data gained.

Permission was sought from each interviewee to record the interview. The pro forma was not sent to any participant before the scheduled meeting, to maximise spontaneous responses to the questions. It was also considered that the interviewer's experience of the construction industry had a positive influence on the interview process, while an unbiased approach to the process was maintained. Three A4 laminated cards of different colours were placed in front of the interviewee to act as aide-memoirs. A green card highlighted age range, a pink card highlighted the five responses of the Likert scale and a yellow card indicated the nine process and six people factors pertinent to the questionnaire. Each interview averaged 45 minutes and the interviews were all later transcribed.

4.11.1 Likert Scale

Rensis Likert developed the Likert scale as a means of gauging participants' attitude to various statements. The scales can comprise odd (five or seven) or even (four or six) numbers of points. The odd number of responses allows the participant to opt-out of expressing a view (Bryman, 2012). The five point scale is most commonly used in construction management research and it is the scale used in this research (refer to appendix A).

The common view held by the statistical community is that the use of the Likert scales generates ordinal data, and that it should be analysed using non-parametric tests. Non-parametric tests are used to analyse data where the distribution is not a fixed scale of measurement (Fellows and Liu, 2015). Norman (2010) argues that a considerable amount of social science research has been carried out using parametric tests (distribution is measureable) applied to data accrued from the use of the Likert scales. He states that, provided the application is robust, little cause for concern has been identified, and that 75 percent of research carried out in social sciences falls within this domain. Whether the Likert scales produce ordinal or interval data has been debated for approximately 60 years. Fellows and Liu (2015) recommend seeking advice from a statistician, to determine whether ordinal or interval data should be used. This researcher had a number of meetings with a statistician from the mathematics department at Loughborough University, who advised that the data from the Likert scales used was ordinal data and that non-parametric testing was more suitable.

4.11.2 Non-Parametric Statistics

Nominal and ordinal data are more appropriately measured using non-parametric methods (Walliman, 2011). While it is generally accepted that non-parametric tests are less powerful in their outcomes, it is also accepted that a reasonable sample size can produce a level of significance comparable to their equivalent parametric tests (Walliman, 2011, p. 215). While it is important to distinguish when it is appropriate to use parametric or non-parametric testing, it is of equal importance to use the correct method, which has sufficient rigour for the outcomes to be of value to the body of the research. Within this research, following further guidance from the statistician at Loughborough University, the Wilcoxon signed rank test was considered an acceptable method based on the ordinal data and the appropriate statistical method to contribute to the objectives outlined in the research (Leedy and Ormrod, 2005).

4.11.3 Wilcoxon Signed Rank Test

The Wilcoxon signed rank test is a non-parametric test used when the interest relates to the location of the median of a population. The Wilcoxon signed rank test is an extension to the sign test which is used to determine the positive or negative results of matched or paired data in relation to a stated median. The data used generally relates to before and after scenarios, and symmetry assumption is not required (Sprent and Smeeton, 2001). The Wilcoxon signed rank test is considered a more powerful and robust alternative to the sign test and to the parametric t-test, such that it can be applied when the data are ranked, and it can be applied to paired samples and/or to repeated data from a single independent sample where the continuous distribution of the data is symmetric about the median (Hollander et al., 2014).

4.11.4 Coding

Coding can take many forms. It may be that the aim is to summarize the text; alternatively, it could be that the transcribed text is expanded even more by adding perceptions of how the interviewee responded to the question, with insight. The strategy adopted here was to rearrange the data into short sentences and/or single words to allow categories to be formed and a coding system to be applied. Flick (2014) emphasises the importance of asking questions of the raw data, such as 'who, what, why', which aid the identification of similarities and differences when interpreting the text. Flick also states that it is fundamentally important when carrying out a form of qualitative analysis to focus on the research question. Based on earlier methods, which get their roots from the grounded theory approach developed by Glazer and Strauss, Flick has developed a 'thematic coding' process. The underlying principle of thematic coding is that the groups selected have some knowledge of the environment being researched and are not individuals or groups picked at random; this principle applies to the interviewees of this research.

A case study approach was used whereby the interviewee was connected to a project which formed part of the study. The code for each interviewee consisted of a project code with a unique number followed by a discipline code, a role code and finally the question or statement number (refer to appendix B). The analysis of all the qualitative data resulted in the emergence of codes for thematic sub-factors, which could be ranked in order of significance.

4.12 Pilot Study of the Interview Questions

Naoum (2013) argues for the implementation of a pilot study when using a questionnaire survey to gather quantitative data, suggesting that the clarity of the questions can be assessed. Bryman and Bell (2011) concur with Naoum and add that a pilot study is also advantageous to the interview method of data collection, as it can resolve ambiguity in the questions asked, give the interviewer experience on when and how to probe for more detailed responses and gauge the approximate duration required to carry out an interview.

With the design of the pro forma set out to gather both quantitative and qualitative data, utilising a semi-structured interview technique, it was considered prudent to engage in a pilot study, consisting of a mixture of academic and industrialist, to test the validity of the questions and the relevance to industry. Six participants agreed to take part. Three are currently employed in academia, with a varied level of construction experience. The remaining three occupy senior management positions within large construction organisations. Details of each are included in Table 4.3.

Table 4.3: Details of Pilot Interviewees

Pilot Interviewee	Employer	Role	Years of Experience in Construction	Years of Experience of Offsite Construction
P1	University	Research fellow	6	N/A
P2	University	Lecturer	10	2
P3	University	Lecturer	49	7
P4	Major contractor	Senior project manager	39	4
P5	Major contractor	Senior project manager	25	10
P6	International contractor	Project manager	24	8

The main amendments that resulted from the pilot survey included:

- Inserting a definition of interface management related to the context of this research
- Adjusting minor grammatical errors
- Removing the factor of 'leadership' as a standalone factor since the 'role of the project manager' is included as a people factor.

The pro forma was revised taking into account the above for use in the main sample interviews. Moreover, none of the data acquired from the pilot interviews was included in the data analysis. However, the data from the pilot study was used for the publication of a conference paper for the annual Association of Researchers in Construction Management (ARCOM) conference in 2012 (McCarney and Gibb, 2012).

4.13 Case Study

The strategy adopted from Saunders et al.'s (2016) research onion (see Figure 4.1) was one of case study. A case study is defined by Yin (2014, p. 16) as 'an empirical inquiry that investigates a contemporary phenomenon (the case) in-depth and within a real-life setting'. A case in this context can refer to an individual, a group, an organisation, a project and many other forms. Gerring (2004) argues that a case study is defined by what is being analysed not by the methods that will be used in the analysis. The main objective for the choice of case studies was that the construction projects had to implement a form of offsite bathroom construction in the present or very recent past. The case study approach superseded other strategies such as surveys, ethnography, action research and grounded theory as the strategy best suited to advance objectives two, three and four as stated in section 1.5.

Although the data gathered from a case study is generally qualitative, the gathering of quantitative data is not precluded when it is considered in the interest of the research (Yin, 2014). The pro forma was designed specifically to gather both quantitative and qualitative data.

4.13.1 Overview of the Sample Cases Selected

Flyvbjerg (2006) posits two distinct strategies for the selection of case studies. 'Random' (identified by chance) selection and 'information-oriented' (identified as relevant to the subject matter) selection. Fellows and Liu (2015) argue that the latter selection strategy provides a greater level of generalisability over the findings of the former. The objective in the selection of case studies was to identify information-oriented projects that wholly or partially engaged in offsite bathroom construction. Eight projects met the criteria of having a form of offsite bathroom construction as part of the works. Agreement was reached with senior management from each of the selected projects that this researcher would be afforded access to observe the process onsite where applicable and interview a selection of staff onsite. It was considered critical to the study that the interviewees would have a level of relevant experience (Flick, 2014) of the construction industry and offsite construction in particular, which may relate only to the case study selected. Observations are considered a form of data collection in their own right (Yin, 2014). However, the observations made by this researcher during visits to site were used to encourage the offering of in-depth qualitative data from the interviewees. The projects were coded A to H. Table 4.4 summarises the five classifications used to group the eight projects.

Table 4.4: Schedule of Projects

Classification and Project Code (A to H)
New-Build Student Accommodation (Pods)
Project A Project B Project C
Refurbishment Hotel (Pods)
Project D Project E
New-Build Prison (PC Concrete)
Project F
New-Build Office (Pre-Engineered)
Project G
Military Accommodation (Full Modular)
Project H

4.13.2 Reliability, Testing and Validity of the Case Study Data

To ensure reliable data that can be tested and validated Saunders et al. (2016) argue that every aspect of the structure, process and practice of interviewing should be directed towards reducing the impact the interviewer and interviewing situation have on the interviewee. Yin (2014) adds that reliability in case study research should demonstrate consistency and repeatability of the research procedure in all cases used to collect data. Punch (2014) suggests two ways in which the reliability can be improved:

1. Consistently use one set of questions and techniques in the interview
2. Reduce misconceptions of what the interviewee says.

To achieve reliability in the results, the same questions within the questionnaire (refer to appendix H) have been asked in the same order in all interviews.

The purpose of validation relates to ensuring the trueness and accuracy of the data and the generalisability of the findings in the formation of the conceptual model (Fellows and Liu, 2015; Saunders et al., 2016). Flick (2014) argues that an accurate transcription of the interview forms the basis for testing, valid and reliable analysis and interpretation. The process adopted to validate the utility of the conceptual model aligns with the validity strategy recommended by Creswell (2014), which concurs with Bryman's (2012) 'Face validity' approach. The actual process consisted of interviewing four project managers, experienced in offsite bathroom construction, who did not take part in the pilot or main interview process. The interviewees were sent a copy of the conceptual model (Fig 6.10) and figures 6.1 to 6.9, which detailed the relevant sub-factors in advance of the interview. The interviews took place at the interviewees' place of work. Permission was granted to record the interviews for transcription. Anonymity was assured by the interviewer.

4.14 Thematic Analysis

Clarke and Braum (2013, p. 120) acknowledge thematic analysis as 'a method for identifying and analysing patterns (themes) in qualitative data'. The premise of this research is centred on process and people factors (themes). Moreover, central to the analysis process was the search for and emergence of sub-factors (sub-themes) that have an influence on the main themes. Bryman (2012) acknowledges that thematic analysis has been commonly used to analyse qualitative data transcribed from interviews. However, Bryman also argues that many researchers view it as a tool to supplement other forms of analysis. Furthermore, as an analysis process it has not received adequate recognition as a standalone method of analysis.

Braun and Clarke (2006) argue that the flexibility in the use of thematic analysis should be considered as an advantage to its analysis function and that thematic analysis should be considered a method on its own right. Saunders et al. (2016) concur with Braun and Clarke adding that it can be used to analyse large or small amounts of qualitative data in an orderly and logical way, with the objective of identifying repetitions and patterns that lead to the emergence of new themes and sub-themes. Braun and Clarke (2006) offer six stages of the thematic analysis process: familiarisation with the data, coding, searching for themes, reviewing themes, defining and naming themes and writing up. It is worth noting that the process is not linear but more iterative and reflective in its approach. Based on the epistemological position of this researcher (experienced in managing construction projects), the research questions and objectives underpinning this thesis and the above arguments, thematic analysis was considered the appropriate method to analyse the qualitative data from the 82 interviews.

4.15 Data Analysis

The quantitative data from the interviews were analysed using the software packages Minitab and Microsoft Excel. The questions in section A (general information) of the pro forma that provided numerical data, for example age ranges and levels of experience, were organised in Minitab to provide histograms. Saunders et al. (2016) state that the use of graphs in quantitative data clearly denotes high and low values in a spread of data.

The numerical data gathered from the Likert scale questions in sections B, C and D of the pro forma were analysed in Minitab, and the resulting frequency tables showed the spread of responses over the five point scale (refer to appendix C). The same data were further analysed in Minitab using the Wilcoxon signed rank test to calculate the median value and the significance of the results at a 5% level, to determine if the level of response could be generalised as representative of the population (refer to appendix D).

Prior to analysing the 15 factors (nine relating to process and six to people), it was considered prudent to analyse the three ranking questions contained in section E of the pro forma. The interviewees were asked to rank the factors from one to five, with a ranking of one given to the most important factors relative to the following:

- Offsite forms of bathroom construction
- Interface management of traditional bathroom construction
- Interface management of offsite forms of bathroom construction.

The ranking responses were aggregated using a weighting of five for top-ranked factors and descending to one for fifth-ranked factors, to calculate a total weighting for each of the 15 factors, which could then be ranked in order (refer to tables 5.4 to 5.6 in Chapter 5). A further cumulative ranked table was formulated from the weightings achieved by each of the factors in the preceding three tables to rank in order of the cumulative weighting for each of the 15 factors. It was concluded that the factors ranked 10 to 15 would no longer be included in the remainder of the analysis process due to their low weighted score and that the analysis would continue for the factors ranked 1 to 9 inclusive (refer to table 5.7 in Chapter 5).

A large number of qualitative data were collected during the interview process. While a contemporary approach to analysing qualitative data in construction management research is to use a software package such as NVivo, Blismas and Dainty (2003) argue that computer aided analysis tools are not a panacea for the analysis of qualitative data; moreover, consideration must be given to the intuition and reflectivity of the researcher. Fellows and Liu (2015) agree that an open mind must be used on the form of analysis, with the expertise and experience of the researcher foremost in the decision of whether to analyse manually or use a computer package. It was therefore decided that, to maximise the richness of the data and the epistemological stance of this researcher, the data would be analysed manually using Microsoft Excel.

4.15.1 Process used to populate conceptual model

An Excel spreadsheet was set up for each question and statement. The comments from interviewees were uploaded and scrutinised sentence by sentence to establish pertinent sub-factors and themes. The process was iterative such that a number of passes were required for each question to satisfy this researcher of the relevance of the sub-factors and the appropriate relevance of the sentence to a sub-factor(s), which was given a value of one. Yin (2014) refers to this method of analysis as 'pattern matching', whereby the repeatability of the data helps to strengthen the validity of the case study approach. On completion of the analysis the total score for each sub-factor was identified (refer to appendix E). The total scores allowed the sub-factors to be ranked with the highest score first and tabled in descending order.

The top two or three sub-factors from each question or statement were further analysed by breaking down the verbal responses from interviewees by classification of project(s) (refer to table 5.12 in Chapter 5 for examples). Analysis of the textual data relevant to the sub-factor was carried out, incorporating direct quotations from interviewees when it was considered that the quote would add gravitas to the analysis. This resulted in the emergence of the main findings from the qualitative analysis of the sub-factors.

The nine factors were discussed further in chapter 6. The main statements in the proforma (refer to appendix A) applicable to each of the nine factors were discussed by making reference to the quantitative results and the highest rated sub-factors identified in the qualitative analysis. Where a sub-factor was identified as similar in context to more than one statement, it was only included once in the conceptual model. The final sub-factors were shaped from a discussion of the sub-factors with the literature, to inform the sub-factors that would contribute a positive influence to the factor. This process was carried out for each of the nine factors, which formed the conceptual model.

4.16 Research Ethics

Ethical issues play a pivotal role in all areas of the research process. Ethical consideration should be given as early as the formulation of the research topic, which also gives insight into the intendant participants. Paramount to the review of existing literature is giving recognition to the authors, whose ideas contribute to the analysis of the literature in a format that avoids plagiarism (Fellows and Liu, 2015). Bryman (2012) suggests that, in social research, ethical consideration must be given to the relationship of the researcher to the participants in the research. Saunders et al. (2016) argue that the researcher must give ethical consideration to the following in the process of data collection and analysis:

- Gaining access to possible case studies through intermediaries
- Clearly and openly divulging the purpose of the research during the initial meeting and all subsequent interviews
- Confirming the level of access required, for example the schedule of interviews per case study and the approximate length of time required for the interview process
- Confirming the privacy of respondents and the interviewee's opportunity to withdraw at any point during the interview process, with no repercussions
- Maintaining confidentiality of interviewees to avoid any embarrassment with fellow colleagues
- Avoiding deception by giving interviewees the opportunity to review transcribed data and to access the thesis should they so wish.

While ethical consideration in construction management research is mainly centred on human interaction, equal consideration should be given to the manipulation of the data in the process of concluding the thesis and any subsequent publications.

Moreover, it is incumbent on the researcher not to use a method of analysis which will knowingly distort the results and subsequent findings of the research (Fellows and Liu, 2015).

The ethical code adopted by this researcher during the entire research process complied with the above points, while also adding the principles of honesty and integrity to the entire process. The literature review was carried out to avoid any form of plagiarism. At no point in the transcribing of the data were any data fabricated or embellished such that a conflict of interest would result. Therefore, the data detailed is a 'warts and all' account of the interviews. The analysis of the data was carried out using methods pertinent to the type of data gathered, which resulted in findings and a conclusion to the research. A further ethical consideration should allow future researchers the opportunity to replicate the study at a later date; however, unlike experimental research, case study research is more challenging due to its transient nature.

4.17 Summary

This chapter has taken an in-depth review of the various methodological paradigms that have a direct effect on the method or methods used to collect and analyse data, with the primary aid of the research onion to justify their use as optimal approaches. The case study strategy was justified as best suited to gather data from participants that were currently engaged in offsite forms of bathroom construction, over a cross-sectional timeframe.

It is recognised that quantitative and qualitative methods are individually capable of being used to collect and analyse data in construction management research. However, combining both methods into a mixed method was justified as pertinent to gathering data from the participants engaged in each of the intended case studies. Moreover, the mixed method lends itself to validation of the data through triangulation. A pilot study of the pro forma preceded the interviews that were used to collect the data. After amending the pro forma the interviews were carried out using a semi-structured approach. The quantitative data, which were classed as ordinal for the purpose of measurement, were analysed using the Wilcoxon signed rank test, while the qualitative data were coded and manually analysed using thematic analysis. An ethical code of honesty and respect was maintained by the researcher during all stages of the research. The next chapter will proceed to analyse the data and identify findings that will contribute to the research outcome.

Chapter 5 – Data Analysis and Findings

5.1 Introduction

This chapter will analyse the data gathered from 82 interviews, with a mixed method approach having been adopted (refer to Chapter 4). The quantitative data are analysed using the Wilcoxon signed rank test to determine the significance of the data, while the qualitative data are analysed manually to uncover sub-factors that emanate from the interviewees' responses to the various statements and questions, with further findings originating from the sub-factor data analysed.

Prior to analysing this quantitative and qualitative data, the responses to three sets of ranking questions were evaluated and accumulated to determine the order of ranking of the following factors: procurement, supply chain management, whole life costing, health and safety, design management, lean construction, sustainability, tolerance, quality, communication, role of the project manager, culture, client and design team, perception and integration. The total weighting of these 15 factors was further reviewed, to ascertain the cut-off point for further analysis. The factors ranked one to nine, based on cumulative total weighting, were judged to warrant further analysis, while the total scores of factors ranked ten to fifteen were considered insufficient and therefore no further analysis will relate to these factors within this thesis.

5.2 General Information

The interview pro forma (see Appendix A) details the statements and questions put to the interviewees by the interviewer.

5.2.1 Trade/Graduate Background of Interviewees

The background of the interviewees was identified from three categories:

- Trade: (n=31) interviewee who has served an accredited apprenticeship onsite e.g. joiner, plumber, etc.

- Graduate: (n=46) interviewee who has gained a university degree e.g. architecture, quantity surveying, etc.
- Trade/graduate: (n=5) interviewee who has served an apprenticeship and gained a university degree.

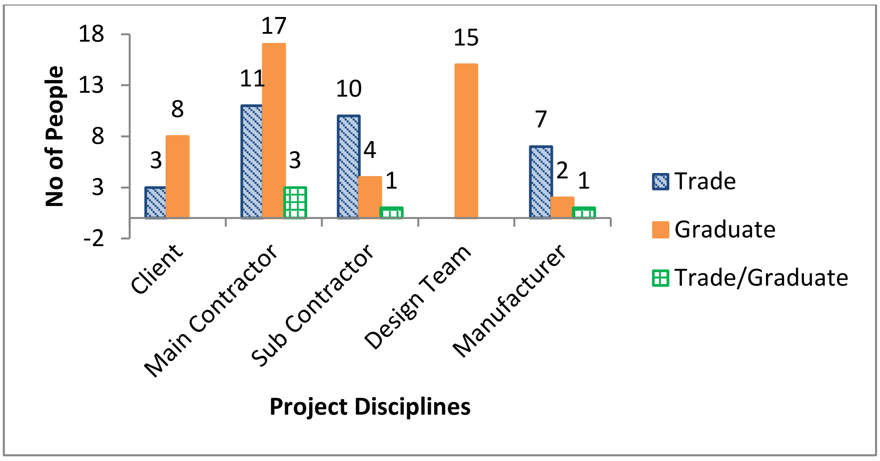

Figure 5.1: Background of interviewees

In summary, the client, main contractor and design team interviewees come mainly from a graduate background, with subcontractors and manufacturers coming mainly from a trade background. Interviewees came from 43 different companies across the various disciplines, with eight clients, seven main contractors, ten subcontractors, thirteen design teams and five manufacturers represented.

5.2.2 Breakdown of Interviewees

The interviewees confirmed the project that they were associated with at the time of the interview. Table 5.1 details the classification of projects, the project title within each classification and a breakdown of interviewees relative to client, main contractor, subcontractor, design team and manufacturer disciplines. Project classifications are new build student accommodation (NBSA), refurbished hotel (RH), new build prison (NBP), new build office (NBO) and military accommodation (MA).

Table 5.1: Table of interviews

Classification	Project	Client	Main Contract-or	Sub-Contract-or	Design Team	Manufac-turer	Total
New build student accom. (pods)	A	2	4	1	1	2	10
	B	1	1	1	4	(i)	7
	C	2	2	1	1	1	7
Refurbished hotel (pods)	D	1	(ii) and 3	2	2	2	10
	E	1	3	(ii)	(ii)	1	5
New build prison (PC concrete)	F	2	6	2	2	1	13
New build office (pre-engineered)	G	1	6	4	3	(iv)	14
Military accom. (full modular)	H	1	6	4	2	(iii) and 3	16
Total		**11**	**31**	**15**	**15**	**10**	**82**

i Manufacturer common to projects A and B

ii Common to projects D and E

iii Manufacturer common to projects D and H

iv Manufacturer went into administration after completion of project

5.2.3 Value and Duration of Projects

Table 5.2 shows that the projects ranged in value from £2.8 million to £116 million, with durations between 29 and 111 weeks, which illustrates a wide range of projects in terms of value and duration that in turn demonstrates that the views expressed by the interviewees are representative of the industry at large. Worthy of note is that the combined value of projects A, B and C, which fall within the NBSA classification, totals £42.8m and projects D and E, which form the RH classification, total £8.8m.

Table 5.2: Value and durations of projects

Classification	Project	Value of Project (£m)	Duration of Project (Weeks)
NBSA	A	17.5	78
	B	11.9	70
	C	13	66
RH	D	6	36
	E	2.8	29
NBP	F	27	60
NBO	G	116	111
MA	H	36	74

5.2.4 Age Range of Interviewees

Figure 5.2 provides the age ranges of the interviewees, showing a good and varied range of ages within each discipline category.

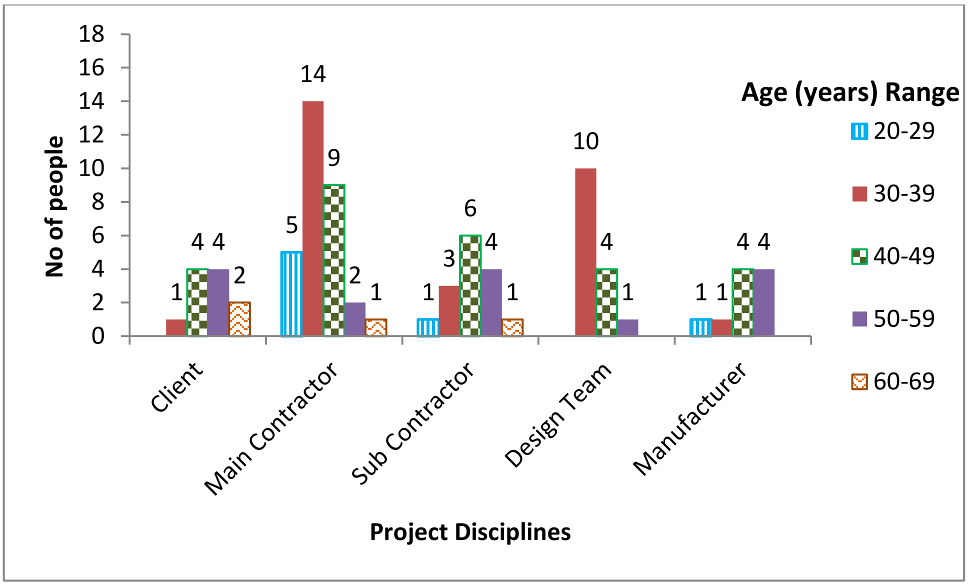

Figure 5.2: Age range of interviewees

5.2.5 Levels of Interviewees' Experience

Figure 5.3 shows the interviewees' accumulated years of experience in the construction industry, in relation to onsite bathroom construction, offsite methods of bathroom manufacture and installation, and other forms of construction.

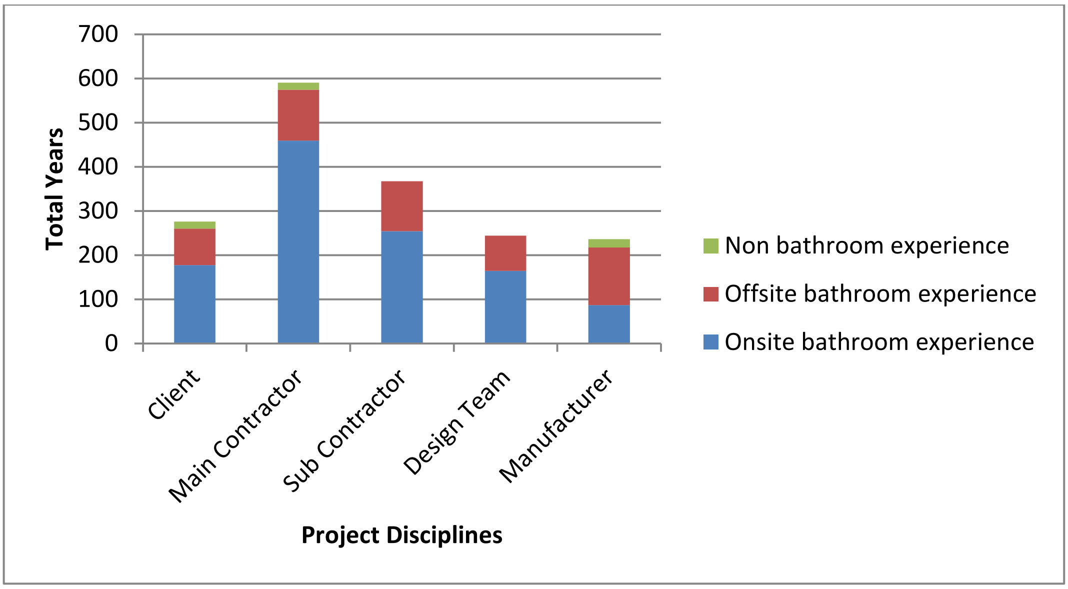

Figure 5.3: Interviewees' experience in the construction industry, and onsite and offsite bathrooms

Interestingly, the level of onsite bathroom experience in comparison to total industry experience is relatively high for the client (64%), main contractor (78%), subcontractor (69%) and design team (67%) in comparison to the manufacturer (37%). Conversely, the level of offsite experience compared to total construction experience for each discipline is demonstrated as client (30%), main contractor (19%), subcontractor (31%), design team (33%) and manufacturer (55%).

The results indicate that, when a client considers offsite bathroom solutions, they should communicate with a manufacturer and not just the design team as the manufacturer will have more in-depth experience of the offsite process in comparison to the design team. Furthermore, with more and more main contractors engaged in design and build projects and therefore able to influence design it could be construed that their lack of offsite bathroom construction experience could inhibit its inclusion in the design.

5.2.6 Areas of Offsite Experience

The interviewees were asked to identify their areas of offsite construction experience. Table 5.3 shows the range of experience per project classification. Worthy of note is that while the NBSA and RH projects used bathroom pods, and therefore the interviewees from both classifications could confirm experience in this area, overall 60 of the 82 interviewees (73%) confirmed a level of bathroom pod experience. The MA classification was the only one to use full modular construction; however, 33% of all interviewees had experience of this method. The results for the NBO classification, which used flat pack, and the NBP project, which used PC cells, were 23% and 20% respectively. The results denote a very good level of experience of bathroom pods and a fair level of experience in relation to the other methods of offsite bathroom construction, which could also be interpreted as denoting considerable potential for growth in these areas.

Table 5.3: Number of interviewees with experience of different offsite methods

Classification	Bathroom pods	Plant rooms	Service risers	PC cells	Modular construction	Flat pack construction	Timber Kits
NBSA	23	2	5	1	5	0	2
RH	15	1	0	1	3	1	0
NBP	6	1	4	13	2	4	0
NBO	6	3	4	1	1	14	0
MA	10	3	3	0	16	0	0
Total	**60**	**10**	**16**	**16**	**27**	**19**	**2**

With the exception of plant room, service risers and timber kits, the above are forms of offsite bathroom construction covered by this research. The categorical variables of background, age range and experience have not been included in further quantitative analysis as the main aim was not to compare across variables, but to analyse the data as a whole. It is anticipated that further studies will be carried out at a later date utilising the categorical variables.

5.2.7 Ranking of Factors

Following the interviewees' responses to the questions regarding process and people factors, they were asked to rank their top five factors in order of importance from the list of factors in relation to 'offsite forms of bathroom construction' (Table 5.4), 'interface management of traditional bathroom construction' (Table 5.5) and 'interface management of offsite forms of bathroom construction' (Table 5.6). The results were tabulated using a weighting of five for factors ranked first (most important) down to a weighting of one for factors ranked fifth (least important). The total weightings for each factor were accumulated and ranked in order of importance with the factor with the highest total weighting ranked first, down to the factor with the lowest total weighting ranked fifteenth. Table 5.7 shows the total weightings from Tables 5.4, 5.5 and 5.6 for each factor, and a cumulative total weighting is calculated and an overall ranking is established for each of the 15 factors.

Table 5.4: Ranking for 'offsite forms of bathroom construction'

Factor	Ranked Order	Ranked 1st/Weighting (5)		Ranked 2nd/Weighting (4)		Ranked 3rd/Weighting (3)		Ranked 4th/Weighting (2)		Ranked 5th/Weighting (1)		Total	Total Weighting
Design management	1	20	(100)	12	(48)	9	(27)	8	(16)	6	(6)	55	(197)
Quality	2	11	(55)	12	(48)	8	(24)	12	(24)	13	(13)	56	(164)
Communication	3	13	(65)	8	(32)	6	(18)	12	(24)	8	(8)	47	(147)
Procurement	4	13	(65)	4	(16)	15	(45)	5	(10)	6	(6)	43	(142)
Client/design team	5	3	(15)	12	(48)	8	(24)	5	(10)	6	(6)	34	(103)
Health and safety	6	8	(40)	9	(36)	2	(6)	3	(6)	6	(6)	28	(94)
Supply chain management	7	1	(5)	6	(24)	8	(24)	13	(26)	6	(6)	34	(85)
Tolerance	8	0	(0)	4	(16)	11	(33)	3	(6)	2	(2)	20	(57)
Sustainability	9	2	(10)	6	(24)	3	(9)	3	(6)	6	(6)	20	(55)
Role of the project manager	10	5	(25)	1	(4)	0	(0)	7	(14)	6	(6)	20	(49)
Lean construction	11	3	(15)	2	(8)	5	(15)	0	(0)	7	(7)	17	(45)
Whole life costing	12	1	(5)	4	(16)	4	(12)	4	(8)	3	(3)	16	(44)
Integration	13	1	(5)	1	(4)	2	(6)	6	(12)	2	(2)	12	(29)
Perception	14	1	(5)	1	(4)	1	(3)	0	(0)	2	(2)	5	(14)
Culture	15	0	(0)	0	(0)	0	(0)	1	(2)	3	(3)	4	(5)

Table 5.5: Ranking for 'interface management of traditional bathroom construction'

Factor	Ranked Order	Ranked 1st/Weighting (5)		Ranked 2nd/Weighting (4)		Ranked 3rd/Weighting (3)		Ranked 4th/Weighting (2)		Ranked 5th/Weighting (1)		Total	Total Weighting
Design management	1	15	(75)	13	(52)	8	(24)	5	(10)	5	(5)	46	(166)
Communication	2	15	(75)	9	(36)	8	(24)	13	(26)	4	(4)	49	(165)
Role of the project manager	3	12	(60)	12	(48)	7	(21)	3	(6)	2	(2)	36	(137)
Procurement	4	10	(50)	9	(36)	9	(27)	6	(12)	5	(5)	39	(130)
Quality	5	5	(25)	10	(40)	9	(27)	8	(16)	22	(22)	54	(130)
Health and safety	6	11	(55)	10	(40)	5	(15)	5	(10)	3	(3)	34	(123)
Supply chain management	7	5	(25)	5	(20)	12	(36)	13	(26)	11	(11)	46	(118)
Client/design team	8	3	(15)	6	(24)	7	(21)	2	(4)	7	(7)	25	(71)
Tolerance	9	2	(10)	0	(0)	7	(21)	7	(14)	7	(7)	23	(52)
Integration	10	1	(5)	0	(0)	4	(12)	6	(12)	6	(6)	17	(35)
Sustainability	11	0	(0)	3	(12)	3	(9)	2	(4)	3	(3)	11	(27)
Whole life costing	12	1	(5)	2	(8)	1	(3)	1	(2)	3	(3)	8	(21)
Lean construction	13	0	(0)	1	(4)	0	(0)	4	(8)	1	(1)	6	(13)
Perception	14	0	(0)	0	(0)	0	(0)	3	(6)	0	(0)	3	(6)
Culture	15	0	(0)	0	(0)	0	(0)	2	(4)	1	(1)	3	(5)

Finally, the interviewees were asked to rank their top five factors in order of importance from the list of factors in relation to 'interface management of offsite forms of bathroom construction on this project' (Table 5.6).

Table 5.6: Ranking for 'interface management of offsite forms of bathroom construction'

Factor	Ranked Order	Ranked 1st/Weighting (5)		Ranked 2nd/Weighting (4)		Ranked 3rd/Weighting (3)		Ranked 4th/Weighting (2)		Ranked 5th/Weighting (1)		Total	Total Weighting
Design management	1	23	(115)	9	(36)	13	(39)	8	(16)	4	(4)	57	(210)
Communication	2	14	(70)	12	(48)	10	(30)	7	(14)	7	(7)	50	(169)
Quality	3	5	(25)	9	(36)	6	(18)	13	(26)	13	(13)	46	(118)
Client/design team	4	8	(40)	7	(28)	10	(30)	3	(6)	5	(5)	33	(109)
Procurement	5	8	(40)	4	(16)	13	(39)	3	(6)	3	(3)	31	(104)
Supply chain management	6	1	(5)	9	(36)	5	(15)	12	(24)	10	(10)	37	(90)
Role of the project manager	7	8	(40)	7	(28)	2	(6)	5	(10)	5	(5)	27	(89)
Tolerance	8	3	(15)	4	(16)	9	(27)	7	(14)	3	(3)	26	(75)
Health and safety	9	4	(20)	3	(12)	3	(9)	7	(14)	3	(3)	20	(58)
Lean construction	10	2	(10)	8	(32)	1	(3)	3	(6)	3	(3)	17	(54)
Integration	11	1	(5)	2	(8)	3	(9)	8	(16)	9	(9)	23	(47)
Whole life costing	12	2	(10)	4	(16)	1	(3)	2	(4)	4	(4)	13	(37)
Sustainability	13	0	(0)	2	(8)	3	(9)	0	(0)	7	(7)	12	(24)
Perception	14	2	(10)	1	(4)	1	(3)	1	(2)	1	(1)	6	(20)
Culture	15	0	(0)	0	(0)	1	(3)	2	(4)	4	(4)	7	(11)

Table 5.7 shows the aggregate ranking based on the results of the three previous tables, with the overall totals and total weightings for each factor.

Table 5.7: Cumulative ranking of factors (from Tables 5.4, 5.5 and 5.6)

Factor	Ranked Order	Total 5.4	Total Weight	Total 5.5	Total Weight	Total 5.6	Total Weight	Total	Total Weight
Design management	1	55	(197)	46	(166)	57	(210)	158	(573)
Communication	2	47	(147)	49	(165)	50	(169)	146	(481)
Quality	3	56	(164)	54	(130)	46	(118)	156	(412)
Procurement	4	43	(142)	39	(130)	31	(104)	113	(376)
Supply chain management	5	34	(85)	46	(118)	37	(90)	117	(293)
Client/design team	6	34	(103)	25	(71)	33	(109)	92	(283)
Health and safety	7	28	(94)	34	(123)	20	(58)	82	(275)
Role of the project manager	8	20	(49)	36	(137)	27	(89)	83	(275)
Tolerance	9	20	(57)	23	(52)	26	(75)	69	(184)
Lean construction	10	17	(45)	6	(13)	17	(54)	40	(112)
Integration	11	12	(29)	17	(35)	23	(47)	52	(111)
Sustainability	12	20	(55)	11	(27)	12	(24)	43	(106)
Whole life costing	13	16	(44)	8	(21)	13	(37)	37	(102)
Perception	14	5	(14)	3	(6)	6	(20)	14	(40)
Culture	15	4	(5)	3	(5)	7	(11)	14	(21)

Interestingly, design management, communication, quality and procurement score in the top five in all the tables, while supply chain management, client and design team, health and safety, role of the project manager and tolerance consistently rank within the 6–10 range. The remaining factors of lean construction, integration, sustainability, whole life costing, perception and culture consistently fall within the 9–15 range in all of the tables. It was considered pragmatic to focus the remainder of the analysis on factors one to nine as listed in Table 5.7, due to the significant gap in the total weighting of number nine (tolerance = 184) and number 10 (lean construction = 112) as indicated by the red dashed line in Table 5.7.

Before responding to the questions and statements that relate to the factors ranked one to nine, the interviewees were asked to respond to two general statements, to gauge their understanding of the relationship between interface management (IM) and offsite solutions:

- Effective IM is more important when using offsite solutions (Section 5.3)
- Using offsite solutions improves IM on this project (Section 5.4).

5.3 Effective IM Is More Important When Using Offsite Solutions

5.3.1 Quantitative Analysis

5.3.1.1 Frequency Analysis

Table 5.8: Frequency table – effective IM is more important when using offsite solutions

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	8	10
Neither agree or disagree (3)	5	5
Agree (4)	34	42
Strongly agree (5)	35	43

Interestingly, the counts for both agree (42%) and strongly agree (43%) are almost equal, confirming that 85% of interviewees either agreed or strongly agreed that effective IM is more important when using offsite solutions. With 10% disagreeing with the statement and 5% having no view, how important practitioners consider IM to be when using offsite methods of construction is demonstrated. Table 5.9 shows the Wilcoxon signed rank test for these results.

5.3.1.2 Wilcoxon Signed Rank Test

Table 5.9: Wilcoxon signed rank test – effective IM is more important when using offsite solutions

Test of median = 3.000 versus median not = 3.000

Total Number of Samples	Number for Test	Wilcoxon Statistic	P-Value	Estimated Median
82	77	2831.0	0.000	4.5

Null hypothesis (H_0): in the population the median of the difference is equal to 3.

Alternative hypothesis (H_1): in the population the median of the difference is not equal to 3.

The p-value of 0.000 in Minitab is converted to p<0.001 for consistency. Using a significance test at the 5% level, the p-value of <0.001 indicates a very significant output and therefore it is reasonable to reject the null hypotheses and accept the alternative hypotheses.

From a test number (total sample minus number who neither agree or disagree) of 77, the midpoint of the distribution of the responses indicates a median value of 4.5, which corresponds with the alternative hypotheses and the high percentage of agree and strongly agree indicated in Table 5.8, which infers from the results that there is a tendency among the population to agree.

Table 5.10 has been compiled to show the results of the Wilcoxon signed rank tests for the 22 questions which relate to the analysis. The responses for each question are identified against a five point Likert scale (1 = strongly disagree; 5 = strongly agree), and the value of 82 in all of the ‘total’ columns signifies that all interviewees responded to all the Likert scale questions in the pro forma. The ‘number for test’ column quantity for each question signifies the total number of responses minus the responses for neither agree nor disagree. The remaining columns, ‘estimated median’, ‘Wilcoxon statistic’ and ‘p-value’ have all been calculated using the software package Minitab. The ‘significant’ column states ‘yes’ when the p-value is less than 0.05, confirming that the test is significant at the 5% level, with evidence to reject the null hypothesis; conversely, the column states ‘no’ when the p-value is greater than 0.05, which indicates no evidence to reject the null hypotheses and therefore is not significant.

Table 5.10: Wilcoxon signed rank results for the 22 questions or statements

State-ment No.[1]	Responses 1	2	3	4	5	Total	No. for Test	Estimated Median	Wilcoxon Statistic	P-Value	Signifi-cant
14	0	8	5	34	35	82	77	4.5	2831	<0.001	Yes
15	2	8	8	47	17	82	74	4.0	2421	<0.001	Yes
16A	0	6	6	44	26	82	76	4.0	2773	<0.001	Yes
16B	0	14	16	42	10	82	66	3.5	1812	<0.001	Yes
17A	0	1	5	29	47	82	77	4.5	2987.5	<0.001	Yes
17B	0	19	24	32	7	82	58	3.5	1217	0.005	Yes
19A	0	0	1	29	52	82	81	4.5	3321	<0.001	Yes
19B	0	6	9	27	40	82	73	4.5	2599	<0.001	Yes
20A	0	0	2	31	49	82	80	4.5	3240	<0.001	Yes
20B	0	0	5	38	39	82	77	4.5	3003	<0.001	Yes
20C	0	26	13	33	10	82	69	3.5	1635	0.011	Yes
23A	0	1	3	35	43	82	79	4.5	3141	<0.001	Yes
23B	0	8	7	41	26	82	75	4.0	2650	<0.001	Yes
23C	4	41	5	26	6	82	77	3.0	1319	0.355	No
24A	0	0	0	36	46	82	82	4.5	3403	<0.001	Yes
24B	3	3	6	37	33	82	76	4.5	2689	<0.001	Yes
25A	0	0	0	14	68	82	82	5.0	3403	<0.001	Yes
25B	3	39	25	8	7	82	57	2.5	559.5	0.034	Yes
26A	0	0	0	27	55	82	82	4.5	3403	<0.001	Yes
26B	2	40	22	15	3	82	60	2.5	594	0.018	Yes
28A	0	0	2	25	55	82	80	4.5	3240	<0.001	Yes
28B	3	33	17	21	8	82	65	3.0	1057.5	0.925	No

As shown in table 5.10 most of the results are skewed in favour of being significant at the 5% level. This confirms that the majority of interviewees responded to the higher level values of four (agree) and five (strongly agree), which indicates the majority the interviewees agreed with the statements. However, the skewness has had relatively insignificant effect on the analysis and results, due to the ordinal

[1] Refers to statement numbers in pro forma (Appendix A)

data, analysed by a non-parametric method (Wilcoxon Signed Rank Test) (Hollander et al., 2014; Walliman, 2011).

Of the 22 responses 20 confirm significance at the 5% level and, of the 20, 16 have p-values calculated at <0.001, while the remaining four have p-values still significantly less than 0.05. The remaining two of the total 22 have p-values greater than 0.05, which suggests that the null hypotheses should not be rejected, along with neither agree nor disagree, which is considered not significant. The relationship of the frequency test to the Wilcoxon test will be analysed in the quantitative section of each question to check the inference of the sample to the population.

5.3.2 Qualitative Analysis

Table 5.11: Ranking table – effective IM is more important when using offsite solutions

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Most important to co-ordinate design early	24	28
2	Clearly define interfaces	20	20
3	Teamwork and good communication	14	14
4	Design team problems	13	13
5	Benefit of manufacturer’s expertise	12	12
6	Early involvement and procurement	9	9
6	Effective IM of equal importance to offsite and onsite construction	9	9
8	More flexibility with onsite construction methods	8	8
9	More important in relation to onsite construction	5	5
9	Sequence of work and logistics	5	5
11	Value for money	4	4

12	Contractor-led design	3	3
12	Working in isolation offsite	3	3
12	Construction tolerance	3	3

The qualitative analysis will focus on the sub-factors ranked one and two, which contain the two highest levels of responses:

- Most important to co-ordinate design early (5.3.2.1)
- Clearly define interfaces (5.3.2.2).

5.3.2.1 Sub-Factor One: Most Important to Co-ordinate Design Early

Table 5.12 indicates the breakdown of the number of interviewees and their responses from each category to the sub-factor.

Table 5.12: Breakdown of responses/interviewees: effective IM is more important when using offsite solutions – sub-factor one

Classification	Responses	Interviewees
NBSA	13	11
RH	0	0
NBP	7	6
NBO	6	5
MA	2	2
Total	28	24

Interviewees involved in the NBSA projects highlighted that a lack of co-ordination of the design attributed to a problem with threshold details, such that a step had to be formed in two of the three projects, which was not envisaged in the design:

> *'The doors for the modular – there was a hell of a problem there – there was no threshold detail' (B1/C/PM).*

Projects B and C of the NBSA category had toilet pods installed without the entrance doors being fitted; problems occurred in relation to the quality of the fitted architraves around the doors. It was considered that a tolerance issue between the manufactured pods and the onsite installation contributed to the problem. A lack of co-ordination of architectural and service details was also considered an area of particular concern, as was the use of semi-prefabricated pods, whereas fully manufactured pods were considered more beneficial to the project:

> *'Half of it is a lack of coordination between M&E (mechanical and electrical) and architectural, and that applies just as much to any pre-fabricated items. We went for a semi-traditional pod arrangement on this residence, which was a total disaster' (C1/C/SPM).*

The procurement method should allow early participation of the offsite contractor to create a management structure that promotes early communication among all the parties:

> *'With offsite management there is a lot of front end co-ordination, which is very important at that stage; you need to plan it in detail so that it works out when it comes to site' (C4/MC/DM).*

The NBP project highlighted the need for a different mindset from stakeholders when incorporating prefabricated units into traditional construction:

> *'When marrying an offsite solution, you're beginning at the end and working backwards and that is not the typical thought process of the traditional contractor. It's very difficult to get the M&E designers to understand the importance of being right at the very beginning. … We have to have the answers first, which is a complete change from traditional' (F3/MC/PM).*

Thus, it is important to achieve a completed design before the start of the project, unlike most traditional projects which can facilitate a higher degree of later variation. This was also highlighted by the interviewees involved in the NBO project. Also emphasised on the NBO project was the need for sufficient lead-in time to complete and co-ordinate the design, which can be problematic when the client requires a fast-track project:

> *'On fast paced projects you don't have the time to do upfront design, co-ordination and interface management. We were very pushed on this project; ideally we should have had more time' (G6/MC/DM).*

An interviewee on the MA project highlighted the importance of co-ordinating the design due to the impact it can have on the contract programme:

> *'Purely because if you don't get it right it goes drastically wrong. For instance, if you have a site start date of 1st of Feb but your manufacturer doesn't finish until 15th of Feb, you're late – it's going to have a major impact on what happens onsite' (H14/M/QM).*

Delays with the delivery of units can have a detrimental effect on the overall project and therefore its importance should not be under-emphasised.

The main finding from the sub-factor 'most important to co-ordinate design early' is that the procurement route must allow input at the design stage from the contractors and manufacturers associated with the offsite bathroom, to minimise interface problems.

5.3.2.2 Sub-Factor Two: Clearly Define Interfaces

Table 5.13: Breakdown of responses/interviewees: effective IM is more important when using offsite solutions – sub-factor two

Classification	Responses	Interviewees
NBSA	6	6
RH	2	2
NBP	5	5
NBO	5	5
MA	2	2
Total	20	20

The general view of the NBSA interviewees emphasised the need to have the interfaces clearly identified prior to the placing of the procurement order, and this is captured by an interviewee from project B:

> *'You've got to have the interfaces pre-placement of the procurement order' (B2/MC/PM).*

The need for the architect and mechanical and electrical consultants to co-ordinate on all aspects of the design was highlighted, to eliminate any ambiguity with regard to the physical interfaces between the trades. Clearly defined interfaces make the process easier for the various trades involved in the incorporation of the offsite unit onsite:

> *'If you've got a prefabricated pod then so many things are preformed that actually it makes some things easier for the plumbers and joiners to work to' (C3/MC/CM).*

An interviewee from project D of the RH projects considered that the building of a 'mock-up pod' would identify any unclear interfaces before the main process starts onsite:

> *'You do a sample one, you know. You check the product before you roll it out, so I guess a sample pod should be requested first' (D8/DT/QS).*

Consideration should be given by the client to the provision of a mock-up bathroom in the tender and programme documents.

The NBP project identified a particularly disruptive interface, in relation to the size of holes that were pre-formed for service pipes. On installing the pipes, it became apparent the hole was too big; washers had to be supplied and fitted to rectify the problem:

> *'So that has cost us in the region of about £10,000 such is the impact' (F3/MC/PM).*

An interviewee on the NBO project emphasised the need to identify, clearly define and communicate the interfaces early in order that the trade contractors involved have a clear understanding of the work they are required to carry out:

> *'So If you don't sort out your interfaces before you start then you lose the benefit of what you gain and you end up hacking things to pieces' (G3/MC/SM).*

An MA project interviewee also emphasised the importance of having the interfaces clearly identified at the start, due to the adverse impact unclear interfaces can have on the contract programme:

> *'It needs to be right from the start because you're building a building offsite – it's like building a car offsite' (H4/MC/CM).*

The main finding associated with sub-factor 'clearly define interfaces' is that consultants need to co-ordinate and communicate interfaces early in the design process before the procurement process, otherwise the benefits of working offsite will be lost. Furthermore, the tender documents should allow for a mock-up of the bathroom to be constructed, to clearly identify potential interface problems.

5.4 Using Offsite Solutions Improves Interface Management on This Project

5.4.1 Quantitative Analysis

5.4.1.1 Frequency Analysis

Table 5.14: Frequency table – using offsite solutions improves IM on this project

Likert Scale	Count	Percentage
Strongly disagree (1)	2	2
Disagree (2)	8	10
Neither agree or disagree (3)	8	10
Agree (4)	47	57
Strongly agree (5)	17	21

The 78% of combined positive results (agree at 57% and strongly agree at 21%), confirms that interviewees support the view that using offsite solutions improves IM on their project. Interestingly, 2% had reason to strongly disagree, citing the lack of flexibility when installing a prefabricated unit compared to traditional build. Also, the poor quality of the manufacture and the uniqueness of this form of construction to the contractor can result in interface problems. The Wilcoxon signed rank test was used to determine if the results are representative of the population.

5.4.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 15. From a test number of 74, the calculation determined an estimated median of 4.0, which conforms to the high level of agreement of 78% established in Table 5.14, which infers there is a tendency among the population to agree with the statement that using offsite solutions improves IM on this project.

5.4.2 Qualitative Analysis

Table 5.15: Ranking table – using offsite solutions improves IM on this project

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Manufacturer's expertise	12	12
2	Important to get design correct early	11	11
2	Good communication and teamwork	11	11
4	Requires good planning and organising of the total process	9	9
5	Makes no difference to IM	8	8
5	Offsite methods improve IM	8	8
7	Fewer interfaces improves IM	7	7
8	Buildability problems	6	6
9	Offsite is a faster production process	5	5
9	Made IM worse	5	5
11	Dependent on procurement method	4	4
11	Aids programme and time of delivery	4	4
13	Fewer snagging works	3	3
14	Reduced carbon footprint	1	1

The qualitative analysis will focus on the sub-factors ranked one and two:

- Manufacturer's expertise (5.4.2.1)
- Important to get design correct early (5.4.2.2)
- Good communication and teamwork (5.4.2.3).

5.4.2.1 Sub-Factor One: Manufacturer's Expertise

Table 5.16: Breakdown of responses/interviewees: using offsite solutions improves IM on this project – sub-factor one

Classification	Responses	Interviewees
NBSA	4	4
RH	2	2
NBP	1	1
NBO	2	2
MA	3	3
Total	12	12

An interviewee associated with project C of the NBSA projects considered that the pedigree and experience of the manufacturer can considerably improve IM on their project:

> *'We've been manufacturing since 1979 so we have the pedigree already, whereas a lot of the industry today, in the modular construction, is still in its infancy and doesn't have the pedigree behind it' (C7/M/D).*

However, consideration must always be given to inspecting the product when it arrives on site: *'we've got a big checking procedure to go through' (A8/DT/A).*

Traditionally, pod construction would not be considered for a refurbishment project, but the interviewees from the RH projects were confident and pragmatic about their ability to install the units whatever the challenges:

> *'On a refurb, sometimes you might not be able to go down that route; however, if you look hard enough there is always a means of getting them in' (D2/MC/PM).*

Incorporating manufactured units makes the overall process much easier to manage. A subcontractor project manager on the NBP project commented that offsite solutions save considerable time and the product is produced to a higher quality by the manufacturer.

A comment from the NBO project alluded to the benefit of the reduced quantity of works carried out onsite:

'You're delegating to the specialist subcontractor the interface issues that you do not have to manage onsite, which I can see as being effective, but you pay a price for it and that's the trade-off' (G1/C/PM).

However, while in theory the manufacturer's process should be problem free, in reality a high level of co-ordination is required to benefit from the manufacturer's expertise. A comment from the MA project concurred with the earlier comment from project C, which highlighted the importance of procuring a manufacturer with a proven record and if possible a manufacturer with expertise in the particular field:

'That's strengthened by who we've procured and the lessons learnt and they've done it before' (H2/MC/SPM).

Therefore, lessons learned can be used on a partnering arrangement, thus producing a *'finished product that is better'* (H13/DT/CME) and that has fewer interface issues than if onsite methods were used.

The main finding associated with 'manufacturer's expertise' is that designers should look to incorporate as many offsite processes into a project as is possible, and this should equally apply to refurbishment projects. However, regardless of the manufacturer's expertise, the main contractor should maintain close co-ordination and supervision of the manufacturing process and not adopt an 'out of sight out of mind' approach.

5.4.2.2 Sub-Factor Two: Important to Get Design Correct Early

Table 5.17: Breakdown of responses/interviewees: using offsite solutions improves IM on this project – sub-factor two

Classification	Responses	Interviewees
NBSA	4	4
RH	1	1
NBP	2	2
NBO	2	2
MA	2	2
Total	11	11

An interviewee involved in the NBSA projects commented that when using offsite solutions, it is very important to '*co-ordinate the design early … make sure we have the correct handed pods in position, because once we've gone up a level you can't get that pod in' (A8/DT/A).* It makes all stakeholders aware of the design requirements, which in turn will greatly improve the management of the interfaces. A comment from an interviewee on project D of the RH category highlighted:

> *'It's very much client orientated what they want and the design is sort of agreed prior to obviously the making of it and bringing it onsite' (D4/MC/SM).*

There is no opportunity to make alterations to the factory produced units when they arrive on site. An interviewee on the NBP project again emphasised this need:

> *'The design team, early doors, need to be up to speed and in communication with whoever is doing the offsite manufacture in terms of clash detection etc.' (F6/MC/QS).*

This highlights the importance of communication between all parties and the foresight required to resolve any interface clashes. An interviewee from the NBO project commented that using offsite solutions *'forces the issue. It forces you to do it – you have to do it – whereas traditional you leave it and leave it until you get here and work the problem through'* (G8/SC/PM). In other words, the solution is resolved on site during the construction phase and not always to the client's satisfaction, rather than identifying and designing out the problem during the design process. Most interviewees from the MA project argued that using offsite solutions reduced the number of defects on site. This was captured by an interviewee as '*the interfaces have obviously been thought about and detailed better'* (H13/DT/CME), and consequently the associated costs are managed better, due to better detailing and more rigorous testing procedures in the production process.

The main findings attributed to sub-factor 'important to get design correct early' suggest that the procurement route must allow for the client, main contractor and manufacturer to liaise during the design stage, to ensure the client has been informed of the offsite bathroom design options available to the project.

5.4.2.3 Sub-Factor Three: Good Communication and Teamwork

Table 5.18: Breakdown of responses/interviewees: using offsite solutions improves IM on this project – sub-factor three

Classification	Responses	Interviewees
NBSA	1	1
RH	4	4
NBP	2	2
NBO	1	1
MA	3	3
Total	11	11

An interviewee from project A of the NBSA projects explained of good communication and teamwork:

> *'It's making sure that it is fully understood in the design and development side' (A1/C/PM).*

This emphasises the importance of communicating the offsite process from design through to the construction phase of the project. An interviewee from project D of the RH projects commented that using offsite solutions promotes the need for '*open and early communication by getting everyone round the table'* (D1/C/PM) which should include the design team, contractor and manufacturer. Should a team spirit not be fostered by the process, the considered view of an interviewee of project E of the RH projects is that *'if you don't have a joined up thinking between everybody it will fail' (E5/M/NSM).* The latter comment was reiterated by members of the NBP project, who argued that a lack of effective communication and teamwork contribute to a failed project; that is, good communication is vital when using offsite methods and all stakeholders must build up relationships early and promote open communication.

The aspect of relationships was considered by an interviewee from the MA project:

> *'I would say on this project, yes it does work well. There are a lot of relationships built around the different companies to actually work that product' (H6/MC/BSM).*

The interviewee favoured the partnering approach on numerous projects where possible. Another interviewee from the same project also emphasised the need to communicate and for all parties *'to keep talking and it has to be right from the start, right 'til the end'* (H10/SC/PMM). On this particular project the open continuous communication played an effective part in resolving mechanical and electrical problems both in the factory environment and onsite:

> *'In fact a lot of the M&E interfaces are done in the factory. We all work together pretty much on the same projects with the modular work, so who fits the stuff in the factory comes to site as regards the M&E contract' (H15/M/SM).*

The main finding regarding 'good communication and teamwork' is the importance of early and effective communication between the client, design team, contractors and manufacturer when using offsite bathroom construction. This level of communication should be maintained throughout all the stages of the project. Also, the development of a teamwork approach is vital not only in the factory but also between the manufacturer and the contractor to ensure the successful installation and operation of the offsite bathroom onsite.

5.5 The Chosen Procurement Route Can Significantly Affect Interface Management in Bathroom Construction

5.5.1 Quantitative Analysis

5.5.1.1 Frequency Analysis

Table 5.19: Frequency table – the chosen procurement route can significantly affect IM in bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	6	7
Neither agree or disagree (3)	6	7
Agree (4)	44	54
Strongly agree (5)	26	32

The results of the frequency counts demonstrate agree at 54% and strongly agree at 32%, confirming that 86% of interviewees either agree or strongly agree with the statement that the chosen procurement route can significantly affect IM in bathroom construction. Also worth noting was the extremely low combined disagree and strongly disagree score of 7%, and 7% having no view of the statement.

5.5.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 16A. From a test number of 76, the calculation determined an estimated median of 4.0, which conforms to the high level of agreement of 86% established in Table 5.19, which infers there is a tendency within the population to agree with the statement that the chosen procurement route can significantly affect IM in bathroom construction.

5.5.2 Qualitative Analysis

Table 5.20: Ranking table – the chosen procurement route can significantly affect IM in bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Design and build preferred method	17	18
2	Early involvement with stakeholders improves IM	11	11
3	Contractor-led route preferred	10	10
4	More significant interfaces with traditional route	9	9
5	Form of contract will influence IM	8	8
6	Procurement route based on cost will affect interfaces	7	7
6	Procurement route has no effect on IM	6	7
8	Nominated supplier	6	6
9	Offsite can reduce interfaces on traditional route	5	5
10	Adequate time to complete design	4	4
10	Improved quality control	4	4
12	Construction management not as strong in co-ordination and design	2	2

The qualitative analysis will focus on the sub-factors ranked one, two and three:

- Design and build preferred method (5.5.2.1)
- Early involvement with stakeholders improves IM (5.5.2.2)
- Contractor-led route preferred (5.5.2.3).

5.5.2.1 Sub-Factor One: Design and Build Preferred Method

Table 5.21: Breakdown of responses/interviewees: the chosen procurement route can significantly affect IM in bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	7	6
RH	5	5
NBP	2	2
NBO	3	3
MA	1	1
Total	18	17

Interestingly, an interviewee on project A of the NBSA projects stated:

> *'I think the design and build method of contract works an awful lot better for offsite' (A1/C/PM).*

This was further emphasised by other members of the design teams, who worked on projects B and C of the NBSA projects, all of whom considered that the contractor having '*total control of the contract*' (B1/C/PM) created fewer surprises in the project, and with the use of offsite bathroom construction there were fewer interfaces. Although the RH projects were procured under the design and build form of procurement, both clients had stipulated the use of pods from specific manufacturers. However, the interviewee who indicated preference for the design and build method also highlighted the importance of building '*a cosier relationship with your client to get the project*' (E5/M/NSM). The respondents from the remaining projects, NBP, NBO and MA, who favoured the use of design and build were all in agreement with the comment that *'more flexibility in choice and making changes to the design is a lot easier'* (G7/MC/BSM). This resulted in the contractor being able to manage the resulting interfaces more efficiently, which gave a product of better quality.

The main finding regarding 'design and build preferred method' is that the total control acquired by the main contractor from the design and build procurement route reduced the level of interface problems on the project. Furthermore, it was considered important that the main contractor and manufacturer develop and maintain good relationships with clients, to inform clients of the merits of offsite bathroom construction.

5.5.2.2 Sub-Factor Two: Early Involvement with Stakeholders Improves IM

Table 5.22: Breakdown of responses/interviewees: the chosen procurement route can significantly affect IM in bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	4	4
RH	5	5
NBP	1	1
NBO	1	1
MA	0	0
Total	11	11

An interviewee from the NBSA projects highlighted the need for '*direct links and early involvement'* (A4/MC/QS) between suppliers, managers and construction consultants during the tender process. Also alluded to was the benefit of the contractor's input to design:

> *'You have to be very canny with your procurement and what you're actually buying. As we all know, unless you have an input to the design, you aren't going to be able to change anything in, say, pods and therefore you will only get what the manufacturer provides' (B2/MC/PM).*

Therefore, the contractor's input at design can allow change where it is deemed to be of benefit of the project. This also means the contractors are more knowledgeable about their work in relation to connecting the pods when they are delivered to site: *'you know what you are getting before it gets here'* (B7/SC/Con M).

The latter point was also mentioned by interviewees involved in the RH projects. Also mentioned on project E of the RH projects was the '*long lead time associated with the pods'* (E2/MC/Con M), and the need to plan early for the delivery of pods. The positioning of the pod was critical to the programme, as the formation of the room is set out from the location of the pod: *'you can't build, you can't decorate if the pod isn't there'* (E4/MC/SM). This affects all follow-on trades. A comment from the assistant project manager of a subcontractor on the NBO project highlighted:

> *'Yeah well, our jobs were supposed to follow, like, for ceiling height and stuff. It all got approved and the M&E contractors were meant to co-ordinate with our drawings … **but they never did**' (G10/SC/APM).*

A lack of involvement by the mechanical and electrical contractors on the project resulted in interface difficulties in relation to ceiling heights that could have been eliminated by early involvement of the trades, emphasising the importance of early involvement of all stakeholders to improve IM regardless of the project type.

The main finding associated with 'early involvement with stakeholders improves IM' is that the main contractor and all subcontractors with an input to the offsite bathroom construction should be involved at the design stage. Furthermore, the lead in time for design and installation of offsite bathrooms is critical to the programme, due to the configuration of the build.

5.5.2.3 Sub-Factor Three: Contractor-Led Route Preferred

Table 5.23: Breakdown of responses/interviewees: the chosen procurement route can significantly affect IM in bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	4	4
RH	2	2
NBP	1	1
NBO	1	1
MA	2	2
Total	10	10

Project B of the NBSA projects was procured using design and build. An example highlighted by the main contractor taking the lead with design issues was that they were able to '*add on additional ball fix valves to make the plumber's life easy, but that was all because of the interface'*(B2/MC/PM), referring to connecting to the end of the cold and hot water feeds before the pods left the factory. This inclusion eliminated a possible interface problem onsite and made the plumbing connections simpler. The design manager of project C commented:

> *'If it was a design and build route, we would have been much more hands on with that. It would have been much better managed' (C4/MC/DM).*

An interviewee involved in project D stated:

> '*The main contractor is central to the procurement of bathroom pods and … this should result in good communication between the main contractor and the manufacturer*' (D7/DT/A).

A comment from the professional quantity surveyor on the NBP project highlighted:

'If we look at a true design and build form of construction, where you have the complete design responsibility being passed over to the contractor, certainly the interface management again from a design point of view is clearly allocated to the contractor and he should be well on top of ensuring the co-ordination of different trade packages' (F12/DT/QS).

This was also the mechanism which allowed the main contractor on the NBO project to change from a traditional bathroom construction to a pre-engineered build, saving considerable time on the project. The contractor-led approach used on the MA project moved from a multi-supplier and wholesalers approach to a more streamlined supply chain approach – '*same labour, same wholesalers, same supply chain*' (H8/SC/PM) – whereby members of the team promoted better controls and communication. The main contractor promoted a culture of co-operation and co-ordination for all members of the supply chain: *'under the [contractor name] hat, we do co-ordination quite well together' (H13/DT/CME).* This resulted in a cohesive team spirit, with fewer interface issues and better production outputs as the project progressed.

The main finding regarding 'contractor-led route preferred' is that having the main contractor in total control of the design and build allows for greater levels of innovation and adaptability to be introduced into the project. Also, the lines of communication and co-ordination were more direct, which aided the management of interfaces.

5.6 The Chosen Procurement Route Has More Influence on Offsite than Onsite Bathroom Construction

5.6.1 Quantitative Analysis

5.6.1.1 Frequency Analysis

Table 5.24: Frequency table – the chosen procurement route has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	14	17
Neither agree or disagree (3)	16	20
Agree (4)	42	51
Strongly agree (5)	10	12

The results of the frequency tally demonstrate an agree level of 51%, which is on a par with the level of 54% found in the statement covered in Section 5.5, ‘the chosen procurement route can significantly affect IM in bathroom construction’. The combined agree (51%) and strongly agree (12%) scores emphasise a positive level of agreement of 63% to the statement that the chosen procurement route has more influence on offsite than onsite bathroom construction. It is worth noting that this statement attracted a higher level of disagreement (17%) compared to that found with the statement covered in Section 5.5 (7%), with some 20% neither agreeing nor disagreeing. An overview of both statements would suggest that the chosen procurement route has a significant influence on IM, in particular in relation to offsite forms of bathroom construction.

5.6.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 16B. From a test number of 66, the calculation determined an estimated median of 3.5, which conforms to the level of agree and strongly agree of 63% established in Table 5.24, which infers there is a tendency within the population to agree with the statement that the chosen procurement route has more influence on offsite than onsite bathroom construction.

5.6.2 Qualitative Analysis

Table 5.25: Ranking table – the chosen procurement route has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	The procurement route makes no difference to offsite or onsite construction	37	37
2	Design and build preferred route for offsite	31	31
3	Benefit from manufacturer's experience	16	16
4	Project type can influence use of offsite methods	9	10
4	Buildability and logistics can influence the use of offsite methods	10	10
6	Cost and time the main deciding factors	9	9
7	Offsite a faster and cheaper process	7	7
8	Offsite methods more problematic on traditional route	5	5
8	The more interfaces, the more problem areas	5	5
10	Construction management preferred route	4	4
11	Risk factors mainly with contractor and manufacturer	3	3
11	Manufacturer's influence on supply chain	3	3
13	Insufficient time allowed to develop design	2	2
13	Coordination improved by BIM model	2	2
13	Tolerances must be identified	2	2
13	Form of contract more of an influence than procurement route	2	2
13	Offsite method does not lend to alterations onsite	2	2
13	Procurement route established before methods of construction detailed	2	2
19	Offsite constrains contractor in profit margins	1	1

The qualitative analysis will focus on the sub-factors ranked one and two:

- The procurement route makes no difference to offsite or onsite construction (5.6.2.1)
- Design and build preferred route for offsite (5.6.2.2).

5.6.2.1 Sub-Factor One: The Procurement Route Makes No Difference to Offsite or Onsite Construction

Table 5.26: Breakdown of responses/interviewees: the chosen procurement route has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	10	10
RH	10	10
NBP	3	3
NBO	6	6
MA	8	8
Total	37	37

It can be seen from Table 5.26 that a considerable number of interviewees consider that the procurement route does not have more of an influence on IM in either offsite or onsite bathroom constructions. An interviewee from the NBSA projects considered that in the main '*it really makes no difference*' (A7/SC/F). However, reference was also made to the procurement route being more influential towards cost: *'I would probably neither agree nor disagree. Yeah I think it's relative to budget'* (A2/C/OM). This indicates that cost is the ultimate decision factor in relation to the choice of procurement route. However, a director of a manufacturer made the comment that it is vital '*to get your procurement right – full stop*' (C7/M/D), confirming the importance of the correct procurement route as it can impact on the success of the project.

A comment from the main contractor's project manager from project D suggested:

> *'It has a greater influence offsite because the client dictates what he wants and the quality, the whole procedure' (D2/MC/PM).*

This suggests that the client may stipulate offsite as the preferred method to get the quality desired. However, an alternative view was expressed:

> *'I would neither agree nor disagree with that one because the spec of materials doesn't change whether it's going to a factory or it's coming to site' (D4/MC/SM).*

In other words, the form of procurement has little effect on the quality of the final product.

A comment from the manufacturer of the pods for project E suggests that while the procurement route makes no difference, '*it really matters that people get on*' (E5/M/NSM), emphasising that the working relationships of the supply chains of both offsite and onsite are very important. The professional quantity surveyor from the NBP project considers that *'the procurement route shouldn't affect the interface'* (F12/DT/QS). However, the client's project manager from the NBO project suggested that the procurement route would have '*more influence on the onsite production due to more interfaces to manage onsite*' (G1/C/PM), while a director of one of the subcontractors on the same project added:

> *'I don't think it matters as long as you've got your design available when you're procuring it' (G11/SC/D).*

The main finding regarding sub-factor 'the procurement route makes no difference to offsite or onsite construction' is that the direct cost of the project is considered more important than the form of procurement. Furthermore, the inference from the interviewees is that the procurement route had no influence on the specification, design, quality and interfaces. However, the importance of good relationships was highlighted, and this can be influenced by the procurement route chosen.

5.6.2.2 Sub-Factor Two: Design and Build Preferred Route for Offsite

Table 5.27: Breakdown of responses/interviewees: the chosen procurement route has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	6	6
RH	5	5
NBP	10	10
NBO	9	9
MA	1	1
Total	31	31

Although a considerable number of interviewees considered that the choice of procurement route makes no difference to offsite or onsite bathroom construction, an interviewee from project B of the NBSA category stated:

> *'Design and build is better suited to offsite construction – you have the scope to change things' (B2/MC/PM).*

In effect, design and build allows the main contractor greater scope to introduce offsite elements into the project compared to other forms of procurement. An interviewee associated with the NBSA projects suggested that *'you have one person that's responsible for the parts coming together'* (C4/MC/DM). This relates the idea that the single point of responsibility of the contractor for both design and build is better suited to offsite construction. A further comment from a subcontractor's project manager on project D was:

> *'As long as it's logistically possible to get pods onsite, then design and build offsite is a must' (D5/SC/PME).*

This confirms offsite as the preferred choice over onsite methods of bathroom construction.

An interviewee from the NBP project commented that the use of design and build and offsite production provides the catalyst for '*the drive for tighter programmes*' (F2/C/PME), as all the responsibility lies with the contractor. A site manager from the NBO project made the point:

'Design and build gives you a chance to develop your own design to your cost advantage and to your safety advantage – you can tailor what you build then, can't you' (G5/MC/SM).

His comment confirms that design and build allows the contractor to have greater control over all aspects of the project, and in particular the design which has a major influence on cost and health and safety, regardless of whether onsite or offsite methods are used. Interestingly, the design manager on the same project commented:

'I think it should be D&B (design and build) yeah. There are too many interfaces to really let the architect retain responsibility for that' (G6/MC/DM).

That is to say, it is not advantageous to allow the architect to have sole responsibility for design under a traditional procurement route; it is far better to also engage the contractor's experience.

The main finding regarding sub-factor 'design and build preferred route for offsite' is that by integrating design and construction under the control of the main contractor, the 'single point of responsibility' will have the benefits of reducing the level of interfaces, allow for better control of the programme of works and lead to safer methods of construction.

5.7 Effective Supply Chain Management Significantly Improves Interface Management in Bathrooms

5.7.1 Quantitative Analysis

5.7.1.1 Frequency Analysis

Table 5.28: Frequency table – effective supply chain management significantly improves IM in bathrooms

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	1	1
Neither agree or disagree (3)	5	6
Agree (4)	29	35
Strongly agree (5)	47	58

The combined result of agree (35%) and strongly agree (58%) confirms that 93% of interviewees either agree or strongly agree with the statement that effective supply chain management significantly improves IM in bathrooms. Also worthy of note is that only 1% disagreed and 6% neither agreed nor disagreed with the statement. The one dissenting voice exclaimed that supply chain management had no significant influence on improving IM; this may be attributed to the fraught relationships between the main contractor and subcontractors on project C.

5.7.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 17A. From a test number of 77, the midpoint of the distribution of the responses indicates a median value of 4.5 which corresponds with the alternative hypotheses and the 93% of agree and strongly agree indicated in Table 5.28, which infers from the results that there is a tendency among the population to agree with the statement that effective supply chain management significantly improves IM in bathrooms.

5.7.2 Qualitative Analysis

Table 5.29: Ranking table – effective supply chain management significantly improves IM in bathrooms

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Relationships with supplier	19	20
2	Requires good management and planning	12	12
3	Co-ordinated flow of information approach	11	11
4	Partnerships	10	10
5	Influenced by procurement method	6	6
6	Standardisation approach	4	4
6	Influenced by good communication	4	4
8	Makes no difference	3	3
9	Importance of warranties and guarantees	2	2
9	Build mock-up	2	2
11	More relevant to traditional bathroom construction	1	1

The qualitative analysis will focus on the sub-factors ranked one, two, three and four:

- Relationships with suppliers (5.7.2.1)
- Requires good management and planning (5.7.2.2)
- Co-ordinated flow of information approach (5.7.2.3)
- Partnerships (5.7.2.4).

5.7.2.1 Sub-Factor One: Relationship with Suppliers

Table 5.30: Breakdown of responses/interviewees: effective supply chain management significantly improves IM in bathrooms – sub-factor one

Classification	Responses	Interviewees
NBSA	5	5
RH	4	4
NBP	3	2
NBO	3	3
MA	5	5
Total	20	19

An interviewee from the NBSA projects commented on the relationship with suppliers:

'It probably comes down to the softer elements, which is all about the relationship built up with the supplier' (A1/C/PM).

What also became evident from respondents was that a small well-informed supply chain was preferred by the main contractors to a large supply chain base. The consultant mechanical engineer on project C highlighted how a lack of communication between members of the supply chain resulted in the bathroom pods being delivered to site unfinished:

'But what wasn't apparent was that they were built but not fitted out. … The wash hand basin, the pan, everything had to be fitted out. So if you are going to get the best value of offsite, you get it built, finished, sealed up then delivered' (C6/DT/CME).

Additional works being instructed by the design team to the trade contractors to fit out and complete the bathrooms caused additional time and costs to the project.

An interviewee on project D of the RH projects explained how a good relationship with the suppliers was vital as on some occasions bathrooms were constructed in situ, using the same standard of fittings as installed in the pods:

'I've got those supply chain agreements in place, with the same people for the fittings etc.' (D1/C/PM).

The contracts manager for the main contractor on project E highlighted that relationships were important with regard to payment, especially when using a French manufacturer as payment had to be made in Euros and not Sterling:

'We worked closely with our buying department. These guys were really good. They dealt with issues such as actually paying the French – you're paying them in Euros as opposed to pounds – so there were anomalies like that' (E2/MC/ConM).

The importance of direct contact and supervision of suppliers was emphasised:

'After the French experience, we decided to go down to see the pods in the factory. It was no, let's just go and see the pods and just double, double check them' (E3/MC/QS).

Interviewees from the NBP project commented that good relationships with suppliers often led to repeat business: *'if you use them once successfully, you're pushing to keep the same'* (F5/MC/APM).

The relationship with the manufacturer was vital as the work was done offsite:

'It really needs to be effective and it needs to be a good relationship, because so much is done upfront and offsite that it has to be effective or you end up with problems onsite' (F6/MC/QS).

The close relationship required between main contractor and supplier was emphasised. The NBO and the MA projects interviewees' comments focused on tried and test suppliers, who are resolute in effective communication and the co-ordination of information flow between supply chain members:

'Because you work well with them you develop relationships. It's always done on a professional basis' (G8/SC/PM).

The manufacturing approach used on the MA project created a close relationship between all suppliers as all trades that fit out the modules in the factory were responsible for the installation onsite:

'Obviously what comes out of the factory, the guys on site accept because it's their own blokes that have put it in, so you've got that single point of contact if something goes wrong' (H6/MC/BSM).

This reduces the blame culture and promotes a good team spirit.

The main findings regarding ‘relationship with suppliers’ highlights the importance of ‘soft’ issues such as communication and co-ordination. It was also suggested that small well-informed supply chains were preferred by main contractors to large supply chains as good relationships with suppliers can often lead to repeat business, sometimes in the form of partnering arrangements. Furthermore, while good relationships between the main contractor and manufacturer were viewed as beneficial to offsite bathrooms, it was also important to manage problems head on with a level of open communication and transparency, endeavouring to maintain a good working relationship.

5.7.2.2 Sub-Factor Two: Requires Good Management and Planning

Table 5.31: Breakdown of responses/interviewees: effective supply chain management significantly improves IM in bathrooms – sub-factor two

Classification	Responses	Interviewees
NBSA	2	2
RH	4	4
NBP	1	1
NBO	3	3
MA	2	2
Total	12	12

The general response from all the projects confirmed that good management and planning go hand in hand. The client’s operations manager from project A of the NBSA projects highlighted the importance of ‘*milestones and practical completion dates*’ (A2/C/OM) in the programme, which must be communicated to the relevant stakeholders. The consultant mechanical engineer re-stated that poor management and planning caused the difficulties in fitting out the bathroom pods on project C:

> *‘It wasn’t as if you had bought something from Ikea. These pods appeared pre-built but they weren’t pre-built; they were not finished. The guys onsite had to drill holes to fix things. You think, “wait a minute”’ (C6/DT/CME).*

The interviewees from the RH projects commented on the difficulty that resulted from using a French manufacturer, when no allowance was made for the fact that '*in August the whole factory was closed for a month*' (D7/DT/A), thus jeopardising the programme as traditionally only a two week holiday period is allowed.

A construction manager from the NBP project exclaimed that although the main supply chain members were part of the parent company, it demanded the same input if not more to ensure the required quality was achieved:

> *'Even though we had in-house subs, it's vital to manage the interrelationships between them' (F8/MC/CM).*

A comment from the architect associated with the NBO project highlighted that '*everyone understands, you know, what they are meant to be doing*' (G12/DT/A), emphasising the importance of communication to the effective management and planning of the project. The architect associated with the MA project emphasised the difficulties encountered when there is a change in management personnel:

> *'You're just running over old ground quite a lot. … The guy doesn't know as much as [previous manager's name] did, so …' (H12/DT/A).*

Relationships can change. A subcontractor project manager emphasised the importance of early involvement of all stakeholders and the need for detailed pre-planning to avoid difficulties with offsite elements:

> *'Management of a supply chain, it's crucial, because if they say "I can't get all this stuff for four weeks", it just kills the job' (H8/SC/PM).*

The findings regarding 'requires good management and planning' suggest that efficient management and planning are interrelated with effective communication, in particular when important milestones require to be met and non-English speaking suppliers are part of the supply chain. Conversely, ineffective communication between members of the supply chain will result in poor levels of management and planning. Consideration must be given to managing in-house subcontractors, which can be problematic, and the strategy for integrating changes in personnel during the project.

5.7.2.3 Sub-Factor Three: Co-ordinated Flow of Information Approach

Table 5.32: Breakdown of responses/interviewees: effective supply chain management significantly improves IM in bathrooms – sub-factor three

Classification	Responses	Interviewees
NBSA	4	4
RH	3	3
NBP	1	1
NBO	2	2
MA	1	1
Total	11	11

The management of the flow of information would appear to be an important factor in the management of the supply chain to minimise the interface problems that can arise. Comments from interviewees involved in projects A and B of the NBSA projects suggest not only that the co-ordinated flow of information relates to ensuring all members of the supply chain are '*working to the most up to date drawings*' (B5/DT/CCE) but also that trades are working '*in the right place at the right time*' (A2/C/OM). Interviewees associated with project D related the flow of information to ensuring that the specification for the pod is to the '*brand standard*' (D7/DT/A) required by the client. A construction manager from the NBP project commented that it was vital to '*manage our subcontractors otherwise we would have issues all over the place*' (F8/MC/CM), to avoid interface problems occurring onsite. The respondents from the NBO and MA projects linked the flow of information to the responsibility given to members of the supply chain as part of the delegation process: *'you've delegated that co-ordination and supply chain management to him'* (G1/C/PM). They added that communication is central to the project's success.

The main findings regarding 'co-ordinated flow of information approach' suggest that poor management of the flow of information is a primary cause of interface problems and that the management of an integrated supply chain that communicates effectively is paramount to ensure that the correct information and sequencing of operations is timeously available to the correct members of the supply chain, with the objective of efficiently managing potential interface problems.

5.7.2.4 Sub-Factor Four: Partnerships

Table 5.33: Breakdown of responses/interviewees: effective supply chain management significantly improves IM in bathrooms – sub-factor four

Classification	Responses	Interviewees
NBSA	4	4
RH	2	2
NBP	1	1
NBO	1	1
MA	2	2
Total	10	10

The client's project manager from project A of the NBSA commented on the strong bond that can develop within an effective supply chain – *'you're in it together'* (A1/C/PM) – intimating that unofficial partnerships develop within projects, where '*it's going to be a benefit to various people'* (B3/DT/A). The client's senior project manager from project C alluded to the importance of education in fostering partnerships:

> *'When you introduce a new product, you need to educate the contractor; they need to spend time learning how the process works, how it's installed, how it's delivered to site and what the advantages are' (C1/C/SPM).*

This statement would suggest that, when introducing offsite forms of bathrooms into a project, the principles of training and education that would be offered within an onsite project should be made available to the offsite members also. The director of the manufacturer for project D of the RH projects commented on the importance of *'bringing supply partners onboard'* (D9/M/D), emphasising the financial and working benefits that result from close working relationships.

An interviewee from project F of the NBP category alluded to the bond that can be developed when you work with the same supplier on various projects. The project manager of a subcontractor on project G of the NBO commented on how the main contractor had greatly reduced the number of subcontractors within its supply chain such that the level of work was spread more evenly between the suppliers, stimulating a better level of trust and better relationships. A similar practice had been used on project H of the MA category:

> *'We are lucky that we have, it's called "a super six", which is basically six subcontractors that work across the projects' (H5/MC/CM).*

The building services manager further explained that the subcontractor that installs the services offsite also completes the onsite connections so that *'they are fully brought into the process'* (H6/MC/BSM), which reduces interface problems.

The main findings from the sub factor 'partnerships' would suggest that members of the supply chain that are engaged in projects where integration is encouraged will tend to form unofficial partnerships, which can prove to be as effective as contractual partnerships. Training and education on all aspects of offsite bathroom construction should be disseminated to all members of the supply chain. Main contractors should be encouraged to reduce the size of their supply chain databases to a level that would give subcontractors a more sustainable opportunity to work in a more trusted and integrated environment with the main contractor.

5.8 Supply Chain Management Has More Influence on Offsite than Onsite Bathroom Construction

5.8.1 Quantitative Analysis

5.8.1.1 Frequency Analysis

Table 5.34: Frequency table – supply chain management has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	19	23
Neither agree or disagree (3)	24	29
Agree (4)	32	39
Strongly agree (5)	7	9

The responses to the statement that supply chain management has more influence on offsite than onsite bathroom construction denote a spread among the sample of respondents; with agree being the largest recipient at 39%. Interestingly, 23% disagree and 29% neither agree nor disagree, which demonstrates that there is not an overwhelming agreement to the statement. However, it is worth noting that the combined result of agree (39%) and strongly agree (9%) of 48% compared to the combined result of 23% for disagree (23%) and strongly disagree (0%), would suggest that in the main the sample agree with the statement.

5.8.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 17B. From a test number of 58, the midpoint of the distribution of the responses indicates a median value of 3.5, which corresponds with the alternative hypotheses and the 48% of agree and strongly agree indicated in Table 5.34, which infers from the results that there is a tendency among the population to agree with the statement that supply chain management has more influence on offsite than onsite bathroom construction.

5.8.2 Qualitative Analysis

Table 5.35: Ranking table – supply chain management has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	The same influence for both	29	29
2	Single modular company advantageous to supply chain management	19	20
3	Management of the supply chain important for its influence	15	15
4	Onsite requires more co-ordination	12	12
5	Problems with supply chain can have a greater impact on offsite	8	8
6	Influenced by cost	5	5
6	Project type can influence form of supply chain management	4	5
8	Design can influence form of supply chain management	4	4
8	Quality control issues	3	4
10	Client influence on supply chain management	2	3

The qualitative analysis will focus on the sub-factors ranked one and two:

- The same influence for both (5.8.2.1)
- Single modular company advantageous to supply chain management (5.8.2.2).

5.8.2.1 Sub-Factor One: The Same Influence for Both

Table 5.36: Breakdown of responses/interviewees: supply chain management has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	7	7
RH	6	6
NBP	2	2
NBO	6	6
MA	8	8
Total	29	29

The sub-factor of 'the same influence for both' generated the top rank of 29 responses, which equates to 35% of the 82 respondents of the sample. This rates only slightly below the agree figure of 39% but above the 29% who neither agreed nor disagreed in Table 5.34, suggesting slight disparity between the quantitative and qualitative results. This comparison, although not based on any mathematical test, concurs with the median value of 3.5, which suggests that the midpoint of the population lies between agree and neither agree nor disagree. All respondents who commented on this sub-factor, regardless of project type, made very little additional explanation, other than:

'Everybody's going to need both in some respect. I think it's both' (A9/M/NSM).

'I don't think it makes any difference' (C3/MC/CM).

'I think it's very much the same scenario' (D4/MC/SM).

'Supply chain management has to be maintained offsite and onsite' (H5/MC/CM).

Agreement is confirmed across the project types on the importance of supply chain management.

The main finding regarding 'the same influence for both' suggests that the same level of management of the supply chain is required regardless of whether the subcontractor is located onsite or working offsite, to ensure effective management of the interfaces in bathroom construction.

5.8.2.2 Sub-Factor Two: Single Modular Company Advantageous to Supply Chain Management

Table 5.37: Breakdown of responses/interviewees: supply chain management has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	7	6
RH	5	5
NBP	2	2
NBO	5	5
MA	1	1
Total	20	19

The majority of respondents focused on the single point of contact with an offsite manufacturer as being very advantageous. Within projects B and C of the NBSA projects, comments related to the fact that the manufacturers '*already have a process, a chain, you know*' (B3/DT/A), and therefore are not continually reinventing the wheel as can be the case with onsite supply chains. Additional to the tried and tested process was the high level of quality control normally found in the factory set-up – '*the quality is all in one*' (B4/DT/PM) – which provides a quality product. Another interviewee commented:

> *'In terms of offsite, I think the advantage you would have is fewer trades, so you'd have less supply chain members to manage' (C4/MC/DM).*

The manufacturer from project E of the RH projects commented that the manufacturing process normally affords '*more time to work on a really good supply chain*' (E5/M/NSM) compared to achieving the same product onsite. Also, there is greater consistency of quality with the product.

The client's project manager for electrical on the NBP project commented:

> *'I've been to offsite facilities. They were constructing modular units, fully fitted out with all electrical fittings, and they had a fantastic facility, minimum waste, sent back all their off-cuts' (F2/C/PME).*

This can only be a benefit to the other supply chain members, where facilities and methods of working promote a more professional environment. A comment from the client from the NBO project intimated the contractor's only involvement with the modular company is confirming '*bring that pod in for the fourteenth floor on the seventh of July*' (G1/C/PM), suggesting that the main contractor has little contact with or management of the modular company. The influence of the single modular company on their supply chain was also affirmed by a construction manager on the MA project due to the fact that '*60 to 80 percent of the product is built offsite*' (H4/MC/CM), therefore reinforcing the importance of the modular company's influence on the supply chain for this project.

The main findings regarding 'single modular company advantageous to supply chain management' suggest that having a single point of contact with the modular company benefited relationships and the quality of the product, and considerably reduced material wastage within the process. The offsite process was considered to be better organised compared to the frantic process onsite, which continually appeared to reinvent the wheel, leading to an inferior quality bathroom. Furthermore, a number of main contractors consider that the only contact they require to have with their manufacturer is providing delivery dates, and this practice could be interpreted as ineffective management.

5.9 Health and Safety is Significantly Improved Thro ugh Effective Interface Management

5.9.1 Quantitative Analysis

5.9.1.1 Frequency Analysis

Table 5.38: Frequency table – health and safety is significantly improved through effective IM

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree nor disagree (3)	1	1
Agree (4)	29	35
Strongly agree (5)	52	64

The responses to the statement that health and safety is significantly improved through effective IM demonstrate a very clear strongly agree response of 64%, with a further 35% agreeing to the statement, resulting in a cumulative response of 99%. Worthy of note is that no interviewees disagree or strongly disagree and only 1% neither agree nor disagree.

5.9.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 19A. From a test number of 81, the estimated median is calculated at 4.5, which relates to the high percentage of agree and strongly agree indicated in Table 5.38, which infers from the results that there is a tendency among the population to agree or strongly agree with the statement that health and safety is significantly improved through effective IM.

5.9.2 Qualitative Analysis

Table 5.39: Ranking table – health and safety is significantly improved through effective IM

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Good communication and relationships have a positive effect on health and safety and IM	18	19
2	Reduced site works improves health and safety	12	13
3	Effective management important to good health and safety	12	12
4	Health and safety rules should be the same in a factory as onsite	5	5
4	Manual handling	5	5
6	Design has an influence on health and safety and IM	2	2
7	Health and safety rules not applied in a factory as onsite	1	1
7	Poor relationships will affect health and safety and IM	1	1
7	Role of CDM coordinator	1	1
7	Crane units into position onsite	1	1
7	Site safety rules	1	1

The qualitative analysis will focus on the sub factors ranked one, two and three:

- Good communication and relationships have a positive effect on health and safety and IM (5.9.2.1)
- Reduced site works improves health and safety (5.9.2.2)
- Effective management important to good health and safety (5.9.2.3).

5.9.2.1 Sub-Factor One: Good Communication and Relationships Have a Positive Effect on Health and Safety and IM

Table 5.40: Breakdown of responses/interviewees: health and safety is significantly improved through effective IM – sub-factor one

Classification	Responses	Interviewees
NBSA	4	4
RH	4	4
NBP	1	1
NBO	4	4
MA	6	5
Total	19	18

Good communication and relationships proved to be the main factors which influence the improvement of health and safety through effective IM. An interviewee from project A of the NBSA projects highlighted the importance of good relationships with subcontractors: *'you'll get the best out of them on health and safety'* (A5/MC/PM). The client from project B added that communication was noted as '*part of the management and efficiency*' (B1/C/PM). Comments from an interviewee within project D of the RH projects relate to the relationships and communication with the manufacturer:

> *'Sending a guy up with the first delivery to run through us man-handling helped no end' (D2/MC/PM).*

The main contractor's contract manager from project E commented: *'health and safety is one of the top things that is always being considered'* (E2/MC/Con M)**.**

An interviewee from the NBP suggested that good communication lends itself to effective IM, which in turn reduces accidents. Interviewees from the NBO commented that '*communicating the general construction of the interfaces*' (G5/MC/SM) is important to executing the works safely: '*I think it's just communication really*' (G14/DT/P). Interviewees from the MA project also commented on the relationship with subcontractors with respect to IM: '*ultimately it's about us all working together*' (H5/MC/CM). The good relationships built up over many projects helps both strong relationships and communication – '*they know you and you know them*' (H6/MC/BSM) – and this was further emphasised with the relationship with the manufacturer – '*just on this modular one, it far exceeds everything else*' (H16/M/SM) – confirming that effective IM aids health and safety.

The main finding regarding 'good communication and relationships have a positive effect on health and safety and IM' is that effective communication is the main catalyst for building strong relationships between stakeholders. This will have a positive effect on the interfaces within the project, which in turn will promote a health and safety culture, whereby all parties are pulling in the same direction for the success of the project.

5.9.2.2 Sub-Factor Two: Reduced Site Works Improves Health and Safety

Table 5.41: Breakdown of responses/interviewees: health and safety is significantly improved through effective IM – sub-factor two

Classification	Responses	Interviewees
NBSA	1	1
RH	6	5
NBP	1	1
NBO	3	3
MA	2	2
Total	13	12

Although the question was not directly related to offsite works, a number of interviewees chose to relate their comments to the influence of reducing onsite works by applying works offsite. A subcontractor from project C stated that *'yes, the less work you have to do onsite, it's got to be better'* (C5/SC/OM). An interviewee from project D of the RH projects commented that the reduction of site works such as '*cutting tiles and using abrasive wheels*' (D5/SC/PME) was better controlled under offsite conditions. A comment from an interviewee on project E of the RH projects related to the dangers that occur with the number of trades working in small areas onsite:

> *'Offsite you've got one guy in the small area at a time; onsite you've got all trades working in an area and it's a "bun fight" as they say' (E4/MC/SM).*

The project manager for the NBP project commented on the benefit of having a reduced number of operatives' onsite:

'They are able to work in a sequence that allows them to work freely and unobstructed' (F3/MC/PM).

This was echoed by the client's project manager on the NBO project:

'From a H&S (health and safety) point of view, you can see that it's probably better to have it fabricated offsite' (G1/C/PM).

Further comments from interviewees on the NBO project related to access problems, working at heights and cutting of materials – issues that can be managed more effectively offsite. Interviewees on the MA project relate effective IM to the offsite environment: *'it all goes back to the least amount of people onsite as possible'* (H15/M/SM).

The main findings regarding 'reduced site works improves health and safety' are that every effort should be made to minimise the works that are required to be executed onsite. Offsite construction can be better co-ordinated, controlled and sequenced, thus promoting a safer working environment compared to onsite. The correlation of less work onsite requiring less labour, resulting in a reduction of accidents, provides a strong moral argument for adopting offsite practices where possible within a project and in particular with bathroom construction.

5.9.2.3 Sub-Factor Three: Effective Management Important to Good Health and Safety

Table 5.42: Breakdown of responses/interviewees: health and safety is significantly improved through effective IM – sub-factor three

Classification	Responses	Interviewees
NBSA	3	3
RH	2	2
NBP	2	2
NBO	1	1
MA	4	4
Total	12	12

A comment from an interviewee from project C of the NBSA projects related the significant improvements of effective management to health and safety: *'they're* *not falling over each other's feet*' (C1/C/SPM). A comment from project D of the RH projects related the importance of including health and safety as an item within the agenda for any meetings with subcontractors. However, it was also commented:

> *'I think we all know that health and safety has gone over the top over the last few years. It's making life a bit hard, which affects the cost of the job' (D6/SC/PMM).*

This comment illustrates a particular view, not uncommon in the industry, that the high level of bureaucracy associated with health and safety is believed to be counterproductive and costly. Interviewees from the NBP project expressed the view that efficient working *'is usually a safer way of working'* (F12/DT/QS), and that works properly co-ordinated and correctly sequenced '*are more likely to go well from a health and safety point of view*' (F13/M/CCE). This view was shared by interviewees from the MA project, who also expressed the need for '*asking subcontractors to be proactive in their approach, making sure that they raise things to us*' (H5/MC/CM), thus reiterating the importance of sub-factor one, communication and trust.

The main findings regarding 'effective management important to good health and safety' are that less bureaucracy and more pragmatic management of the works are more effective in the management of health and safety. When meeting with subcontractors, health and safety should be a specific item on the agenda and managed proactively by encouraging subcontractors and manufacturers to contribute on an equal footing in the areas of health and safety and IM, rather than being reactive and continuing with the blame culture, which is more the norm in the main contractor/subcontractor relationship. Finally, efficient management of the sequence of the works normally equates to a safer method of working, which could be construed as a positive effect of offsite working.

5.10 Good Health and Safety Outcomes Are More Easily Achieved in Offsite Bathroom Construction Compared to Onsite Bathroom Construction

5.10.1 Quantitative Analysis

5.10.1.1 Frequency Analysis

Table 5.43: Frequency table – good health and safety outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	6	7
Neither agree or disagree (3)	9	11
Agree (4)	27	33
Strongly agree (5)	40	49

As with Table 5.38, the sample has a strong proportion that strongly agree (49%) and a comparable proportion that agree (33%) with the statement, culminating in an agree and strongly agree total of 82%, compared with 7% that disagree, while the remaining 11% neither agree nor disagree.

5.10.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 19B. From a test number of 73, the estimated median is calculated at 4.5, which relates to the high percentage of agree and strongly agree indicated in Table 5.43, which infers from the results a tendency among the population to agree or strongly agree with the statement that good health and safety outcomes are more easily achieved in offsite than onsite bathroom construction. The significance of the quantitative results of the two statements covered in Sections 5.9 and 5.10 would indicate a strong correlation between effective IM and offsite bathroom construction in relation to health and safety.

5.10.2 Qualitative Analysis

Table 5.44: Ranking table – good health and safety outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Factory more controlled environment, fewer hazards	36	38
2	They both have safety risks	13	13
3	Onsite more hazards	11	12
4	Less labour onsite, less risk	9	10
5	Craning units onsite, more hazards than traditional build	8	9
6	Safety standards in factory not as stringent as onsite	6	6
7	Design can influence health and safety	5	5
8	Offsite promotes less manual handling	4	4
8	Fewer interfaces promotes less risks	4	4
10	Offsite promotes greater level of pre-planning	2	2
11	Client KPIs	1	1

The qualitative analysis will focus on the sub factors ranked one, two and three:

- Factory more controlled environment, fewer hazards (5.10.2.1)
- They both have safety risks (5.10.2.2)
- Onsite more hazards (5.10.2.3).

5.10.2.1 Sub-Factor One: Factory More Controlled Environment, Fewer Hazards

Table 5.45: Breakdown of responses/interviewees: good health and safety outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	14	12
RH	8	8
NBP	4	4
NBO	4	4
MA	8	8
Total	38	36

Almost all of the 36 interviewees who aligned with this sub-factor specifically mentioned 'controlled environment'. Interviewees from project A commented that '*in a factory all the systems are in place*' (A3/MC/PM) and said of the onsite environment, '*it's a little bit more unpredictable*' (A3/MC/PM). Further comments related to a consistent workforce and a more controlled movement of plant. The design team's project manager from project B commented:

> *'H&S can be much easier achieved on your bathroom pod because it's all there; it's all thought through. The connections in interface in particular with M&E are all thought through, so H&S is much improved – it's a huge issue' (B4/DT/PM).*

A further comment from the consultant civil engineer on project B related to reducing the time spent onsite: '*you minimise the H&S risks*' (B5/DT/CCE). To minimise the risk requires a higher level of pre-planning.

An interviewee from project D of the RH projects emphasised another major benefit of the controlled environment as '*more control of your people and your area in an offsite situation*' (D10/M/ProM). A subcontractor project manager from the NBP project added his views on how this benefits the workforce:

> *'I think the more you can do offsite is a benefit to everyone. It's confined … It's a working space where people are popping in every day, they're used to the whole environment, and they are not putting themselves to as much risk as they would onsite. If they could deliver the whole job on the back of a lorry I would take it' (F9/SC/PM).*

Interviewees from the NBO highlighted that '*we use fewer labour man-hours onsite*' (G8/SC/PM) while '*operating with offsite construction in a more controlled environment*' (G14/DT/P), thus improving health and safety both onsite and offsite. An MA interviewee also concurred with the benefits of reduced labour onsite and highlighted that '*you've got a production line, and you will have proper health and safety standards*' (H13/DT/CME).

The main finding regarding 'factory more controlled environment, fewer hazards' is that by minimising work carried out onsite, the positive effect of reducing accidents overall will be achieved. Moreover, the workforce in the factory is more consistent and familiar with the environment, whereas onsite the workforce is more transient and the environment is continually changing, implying that onsite is a more hazardous environment. Furthermore, offsite bathrooms demand a high level of pre-planning to eliminate interface problems in comparison to the normal onsite process, which in turn reduces health and safety risks.

5.10.2.2 Sub-Factor Two: They Both Have Safety Risks

Table 5.46: Breakdown of responses/interviewees: good health and safety outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	6	6
RH	0	0
NBP	2	2
NBO	1	1
MA	4	4
Total	13	13

An interviewee from the NBSA projects that commented on this sub-factor considered that there were '*different factors in both*' (A8/DT/A) and that neither offsite nor onsite was worse or better than the other in terms of safety. This was further explained as '*there are different risks involved with both*' (C3/MC/CM), highlighting the need to apply a risk assessment regardless of whether the work is carried out offsite or onsite. An interviewee from the NBP project commented on the importance of IM in relation to health and safety, adding:

> *'If they're properly managed onsite and if interface management is there, you should be working in an environment that is relatively safe, albeit you're never*

going to get an onsite environment which in my mind is going to be as safe and as manageable as an offsite factory' (F12/DT/QS).

However, an alternative view was expressed by the senior project manager from the MA project who expressed concerns at the level of safety they had experienced within the manufacturer's factory:

'You know what, I've done a number of factory visits to our current manufacturer and I've been cringing at the level of some of the health and safety I've seen' (H2/MC/SPM).

This confirms that the factory environment cannot be assumed to be operating to the same safety standards as onsite. The respondents considered that health and safety should be enforced equally in both environments: '*why should that be any different from the company site*?' (H5/MC/CM). While, in the main, onsite works are considered more dangerous, the comments above suggest a need to apply the same health and safety standards to both environments.

The main findings regarding 'they both have safety risks' is that offsite and onsite environments have different safety risks. Safety risk assessments should be applied to both environments and a pragmatic approach applied to enforce the appropriate safety standards to each environment. Furthermore, assertions should not be made that the offsite environment will be a safe environment; rather, random safety checks should apply to both offsite and onsite.

5.10.2.3 Sub-Factor Three: Onsite More Hazards

Table 5.47: Breakdown of responses/interviewees: good health and safety outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	6	5
RH	2	2
NBP	1	1
NBO	2	2
MA	1	1
Total	12	11

A number of interviewees challenged the assertion of sub-factor two and considered that the onsite environment presented more hazards than the factory environment. An interviewee from the NBSA project commented that '*there's more hazards here because of other trades*' (A3/MC/PM). Also working at height was considered more prevalent onsite, giving another reason for increased numbers of hazards compared to offsite: '*it's a bit more unpredictable onsite*' (A3/MC/PM).

An interviewee from project D of the RH classification related more hazards directly to the construction of onsite bathrooms, similarly commenting on '*forty people from six different trades, all climbing over each other*' (D10/M/ProM). An interviewee from the NBP project commented that due to the congestion that can occur during the construction of onsite bathrooms, site management are specifically instructed to ensure that '*all the guys onsite adhere to all our health and safety standards*' (F7/MC/QS). Interviewees from the NBO project commented that minor accidents such as '*cut fingers and dust in eyes*' (G6/MC/DM) are more prevalent onsite. Another interviewee from the NBO concurred with previous comments on the number of trades working in the bathroom area, commenting on '*lots of contractors working in the bathroom area tripping over themselves*' (G12/DT/A). An interviewee from the MA project commented that the onsite environment is harder to control in comparison to the factory environment – '*so many issues that it's out with your control*' (H13/DT/CME) – emphasising that a tidy and well-organised site has a better chance of being a safe site.

The main findings related to 'onsite more hazards' suggest that, with the number of trades working within a small bathroom area onsite, accidents are more prevalent. While the majority of injuries relate to minor accidents such as cut fingers and dust in eyes, there is also a greater occurrence of falls from heights due to onsite working practices when compared to offsite bathroom construction.

5.11 Effective Management of the Design Process Significantly Improves Interface Management

5.11.1 Quantitative Analysis

5.11.1.1 Frequency Analysis

Table 5.48: Frequency table – effective management of the design process significantly improves IM

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	2	2
Agree (4)	31	38
Strongly agree (5)	49	60

The results for strongly agree (60%) and agree (38%) combine to 98%, demonstrating a clear agreement to the statement that effective management of the design process significantly improves IM. Worthy of note is that no interviewees either disagree or strongly disagree, while the remaining 2% neither agree nor disagree with the statement.

5.11.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 20A. From a test number of 80, the estimated median is calculated at 4.5, which relates to the high percentage of agree and strongly agree indicated in Table 5.48, which infers from the results that there is a tendency among the population to agree or strongly agree with the statement that effective management of the design process significantly improves IM.

5.11.2 Qualitative Analysis

Table 5.49: Ranking table – effective management of the design process significantly improves IM

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Co-ordination of incomplete design is crucial	16	17
2	Good communication important to the effective management of design	14	15
3	Important to consider buildability	12	12
3	Review design prior to construction	10	12
5	Co-ordination of client requirements important	8	8
6	Important to allocate sufficient time for design	7	7
7	Design manager important to co-ordinate design	5	5
8	Quality of manufacturer design critical to success of units	4	4
9	Clients input at design meetings	3	3
10	Make the basic design simple	2	2
10	Contractor-led design	2	2
10	Mock-up aids design interfaces	2	2
10	Influence of BIM on design	2	2
14	Important to consider maintenance	1	1
14	By others, incomplete design	1	1
14	Poor design can be expensive	1	1

The qualitative analysis will focus on sub factors ranked one, two and three:

- Co-ordination of incomplete design is crucial (5.11.2.1)
- Good communication important to the effective management of design (5.11.2.2)
- Important to consider buildability (5.11.2.3)
- Review design prior to construction (5.11.2.4).

5.11.2.1 Sub-Factor One: Co-ordination of Incomplete Design Is Crucial

Table 5.50: Breakdown of responses/interviewees: effective management of the design process significantly improves IM – sub-factor one

Classification	Responses	Interviewees
NBSA	4	4
RH	2	2
NBP	4	4
NBO	2	2
MA	5	4
Total	17	16

Co-ordinating the design was established as an important factor to aid the management of the design process and in turn improve IM. A respondent associated with NBSA projects highlighted:

> *'You know, if you've got good management of the design, you're always going to improve the interface management of it. They go hand in hand really' (B4/DT/PM).*

The importance of the relationship between design and IM on any project is thus confirmed. However, a respondent from project C referred to problems that occurred on the project due to a stakeholder being '*unwilling to co-operate with the design management process*' (C4/MC/DM). The architect from project D commented that although you may be installing pods throughout the project, variations on the layout mean that '*you need to be on top of the design*' (D7/DT/A). The manufacturer's director of the pods for project D added '*you've got to, shall we say, drive these architects to the point of order*' (D9/M/D).

Comments from interviewees from the NBP project highlighted that co-ordination of the design is *'key to the job'* (F6/MC/QS), and, furthermore, '*there's nowhere to go – it has to be right first time'* (F5/MC/APM). However, problems onsite arose because '*the design just wasn't complete, you know*' (F9/SC/PM).

A comment from the NBO project proved to be more positive in respect to the progress that was being achieved onsite, a contributing factor being that *'co-ordination of the design process significantly improves interfaces'* (G1/C/PM).

Moreover, this was attributed to ‘players’ being on-board early in the design process. The architect from the MA project highlighted the need to co-ordinate the manufacturer’s drawings ‘*with the M&E drawings to make sure everything ties in*’ (H12/DT/A). Problems will always occur; however, co-ordination of design and good IM will significantly reduce problems onsite. Otherwise, ‘*if the design’s wrong, then it’s all wrong and that’s the critical part*’ (H14/M/QM).

The main finding regarding ‘co-ordination of incomplete design is crucial’ is that incomplete design will always result in problems, which in the main will manifest as interface problems, due to the strong link between design and IM. Stakeholders with an input to the design must be encouraged and allowed to participate early in the design process. Particular attention needs to be given to the co-ordination and integration of the mechanical and electrical element of the design.

5.11.2.2 Sub-Factor Two: Good Communication Important to the Effective Management of Design

Table 5.51: Breakdown of responses/interviewees: effective management of the design process significantly improves IM – sub-factor two

Classification	Responses	Interviewees
NBSA	3	3
RH	6	5
NBP	1	1
NBO	3	3
MA	2	2
Total	15	14

The people factor of communication was highlighted by respondents as important to the management of design in relation to effective IM. Interesting comments from respondents associated with projects B and C of the NBSA projects ranged from the importance of ‘*everyone speaking to each other throughout the design’* (B1/C/PM) to the benefit of having a whiteboard in the office: ‘*I believe you can explain it* *better to a guy if you can draw it for him*' (B2/MC/PM). However, not all parties recognised the importance of early communication:

> *'I said: "the reason I'm asking you [subcontractor] so much now is to reduce your problems onsite". He didn't seem to buy into it and he's just caused us so many problems' (C4/MC/DM).*

This led to considerable problems occurring on project C. Communication in relation to the manufacture of the pods for the RH projects was seen as critical, due to variations in pods types: *'even a simple way of how the door opens could make your life complicated'* (D7/DT/A).

Early communication was considered important by the manufacturer:

> *'You know, we have X amount of weeks to manufacture and deliver the pods, so meeting the client as early as possible is a priority. Discussing the specification and pushing them to agree dates and freeze information is an absolute priority' (D9/M/D).*

In other words, '*you design it for building, not building it for design*' (D10/M/ProM), which can occur through a lack of communication within the design process. The architect from the NBO project commented on the importance of having members of the supply chain involved early to reduce interface problems – *'I think it's open discussion*' (G12/DT/A) – and a partner in the design team added that the management of the design allows *'communication of the details that you want'* (G14/DT/P), which can influence the management of interface issues, in particular the offsite/onsite installation.

The respondents of the MA project focused on the interface issues which resulted from the incorporation of the new 'Part L' regulation, which has increased the effectiveness of sustainable buildings with regard to airtightness, commenting that there is *'a lot of to-ing and fro-ing between different people'* and so *'it helps to work together'* (H12/DT/A; H16/M/SM).

The main finding regarding 'good communication important to the effective management of design' highlights the importance of early communication with the supply chain, not only electronically but also face to face, and the importance of encouraging the art of freehand drawing, which is being lost due to the dominance of electronic formats such as CAD, all with the intention of resolving design problems and enhancing relationships among the relevant parties.

5.11.2.3 Sub-Factor Three: Important to Consider Buildability

Table 5.52: Breakdown of responses/interviewees: effective management of the design process significantly improves IM – sub-factor three

Classification	Responses	Interviewees
NBSA	4	4
RH	3	3
NBP	0	0
NBO	4	4
MA	1	1
Total	12	12

The concept of buildability is considered by a number of respondents to be important to the design and how it affects the IM within the build process. An interviewee from project A of the NBSA projects commented:

> *'I think from my point of view if you made something too difficult or too obscure in the design process, it's going to be too obscure to the person that's going to have to build it or make it or put it together' (A2/C/OM).*

Buildability must be included in the initial design process and not be seen as an add-on when difficulties arise. A comment from the client on project C suggested that there is a lack of knowledge and understanding of a '*systematic approach*' (C1/C/SPM) to the overall process, which results in building difficulties. This comment is echoed by a respondent on project E of the RH project:

> *'If anything goes wrong then getting access back in to anything, trying to plumb it, is very hard' E4/MC/SM).*

Comments from the NBO project take a more positive view to '*solve your problems on the drawing board, rather than onsite*' (G1/C/PM). This comment is further emphasised:

> *'The majority of problems we get on site are still design related ... where an interface hasn't been designed' (G6/MC/DM).*

The solutions to the aforementioned problems are summed up by the comment *'yeah, get the design right first time*' (G10/SC/APM), which is the utopian objective of design management. The comments expressed confirm that incomplete design has an impact on buildability, which in turn can result in interface problems onsite.

The main findings regarding 'important to consider buildability' suggest that the complexity of construction should consider buildability during the design stage and not ignore it until the construction stage. Moreover, most buildability issues result in interface problems.

5.11.2.4 Sub-Factor Four: Review Design Prior to Construction

Table 5.53: Breakdown of responses/interviewees: effective management of the design process significantly improves IM – sub-factor four

Classification	Responses	Interviewees
NBSA	2	2
RH	5	4
NBP	1	1
NBO	2	2
MA	2	1
Total	12	10

Comments from respondents emphasise the need to continuously review design prior to issue for construction. An interviewee associated with project A of the NBSA projects explained:

> *'Whoever is in charge of the design has looked at every corner where there could be a problem and hopefully designed it out' (A3/MC/PM).*

An alternative approach was experienced by the design manager on project C:

'I phoned them, I sent them several emails, I needed drawings. When they eventually came to site, loads of problems' (C4/MC/DM).

Comments from interviewees on the RH projects reiterate the former comment from the NBSA – '*go through the design process, iron out any errors*' (D1/C/PM), '*sort out all the problems before it gets to site*' (D4/MC/SM) and '*look for any areas of possible improvement*' (E2/MC/ConM) – emphasising the importance of reviewing the design. The main contractor's quantity surveyor, who was responsible for commercial aspects on both hotels, related the lessons learned from project E, which resulted in early face to face engagement with the manufacturer of project D, '*just to understand their design*' (E3/MC/QS), clarifying the importance of the contractor not abdicating responsibility for the design to the manufacturer.

A comment from an interviewee on the NBP project corresponds with those from project C: *'the drawings weren't right; we really had to start from scratch'* (F9/SC/PM). The advantages of stakeholder early involvement were expressed by an interviewee on the NBO project: *'we had very few issues … because of the upfront design work that was done'* (G3/MC/SM). The Architect on the MA project concurs with the quantity surveyor on the RH project emphasising:

'We spend a lot of time reviewing the drawings before they actually start making them in the factory. If we didn't do what we did at the beginning, then, I mean, it would have a huge impact onsite' (H12/DT/A).

The comments stated demonstrate a mixed approach to reviewing the design prior to construction within the sample.

The main findings regarding 'review design prior to construction' suggest that the additional time spent by the design team effectively reviewing the design before issuing for construction reduces potential interface problems. Manufacturers must be allowed to input early into the design process, preferably communicating periodically on a face to face basis and the main contractor should liaise with the manufacturer during the design process to ensure the offsite/onsite connectivity is understood.

5.12 Design Management Can Significantly Affect Interface Management in Bathrooms

5.12.1 Quantitative Analysis

5.12.1.1 Frequency Analysis

Table 5.54: Frequency table – design management can significantly affect IM in bathrooms

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	5	6
Agree (4)	38	46
Strongly agree (5)	39	48

The results for strongly agree (48%) and agree (46%) are almost equal and combine to 94%, demonstrating a clear strongly agree and agree with the statement that design management can significantly affect IM in bathrooms. Furthermore, the spread of the results corresponds with the results found in the previous statement that effective management of the design process significantly improves IM. Similarly, no interviewees either disagree or strongly disagree, while only 6% neither agree nor disagree.

5.12.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 20B. From a test result of 77, the estimated median is calculated at 4.5, which corresponds with the high result of agree and strongly agree indicated in Table 5.54, which infers from the results that there is a tendency among the population to agree or strongly agree with the statement that design management can significantly affect IM in bathrooms.

5.12.2 Qualitative Analysis

Table 5.55: Ranking table – design management can significantly affect IM in bathrooms

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Good design promotes fewer interface problems	14	15
2	Design management not any more important to bathrooms	9	9
3	Bad design costs money	5	5
3	Early involvement of all parties aids design management of interfaces	5	5
5	Client input important to design	3	4
6	Lack of design management will hinder successful outcome	3	3
6	Good design management can promote efficient sequencing of tasks	3	3
8	Client relationship with manufacturer	2	2
8	Prototypes aid design management of interfaces	2	2

The qualitative analysis will focus on sub-factors ranked one and two:

- Good design promotes fewer interface problems (5.12.2.1)
- Design management not any more important to bathrooms (5.12.2.2).

5.12.2.1 Sub-Factor One: Good Design Promotes Fewer Interface Problems

Table 5.56: Breakdown of responses/interviewees: design management can significantly affect IM in bathrooms – sub-factor one

Classification	Responses	Interviewees
NBSA	3	3
RH	1	1
NBP	4	4
NBO	2	2
MA	5	4
Total	15	14

The architect from project B of the NBSA projects commented that '*bad design, I guess, will require more interfacing problems*' (B3/DT/A). Furthermore, with bathrooms being highly serviced areas:

> *'It's important for us that we understand where the points of connections are on the pod at the design stage' (C6/DT/CME).*

This comment was also emphasised by an interviewee on the RH project – *'your onsite connection points have to be spot on'* (D9/M/D) – and reiterated by an interviewee on the NBP – *'it's a big issue in the prison certainly'* (F9/SC/PM) – further suggesting that mechanical and electrical is the most problematic interface area applicable to bathroom construction.

An interviewee on the NBO had a positive view:

> *'If you manage the design correctly and make sure it's integrated co-ordinated then it should make things easier' (G13/DT/QS).*

At the same time, an interviewee from the MA project acknowledged that *'yeah, if the design works better, it's going to naturally affect the interface management'* (H3/MC/APM), and also *'it saves a lot of abortive work'* (H7/MC/QS). Of equal importance are good relationships with the supply chain *'to understand what they can and can't do'* (H6/MC/BSM).

The main finding regarding 'good design promotes fewer interface problems' is that bad and incomplete designs have the potential to cause interface problems. With bathrooms being highly serviced areas the mechanical and electrical connections were considered of high importance to avoid costly and time consuming abortive works. The design team should promote the integration of all designers, in particular the mechanical and electrical consultants, when designing bathroom.

5.12.2.2 *Sub*-Factor Two: Design Management Not Any More Important to Bathrooms

Table 5.57: Breakdown of responses/interviewees: design management can significantly affect IM in bathrooms – sub-factor two

Classification	Responses	Interviewees
NBSA	2	2
RH	2	2
NBP	0	0
NBO	2	2
MA	3	3
Total	9	9

The main contractor's project manager for project B expressed the view that '*it's the same scenario regardless of what it is*' (B2/MC/PM), while the professional quantity surveyor from the NBO project added, '*it applies across the board*' (G13/DT/QS). The quality manager of the MA project concurred – '*same thing really*' (H14/M/QM) – reiterating the results of the quantitative analysis contained in tables 5.48 and 5.54 that design management is of equal important to the IM of bathrooms and the project as a whole.

The main finding regarding 'design management not any more important to bathrooms' is that the process is of equal importance to all areas of the project and therefore the management of the bathroom design is not given any preferential focus in comparison to other areas of the project.

5.13 Design Management Has More Influence on Offsite than Onsite Bathroom Construction

5.13.1 Quantitative Analysis

5.13.1.1 Frequency Analysis

Table 5.58: Frequency table – design management has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	26	32
Neither agree or disagree (3)	13	16
Agree (4)	33	40
Strongly agree (5)	10	12

The responses to this statement demonstrate a wider spread compared to the previous two statements covered in Sections 5.11 and 5.12 relating to design management. The tally for agree (40%) and strongly agree (12%) is 52%, compared to a 32% combined result for disagree and strongly disagree, which indicates agreement to the statement that design management has more influence on offsite than onsite bathroom construction. Interestingly, 16% neither agree nor disagree with the statement.

5.13.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 20C. From a test result of 69, the estimated median is calculated at 3.5, which corresponds more with agree than disagree as indicated in Table 5.58, which infers from the results that there is a tendency among the population to agree with the statement that design management has more influence on offsite than onsite bathroom construction.

5.13.2 Qualitative Analysis

Table 5.59: Ranking Table – design management has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Design management same importance for both	31	32
2	Design management more relevant to offsite	23	24
3	Design of onsite connections critical for offsite units	10	14
4	Onsite more flexible to design changes	10	10
4	Offsite less flexible to design changes	10	10
4	Tolerances more critical in the design of offsite	8	10
7	Volume of offsite units demands greater level of design management	8	8
8	Offsite requires earlier participation in design	5	5
9	Clients requirement better achieved with offsite	4	4
9	Site architect little involvement with design of offsite	4	4
11	Design management more relevant to onsite	2	2
11	Onsite involves many more different organisations	2	2

The qualitative analysis will focus on sub-factors ranked one, two and three.

- Design management same importance for both (5.13.2.1)
- Design management more relevant to offsite (5.13.2.2)
- Design of onsite critical for offsite units (5.13.2.3).

5.13.2.1 Sub-Factor One: Design Management Same Importance for Both

Table 5.60: Breakdown of responses/interviewees: design management has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	8	8
RH	7	7
NBP	4	4
NBO	5	5
MA	8	7
Total	32	31

Thirty-one interviewees inferred by their comments that design management has the same importance for offsite and onsite construction. A comment from project B of the NBSA projects suggested:

> *'I think it's probably more important for the whole design management process with all the design team when you are doing traditional, whereas, with your offsite, it's of similar importance and it's a big influence but you're relying more on one supplier' (B4/DT/PM).*

This suggests that both offsite and onsite design applications are of equal importance; a common term used to respond to the statement was '*it's six or half a dozen'* (C2/C/PM). Additional comments from the RH projects clearly state that '*design management is just as important in offsite as onsite*' (D2/MC/PM) and '*it's all very much interrelated*' (E3/MC/QS), suggesting that design management of offsite and onsite should not be separated.

Comments from the NBP and NBO were of a similar nature to the previous projects, with the term '*it's even-stevens between the two really'* (G7/MC/BSM) capturing the point succinctly. An interviewee from the MA project added that both have '*pros and cons*' (H3/MC/APM). Interviewees from the MA project commented that problems can occur when offsite units come to site and generally '*you'll have to manage that problem onsite*' (H7/MC/QS), suggesting that although a project may be predominately made up of offsite units, it is still important to give equal consideration to the onsite elements as '*they both throw up their own set of problems*' (H13/DT/CME).

The main finding regarding 'design management same importance for both' is that the parts of the design, regardless of whether constructed offsite or onsite, are all interrelated, confirming that design management is not considered more important to offsite than to onsite bathrooms. This finding concurs with the finding in 5.12.2.2, which suggests that the management of the design is of equal importance to all areas of the project.

5.13.2.2 Sub-Factor Two: Design Management More Relevant to Offsite

Table 5.61: Breakdown of responses/interviewees: design management has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	9	9
RH	5	5
NBP	5	4
NBO	2	2
MA	3	3
Total	24	23

Twenty-three interviewees took the view that design management is more important in relation to offsite forms of bathroom construction. Respondents from projects A and B of the NBSA projects focused on the design of the pods used on their projects, commenting on design that '*it's more important at the early stages*' (A5/MC/SM). Additionally:

> *'You've got a fixed design, you've got a fixed pod – there's limited ways of piping it. You'll get fabrication drawings from the pod guys and you will go, right that's fine, and you've agreed the way it's piped.' (B6/DT/CME).*

This confirms the need for early involvement of the mechanical and electrical consultants with the manufacturer, as piping routes connecting to pods have less flexibility compared to in situ bathrooms. An important point was raised by a respondent from project C – '*the management of the design process has to get everyone agreeing*' (C6/DT/CME) – further emphasising the need for early agreement of the design when using offsite forms of bathroom construction.

Interviewees from the RH projects added, '*you've got to get your design all correct and agreed up front*' (E1/C/P), '*as soon as they press the button on production*' (D7/DT/A), inferring that there is no leeway for change when production starts. This is echoed by an interviewee on the NBP project, who explained:

> *'With our system being pre-made in our factory, it would be far more costly to make any last minute changes here on site' (F5/MC/APM).*

An interesting comment from an interviewee from the NBO project captured the inference from the respondents: *‘it’s as necessary for onsite, but it’s very important for offsite’* (G8/SC/PM). This comment is reiterated on the MA project as due to ‘*60 to 80 percent of the construction being offsite*’ (H4/MC/CM), ‘*it plays more of a key part in the offsite basically*’ (H14/M/QM).

The key findings regarding ‘design management more relevant to offsite’ suggest that, while design management is relevant to the whole of the project, when volumetric bathrooms are part of the design, it is most important to give priority to the management of their design as early agreement and design freeze are critical to allow manufacturers to proceed in accordance with the programme. Furthermore, last minute changes to volumetric bathrooms would prove to be costly and time consuming.

5.13.2.3 Sub-Factor Three: Design of Onsite Connection Critical for Offsite Units

Table 5.62: Breakdown of responses/interviewees: design management has more influence on offsite than onsite bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	5	2
RH	1	1
NBP	4	4
NBO	3	2
MA	1	1
Total	14	10

Problems with onsite connections varied from project to project. A construction manager from project C of the NBSA projects commented on joinery and drainage problems:

> *‘We had a bit of bother with doorframes fitting into the pods: if the floor is not perfectly level or the pod is slightly out of plumb, it makes the fitting of the door frame and door problematic. … Our labourers fitted the pods … we installed the pop up drainage as per the drawing, but when we came to connect to the pods*

we found the connection was off centre, causing additional alteration work' (C3/MC/CM).

Comments from the NBP and NBO projects also referred to the mechanical service connections as being the most problematic:

'You don't realise it's wrong until you try to connect it up. … Also you get it wrong 240 times' (F11/DT/A).

Another interviewee related connection problems that can occur onsite:

'A pipe is meant to be on that side of the room but it's over there is a real problem for offsite more so than onsite, which has more flexibility' (G10/SC/APM).

The main findings regarding 'design of onsite connections critical for offsite units' show that, while mechanical and electrical and drainage connections are the dominant problem areas, other trades such as joiner work must also be considered when installing offsite bathrooms onsite. Furthermore, the onsite connection problem is likely to be compounded by the number of units installed.

5.14 Tolerances Are Significantly Improved Through Effective Interface Management

5.14.1 Quantitative Analysis

5.14.1.1 Frequency Analysis

Table 5.63: Frequency table – tolerances are significantly improved through effective IM

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	1	1
Neither agree or disagree (3)	3	4
Agree (4)	35	43
Strongly agree (5)	43	52

Slightly more than half of the sample strongly agree (52%) and most of the rest agree (43%), confirming that 95% of the participants either agree or strongly agree, with only 1% disagreeing and 4% neither agreeing nor disagreeing. This demonstrates a clear agreement to the statement that tolerances are significantly improved through effective IM.

5.14.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 23A. From a test result of 79, the estimated median is calculated at 4.5, which corresponds with the result of agree and strongly agree indicated in Table 5.63, which infers from the results that there is a tendency among the population to agree with the statement that tolerances are significantly improved through effective IM.

5.14.2 Qualitative Analysis

Table 5.64: Ranking table – tolerances are significantly improved through effective IM

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Offsite units manufactured to a more controlled tolerance	18	18
1	Offsite units demand a focus on onsite tolerances	17	18
3	Design required to incorporate offsite and onsite tolerances	12	13
4	Co-operation and communication by supply chain required to IM of tolerances	9	10
5	Main contractor pivotal in IM of tolerances	5	5
6	IM is about understanding tolerances	4	4
7	Unsure	2	2
7	Onsite bathrooms require greater tolerances	2	2
7	Procurement route can influence the IM of tolerances	2	2
7	Quality can be affected by tolerances issues	2	2

The qualitative analysis will focus on sub-factors ranked joint one and three:

- Offsite units manufactured to a more controlled tolerance (5.14.2.1)
- Offsite units demand a focus on onsite tolerance (5.14.2.2)
- Design required to incorporate offsite and onsite tolerance (5.14.2.3).

5.14.2.1 Sub-Factor One: Offsite Units Manufactured to a More Controlled Tolerance

Table 5.65: Breakdown of responses/interviewees: tolerances are significantly improved through effective IM – sub-factor one

Classification	Responses	Interviewees
NBSA	6	6
RH	6	6
NBP	0	0
NBO	1	1
MA	5	5
Total	18	18

Two interviewees from the NBSA projects commented that with the units being built in a factory environment '*they are going to be the same: it's repeat, repeat, repeat*' (B7/SC/ConM). This was achieved by a more controlled environment, which lends itself to '*building to a lower [i.e. tighter] tolerance'* (A4/MC/QS). An interviewee from the RH project concurred with the controlled environment and added:

> *'They've designed and worked out the interfaces, snags and potential snags from tolerances basically' (D2/MC/PM).*

Interviewees from the MA project reiterated that '*it's more controlled*' (H4/MC/CM) and '*it's easier to get it right in the factory environment*' (H7/MC/QS). An interviewee commented that inspection of the first unit manufactured allows '*you to make the tweaks in the factory*' (H6/MC/BSM), suggesting that the controlled environment in a factory allows for a tighter control of tolerances within the units '*because it's a factory built product*' (H13/DT/CME).

The main findings from sub-factor 'offsite units manufactured to a more controlled tolerance' suggest that the factory environment is more conducive to implementing the control measures necessary to achieving the tolerances required of the offsite units. Furthermore, the units should all be manufactured to the same consistent standard.

5.14.2.2 Sub-Factor Two: Offsite Units Demand a Focus on Onsite Tolerance

Table 5.66: Breakdown of responses/interviewees: tolerances are significantly improved through effective IM – sub-factor two

Classification	Responses	Interviewees
NBSA	10	9
RH	1	1
NBP	1	1
NBO	2	2
MA	4	4
Total	18	17

The participants associated with the NBSA projects had mixed experiences with regard to the tolerance of offsite units installed onsite. An interviewee from project A expressed a positive view:

> *'The pods come in and they are accurately made. We know what holes we have to create for that thing to fit' (A3/MC/PM).*

However, an interviewee from project B related an interface problem in which '*we came unstuck about thresholds*' (B1/C/PM): onsite adjustment to the timber sub-floor created a minimum threshold that was acceptable to the client, but was not to the original design. Project C experienced problems with lining up drainage pop-ups:

> *'This resulted in: "dig them all up and move them to the right place afterwards" which costs time and money' (C2/C/PM).*

Further problems were experienced with the entrance door to the pods which was due to the pods being installed '*off balance, they've got them all askew*' (C5/SC/OM), suggesting that the pods were installed by unskilled labour. This point was highlighted by an interviewee from the NBP project:

> '*Do we have the right skilled people once they are onsite who can actually modify that? We've got traditional trades. Let's not forget construction is built by people, humans – whether its offsite or onsite, it's still people that do it* (F2/C/PME).

That is, the offsite and onsite processes may vary but the common denominator is the 'human' factor to which adequate training should apply regardless of the environment.

An interviewee from the NBO project explained that due to management inexperience in the offsite/onsite process '*it always takes a long time to resolve who is responsible*' (G5/MC/SM), highlighting the tolerance and interface ambiguities that exists between the trades. Interviewees from the MA project highlighted threshold problems similar to that in project B; however, early intervention resolved the problem:

> *'You need to know the tolerance with that slab, so you don't get a dip in the threshold' (H12/DT/A).*

The important point was raised that '*the guys onsite might think differently*' (H13/DT/CME), suggesting that onsite operatives may have a different perspective on the accuracy of tolerances compared to the offsite trades.

The main findings from sub-factor 'offsite units demand a focus on onsite tolerance' suggest that tolerance and interface issues generally result from inaccurate onsite works, which further indicates that onsite tolerances are less stringently controlled than offsite tolerances and that the onsite workforce have a different mindset about tolerances than the offsite workforce. This would suggest that manufacturers should be involved in onsite inspections as they will be more knowledgeable about the installation of their product than the main contractor.

5.14.2.3 Sub-Factor Three: Design Required to Incorporate Offsite and Onsite Tolerance

Table 5.67: Breakdown of responses/interviewees: tolerances are significantly improved through effective IM – sub-factor three

Classification	Responses	Interviewees
NBSA	3	3
RH	3	3
NBP	3	2
NBO	2	2
MA	2	2
Total	13	12

The experience of the client's project manager on project A of the NBSA projects was that '*they're pretty easy to design, install – absolutely*' (A1/C/PM). Furthermore, when designing the pod, consideration must be given to '*the design of the room outside the pod*' (B2/MC/PM), to achieve the overall tolerances. An interviewee from project D of the RH projects acknowledged that '*it comes down to design*' (D1/C/PM), while an interviewee from project E explained that achieving the required tolerance may require some onsite adjustment: '*move a door from the architect's drawings just slightly if you know what you are doing'* (E4/MC/SM).

An interviewee from the NBP project stated that projects have now become '*quite complex… and are no longer just bricks and mortar*' (F2/C/PME). However, '*if folk are not tuned in'* resulting in *'lack of information at the time*' (F2/C/PME), problems will result. These views were repeated by the interviewees from the NBO and MA projects, who also emphasised the importance of '*early interaction on interfaces*' (G5/MC/SM), through '*getting involved from an early stage*' (H3/MC/APM), which can improve the tolerance issues that result from the interface of the offsite/onsite co-ordination.

The main finding from sub-factor 'design required to incorporate offsite and onsite tolerance' suggests that consideration must be given not only to the tolerances of the manufactured bathroom but equally to the entire room incorporating the bathroom, otherwise problems will occur. Furthermore, the incorporation of manufactured offsite bathrooms onsite will require a different mindset from the actors involved due to working to more stringent tolerances.

5.15 Offsite Units Deliver Better Tolerances than Onsite Bathrooms

5.15.1 Quantitative Analysis

5.15.1.1 Frequency Analysis

Table 5.68: Frequency table – offsite units deliver better tolerances than onsite bathrooms

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	8	10
Neither agree or disagree (3)	7	9
Agree (4)	41	50
Strongly agree (5)	26	31

Half of the sample agree (50%) and a significant proportion strongly agree (31%), resulting in a combined agree and strongly agree score of 81%, confirming that interviewees either agree or strongly agree with the statement that offsite units deliver better tolerances than onsite bathrooms. Worthy of note is that 10% disagree with the statement.

5.15.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 23B. From a test result of 75, the estimated median is calculated at 4.0, which corresponds with the result for agree indicated in Table 5.68, which infers from the results that there is a tendency among the population to agree with the statement that offsite units deliver better tolerances than onsite bathrooms.

5.15.2 Qualitative Analysis

Table 5.69: Ranking table – offsite units deliver better tolerances than onsite bathrooms

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Offsite units manufactured to a high level of tolerance and quality	28	29
2	Onsite preparation and installation works crucial to offsite bathrooms	17	21
3	Onsite tolerances more variance than offsite	12	12
4	No flexibility in tolerance levels of offsite units	10	10
5	No difference in tolerances between offsite and onsite bathrooms	6	6
6	Easier to make adjustments to onsite bathrooms to achieve tolerance	5	5
7	Design important to achieving installation of offsite bathrooms within tolerance	4	4
8	Unsure	3	3
9	Offsite units require more pre-planning to achieve required tolerances	1	1

The qualitative analysis will focus on the sub-factors ranked one and two:

- Offsite units manufactured to a high level of tolerance and quality (5.15.2.1)
- Onsite preparation and installation works crucial to offsite bathrooms (5.15.2.2).

5.15.2.1 Sub-Factor One: Offsite Units Manufactured to a High Level of Tolerance and Quality

Table 5.70: Breakdown of responses/interviewees: offsite units deliver better tolerances than onsite bathrooms – sub-factor one

Classification	Responses	Interviewees
NBSA	10	9
RH	5	5
NBP	5	5
NBO	4	4
MA	5	5
Total	29	28

Interviewees from the NBSA projects that alluded to the above factor all agreed with the statement, commenting that '*they do better tolerances than onsite bathrooms*' (A1/C/PM), '*we have to be to the millimetre*' (A9/M/NSM), '*generally that's one of the attractions of them, yes*' (B4/DT/PM) and '*it takes out human error*' (C1/C/SPM), implying that the mechanical processes and people factors make offsite units a better quality product. However, one interviewee from project B of the NBSA projects disagreed, explaining that to incorporate the pod a recess in the concrete slab may have to be created, which may '*cause the size of the recess and the slab to vary*' (B5/DT/CCE), whereas traditionally '*you would build it to fit the recess*' (B5/DT/CCE). The respondents from the RH projects agree with the sub-factor explaining that '*mass production will give you higher tolerance*' (D4/MC/SM), '*the environment allows for that*' (D10/M/ProM) and '*we are all industrial*' (E5/M/NSM).

Agreement was similar from the interviewees from the NBP, adding '*it's quality checked and tested*' (F9/SC/PM), which was further endorsed by an interviewee from the NBO project who added, '*the finish you get is a lot better than your onsite tolerances*' (G6/MC/DM). Interviewees from the MA project added, '*a lot of the design and the problems is very much dealt with at the factory*' (H5/MC/CM), and there is '*a better set up within the factory*' (H6/MC/BSM). Of equal importance is the fact that '*the factory labour is used to doing bathrooms day in, day out*' (H8/SC/PM).

The main findings from sub-factor 'offsite units manufactured to a high level of tolerance and quality' suggest that the environment, which lends itself to an industrialised mass production process whereby less human activity is incorporated into the process than is demanded of the onsite process, results in the production of a quality bathroom within the tolerance allowed. Also of significance is the consistency of labour involved in the offsite process, compared to the transient labour involved in the onsite equivalent. However, the differentiation of the tolerance levels of the onsite floor to the matching manufactured bathroom floor may result in remedial works.

5.15.2.2 Sub-Factor Two: Onsite Preparation and Installation Works Crucial to Offsite Bathrooms

Table 5.71: Breakdown of responses/interviewees: offsite units deliver better tolerances than onsite bathrooms – sub-factor two

Classification	Responses	Interviewees
NBSA	8	8
RH	4	4
NBP	4	2
NBO	2	2
MA	3	1
Total	21	17

While a general agreement has been expressed on the better tolerance levels of units produced in a factory environment, onsite installation does create challenges, in particular '*if we are not all working off the same tolerances*' (B1/C/PM). An example highlighted on project C of the NBSA projects related to the finish sizes of rooms which meant that '*we had to go for a slimmer radiator against the pod wall*' (C2/C/PM). This change was attributed to using a traditional construction method (block work) rather than a propriety system which would be more compatible when incorporating a manufactured product (pods) such that '*the tolerance in the block work eventually affects the pods*' (C4/MC/DM).

Project D of the RH projects experienced problems with ceiling heights in the bedrooms when incorporating manufactured pods. Due to the level of services in the ceiling voids, '*we kind of had to bring them lower a bit*' (D7/DT/A), and connecting services '*can be a nightmare*' (D8/DT/QS). While no major issues were commented on within the bathroom areas of the NBP, the project manager offered a tolerance problem from a previous project relating to matching the concrete slab level to the pod floor. Due to different tolerance parameters, it was very difficult to get both floors at the same level, and this resulted in '*floorless pods being used on the next job*' (F3/MC/PM).

Interviewees on the NBO project emphasised that '*the structure which the bathroom is installed into has to be as accurate as well*' (G2/MC/PM). The project manager on the MA project offered similar problems with matching floor levels and the problem of maintaining corridor widths on past projects '*when the actual carcass of the units are not always plumb and true*' and made a judgement: '*bathroom pods for me are harder to work with than full modular units*' (H2/MC/SPM).

The main findings from sub-factor 'onsite preparation and installation works crucial to offsite bathrooms' suggest that the installation of volumetric units such as pods should be carried out by skilled labour trained in the installation process, and that consideration should be given during the design process to incorporating engineered proprietary systems to the adjoining surfaces of the pods, which can be constructed to tolerances compatible with manufactured pods.

5.16 Tolerances Would Be More Problematic with Offsite Bathrooms than Onsite

5.16.1 Quantitative Analysis

5.16.1.1 Frequency Analysis

Table 5.72: Frequency table – tolerances would be more problematic with offsite bathrooms than onsite

Likert Scale	Count	Percentage
Strongly disagree (1)	4	5
Disagree (2)	41	50
Neither agree or disagree (3)	5	6
Agree (4)	26	32
Strongly agree (5)	6	7

Interestingly, the counts for disagree (50%) and strongly disagree (5%) combine to 55%, which is greater than the agree (32%) and strongly agree (7%) combined count of 39%, with 6% neither agreeing nor disagreeing, confirming that the majority of the sample disagree with the statement that tolerances would be more problematic with offsite bathrooms than onsite. Worthy of note is that 50% agreed with the previous statement (covered in Section 5.15) that offsite units deliver better tolerances than onsite bathrooms, which would suggest that half of the sample see a clear correlation between offsite bathrooms being manufactured to a better tolerance level than onsite bathroom construction, with the remainder having mixed views.

5.16.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 23C. From a test number of 77, the p-value is calculated at 0.355 and the estimated median is calculated at 3.0, which infers there is no tendency among the population to consistently agree or disagree, and instead there seems to be a polarisation of opinions with views divided between agreeing and disagreeing with the statement that tolerances would be more problematic with offsite bathrooms than onsite.

5.16.2 Qualitative Analysis

Table 5.73: Ranking table – tolerances would be more problematic with offsite bathrooms than onsite

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Tolerance more easily controlled in a factory	24	24
2	Tolerance issues with offsite units more difficult to resolve onsite	15	16
3	Tolerance issues with onsite bathrooms accepted and easier to resolve	12	14
4	Design complete for manufacture	13	13
5	Onsite environment makes control of tolerance more difficult	7	8
6	No difference	7	7
6	Effective co-ordination and communication important in resolving tolerance issues	7	7
8	Tolerances more problematic with onsite than offsite	5	5
9	Better quality and less snagging achieved with offsite tolerances	3	3
10	Unsure	1	1

The qualitative analysis will focus on sub-factors ranked one to four inclusive:

- Tolerance more easily controlled in a factory (5.16.2.1)
- Tolerance issues with offsite units more difficult to resolve onsite (5.16.2.2)
- Tolerance issues with onsite bathrooms accepted and easier to resolve (5.16.2.3)
- Design complete for manufacture (5.16.2.4).

5.16.2.1 Sub-Factor One: Tolerance More Easily Controlled in a Factory

Table 5.74: Breakdown of responses/interviewees: tolerances would be more problematic with offsite bathrooms than onsite – sub-factor one

Classification	Responses	Interviewees
NBSA	8	8
RH	7	7
NBP	2	2
NBO	5	5
MA	2	2
Total	24	24

Interviewees from projects A and B of the NBSA projects considered that the specified tolerance is *'probably easier to get within the factory'* (A4/MC/QS), and this is further confirmed:

> *'The majority of the tolerances that need to be considered are considered offsite and, that's it, they are dealt with' (B3/DT/A).*

The offsite process demands greater focus on tolerance and interface issues when compared to traditional construction. Interviewees from the RH projects concurred, commenting that '*you've got a better environment*' (D10/M/Pro M) and that '*manufactured on a production line, more likely to be manufactured within tolerance*' (E1/C/P). Two interviewees from the NBP, five interviewees from the NBO and two interviewees from the MA projects all agree with the statement above, adding, '*we can control it here more than anyone else can with traditional*' (H14/M/QM), all rejecting the statement that tolerances are more problematic with offsite bathrooms.

The main findings from sub-factor 'tolerance more easily controlled in a factory' suggest that the factory environment of a production line will produce offsite bathrooms within the required tolerance. However, not all offsite production is carried out within a production line process and therefore a greater level of monitoring may be required by the main contractor than they had envisaged by using offsite production.

5.16.2.2 Sub-Factor Two: Tolerance Issues with Offsite Units More Difficult to Resolve Onsite

Table 5.75: Breakdown of responses/interviewees: tolerances would be more problematic with offsite bathrooms than onsite – sub-factor two

Classification	Responses	Interviewees
NBSA	4	4
RH	3	2
NBP	3	3
NBO	5	5
MA	1	1
Total	16	15

While sub-factor one suggests that tolerances are better controlled in the factory environment, respondents to sub-factor two suggested that, should a unit leave the factory out of tolerance, the impact onsite can be extreme. Interviewees from projects A and C of the NBSA projects offered the following examples:

> *'A pod went out millimetres wrong and it buggered up the installation of the fitted furniture' (A9/M/NSM);*
>
> *'If they don't give you enough tolerance to allow you to fit a door frame, there is a problem because there is no scope to take the pod apart and make good the problem' (C3/MC/CM).*

The latter example referred to pods installed onsite without the entrance door.

A comment from a respondent from the RH projects sums up the general view, '*you can't just chop off a bit, it doesn't fit*' (D7/DT/A). This is equally well expressed by an interviewee from the NBP project who said that '*they're either all right or they're all wrong, so it's one or nothing*' (F10/SC/PM). Interviewees from the NBO and MA projects also acknowledged the difficultly with a unit out of tolerance, offering a less than ideal solution:

> *'If you need to make any changes to them then you have to butcher something that's been built offsite' (H13/DT/CME).*

The aforementioned comments reiterate the importance of good quality control within the manufacturing environment and the importance of the main contractor liaising with the manufacturer to be made aware of tolerance issues when the manufactured unit is installed onsite.

The main findings from sub-factor 'tolerance issues with offsite units more difficult to resolve onsite' suggest that out of tolerance units do not lend themselves to an onsite solution, other than possible replacement. Furthermore, incomplete bathroom pods create difficulties when completion is carried out onsite due to the differential of tolerance allowance between offsite and onsite works.

5.16.2.3 Sub-Factor Three: Tolerance Issues with Onsite Bathrooms Accepted and Easier to Resolve

Table 5.76: Breakdown of responses/interviewees: tolerances would be more problematic with offsite bathrooms than onsite – sub-factor three

Classification	Responses	Interviewees
NBSA	3	2
RH	0	0
NBP	4	3
NBO	5	5
MA	2	2
Total	14	12

A number of respondents consider that tolerances are easier to overcome when building traditional bathrooms compared to offsite manufactured bathrooms. An interesting view is offered by an interviewee from project A of the NBSA projects:

> 'I tend to find that in conventional construction clients will walk in and see things are off and just accept it and walk away' (A10/M/OM).

This implies that clients will give more allowance to onsite tolerance compared to offsite. The general perception with regard to onsite tolerances is that *'you can adapt as you go'* (F6/MC/QS) and *'right, move it there'* (F10/SC/PM), as expressed by interviewees from the NBP project.

Additional comments from the participants of the NBO project reflect the idea that *'if you did it traditionally, you could make it fit'* (G5/MC/SM) and *'onsite you can always get over tolerance problems by doing something differently'* (G6/MC/DM). A final comment from the MA project sums up the difference between the construction of onsite bathrooms compared to the construction of offsite units with regard to tolerances – *'you've a degree of forgiveness'* (H2/MC/SPM) – suggesting that there is a more stringent tolerance allowance within offsite compared to onsite constructed bathrooms.

The main findings from sub-factor 'tolerance issues with onsite bathrooms accepted and easier to resolve' suggest that tolerance issues onsite can be more easily resolved and are more forgiving in comparison to offsite manufactured bathrooms, sometimes at the expense of the resulting quality of the bathroom. Provided the out of tolerance components of the onsite bathroom appear visually correct, the client will generally accept the onsite bathroom.

5.16.2.4 Sub-Factor Four: Design Complete for Manufacture

Table 5.77: Breakdown of responses/interviewees: tolerances would be more problematic with offsite bathrooms than onsite – sub-factor four

Classification	Responses	Interviewees
NBSA	2	2
RH	2	2
NBP	3	3
NBO	5	5
MA	1	1
Total	13	13

The client's project manager for project A of the NBSA category highlighted the importance of design when adopting offsite bathroom construction. The manufacturer's operations manager's comments crystallised the need for complete design before manufacture:

> *'We can't have variations – you know it has to be the first one is the same as the last one. People expect that of modular' (A10/M/OM).*

An interviewee from project E of the RH category confirmed the importance of identifying '*design interfaces'* (E3/MC/QS), and this was further emphasised by three interviewees from project F of the NBP, who all referred to design management. This was succinctly expressed as *'unless your interface management has been really good you could have 34 huge problems'* (F10/SC/PM).

Five interviewees from the NBO project all commented on the need for an early approach to design when incorporating offsite bathrooms. The project manager emphasised the significance – *'you have to stop and think about it at an earlier stage'* (G2/MC/PM) – thus ensuring that the necessary tolerances are allowed for. An interviewee from the MA category suggested of offsite and onsite bathroom construction that *'they both have positive and negative. … It all depends on the design'* (H4/MC/CM), which suggests that the method of production can influence the importance of early design completion.

The main findings from sub factor 'design complete for manufacture' suggest that all stakeholders must be aware of the importance of design management in identifying tolerance and interface issues when incorporating offsite bathrooms. The design team must be made aware of the strategic importance of early design completion for both offsite and onsite elements that relate to the offsite bathroom design, to avoid costly variations to the project.

5.17 Quality is Significantly Improved through Effective Interface Management

5.17.1 Quantitative Analysis

5.17.1.1 Frequency Analysis

Table 5.78: Frequency table – quality is significantly improved through effective IM

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	0	0
Agree (4)	36	44
Strongly agree (5)	46	56

Significantly, the counts for strongly agree (56%) and agree (44%) combine to 100%, unanimously confirming that all the interviewees agree with the statement that quality is significantly improved through effective IM.

5.17.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 24A. From a test result of 82, the estimated median is calculated at 4.5, which corresponds with the high result of agree and strongly agree indicated in Table 5.78, which infers from the results that there is a tendency among the population to agree or strongly agree with the statement that quality is significantly improved through effective IM

5.17.2 Qualitative Analysis

Table 5.79: Ranking table – quality is significantly improved through effective IM

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	A teamwork co-ordinated IM approach aids quality	13	13
2	Good management aids quality	7	7
3	Communication important to aid quality	5	6
3	The lack of IM will adversely affect quality	6	6
5	Inspection process	5	5
5	Offsite manufacture aids quality	5	5
7	The amount of snagging can affect quality	3	3
7	Co-ordination of design fundamental to IM of quality	3	3

9	Samples and mock-ups aid quality	1	1
9	Client input aids quality	1	1

The qualitative analysis will focus on sub-factors ranked one and two:

- A teamwork co-ordinated IM approach aids quality (5.17.2.1)
- Good management aids quality (5.17.2.2).

5.17.2.1 Sub-Factor One: A Teamwork Co-ordinated IM Approach Aids Quality

Table 5.80: Breakdown of responses/interviewees: quality is significantly improved through effective IM – sub-factor one

Classification	Responses	Interviewees
NBSA	5	5
RH	1	1
NBP	1	1
NBO	1	1
MA	5	5
Total	13	13

Two interviewees from the NBSA projects used the word '*accountability*' (A1/C/PM; B7/SC/ConM) to promote a teamwork approach which takes responsibility, whereby '*everyone knows what they are doing*' (A1/C/PM), to produce the required quality. An interviewee from the RH projects explained the need to co-ordinate operations, which was endorsed by an interviewee from the NBP project who stressed the importance of '*getting it right first time*' (F5/MC/APM) and similarly by an interviewee from the MA project:

> *'You're not bottle necking any trades so there's a bit less pressure. There's more room for the trades to work in' (H4/MC/CM).*

In other words, when trade workers are given a reasonable environment and realistic timeframe to carry out their work, quality is produced to the required standard. Teamwork to aid quality was advocated by interviewees from the MA project – '*we can work together to make sure we are realistic in our approach*' (H5/MC/CM) – and this was achieved by having '*interface with the supervisors*'

(H8/SC/PM) and '*a good quality team where they go round and check that all the supply chain work was done*' (H12/DT/A).

The main findings from sub-factor 'a teamwork co-ordinated IM approach aids quality' are that co-ordination and accountability of the members of the team will aid the management of interfaces between trades and contribute to a quality product. At the heart of a teamwork approach is organisational interface, whereby all members of the team communicate openly within a transparent environment.

5.17.2.2 Sub-Factor Two: Good Management Aids Quality

Table 5.81: Breakdown of responses/interviewees: quality is significantly improved through effective IM – sub-factor two

Classification	Responses	Interviewees
NBSA	3	3
RH	0	0
NBP	0	0
NBO	2	2
MA	2	2
Total	7	7

Seven interviewees related management to achieving quality. Interviewees from project A of the NBSA projects related good management to '*reducing the amount of snagging*' (A6/MC/SM), also stating that '*quality can slip very easily if not managed right*' (A8/DT/A). An interviewee from the NBO project endorsed the need for proper management and explained that '*quality is significantly improved when properly managed*' (G14/DT/P). An interviewee from the MA project suggested that '*if we have got the interfaces between everyone managed*' (H5/MC/CM), good management will result, emphasising importance IM to the quality of the end product.

The main finding from sub-factor 'good management aids quality' is that effective and efficient management of interface issues will positively contribute to the quality of the final product. Moreover, proactive management is required throughout the project to maintain the specified level of quality with the added benefit of reducing the level of snagging.

5.18 Quality on This Project Is More Easily Achieved in Offsite Bathroom Construction Compared to Onsite Bathroom Construction

5.18.1 Quantitative Analysis

5.18.1.1 Frequency Analysis

Table 5.82: Frequency table – quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	3	4
Disagree (2)	3	4
Neither agree or disagree (3)	6	7
Agree (4)	37	45
Strongly agree (5)	33	40

As with the previous statement covered in Section 5.17, there is a high count of agree (45%) and strongly agree (40%), confirming that 85% of the sample either agree or strongly agree with the statement that quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction. Also worthy of comment is that 8% disagree or strongly disagree and the remaining 7% neither agree nor disagree with the statement.

5.18.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 24B. From a test result of 76, the estimated median is calculated at 4.5, which corresponds with the high result of agree and strongly agree indicated in Table 5.82, which infers from the results that there is a tendency among the population to agree or strongly agree with the statement.

5.18.2 Qualitative Analysis

Table 5.83: Ranking table – quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Offsite environment produces better quality	43	51
2	Onsite environment can result in poor quality	24	25
3	Quality achieved onsite equal to offsite standard	14	15
4	Tolerances of offsite materials can affect quality of offsite	5	5
5	Design impacts on quality	4	4
6	Offsite environment does not produce better quality	3	3
6	Client's input can influence quality	3	3
8	People influence quality	2	2
9	Offsite bathrooms more sustainable quality	1	1

The qualitative analysis will focus on sub-factors ranked one, two and three:

- Offsite environment produces better quality (5.18.2.1)
- Onsite environment can result in poor quality (5.18.2.2)
- Quality achieved onsite is equal to offsite standard (5.18.2.3).

5.18.2.1 Sub-Factor One: Offsite Environment Produces Better Quality

Table 5.84: Breakdown of responses/interviewees: quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	17	14
RH	12	9
NBP	7	6
NBO	8	7
MA	7	7
Total	51	43

Fourteen interviewees from the NBSA projects offered a range of comments as to why they considered the factory environment produced a better bathroom compared to the onsite methods: '*the weather and all that*' (A5/MC/PM), with the weather being considered a substantial factor, and being able to work '*in a nice warm factory*' (B6/DT/CME), which means '*you're doing it in a better environment*' (B6/DT/CME). The quality control procedures were considered more robust, which results in '*very little snagging*' (B5/DT/CCE). This was further qualified by the statement that '*to get that finish onsite would be much more difficult*' (C6/DT/CME). However, one interviewee disagreed with the latter comment:

> *'You can get an amazing quality product through traditional bathrooms, of course you can. It all comes down to the design management, the interface and the required specification for clients and the budget as well' (B4/DT/PM).*

This highlights the correlation between IM and quality. Interviewees from projects D and E of the RH projects concurred with the comments on the better environment and quality control procedures adding that they have *'stage inspections and we do have a very rigid quality control'* (D9/M/D), which ensures the units are produced *'within our set tolerances'* (D9/M/D). However, an interviewee offered *'obviously it's down to the supplier'* (E4/MC/SM), suggesting that not all offsite environments are the same.

This was experienced on project D where a batch of bathroom pods meant broken tiles and excessive gaps between the architraves and the wall – *'we were snagging; oh, what has happened here?'* (D7/DT/A) – confirming that quality is not always assured when a bathroom is built offsite. Interviewees from the NBP, NBO and MA projects expressed similar thoughts on the controlled environment and quality checks and added that *'quality is constant'* (F3/MC/PM), *'the QA* (quality assurance) *process in the factory, it's a bit like manufacturing a car'* (G5/MC/SM) to *'we don't let anything out of the factory unless it's perfect'* (H3/MC/APM), which suggests that inspections from the main contractor are of equal importance to those of the manufacturer.

The main finding from sub-factor 'offsite environment produces better quality' is that, if the working environment is compatible with the standards of a modern manufacturing factory and quality procedures are followed and checked, a quality product should consistently result. A strong link exists between identifying and resolving interface problems during the design stage before manufacturing and producing a quality bathroom.

5.18.2.2 Sub-Factor Two: Onsite Environment Can Result in Poor Quality

Table 5.85: Breakdown of responses/interviewees: quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	7	7
RH	4	4
NBP	0	0
NBO	8	7
MA	6	6
Total	25	24

Conversely to the responses in sub-factor one, constructing onsite bathrooms and being more exposed to the influence of the weather was considered a clear disadvantage by an interviewee from project B: '*you're working in the pissing rain or freezing cold and possibly at height*' (B6/DT/CME). These are not conditions conducive to building a quality bathroom onsite. A further comment from project B on quality onsite was:

> *'You're relying on individual trades onsite, different subcontractors going into liquidation, availability of labour. With offsite you buy the product and you get a guarantee from your manufacturer. If you don't get the product you were expecting, it goes back' (B4/DT/PM).*

The latter comment is emphasised by an interviewee from the RH projects as '*it would be down to the tradesmen*' (D7/DT/A). Furthermore, there may be '*five or six other activities are going on around you*' (E2/MC/Con M). Interviewees from the NBO project commented on the environment as sometimes being '*wet and windy'* (G3/MC/SM) and on the multitude of trades: '*you start getting a lot of trades in there*' (G6/MC/DM).

The analogy of *'it's like building a car from scratch'* (G5/MC/SM) was used to describe the building of each onsite bathroom. Interviewees from the MA project described onsite working conditions as '*cold, poorly lit*' (H1/C/PM) and also stated that '*the tolerances are wider, so you end up with more errors*' (H14/M/QM), suggesting that the quality control onsite is not as stringent and will result in a greater level of snagging compared to bathrooms constructed offsite.

The main findings from sub-factor 'onsite environment can result in poor quality' are that inclement weather and site conditions are generally not conducive to building a quality bathroom. This together with a total reliance on human endeavours, with trades working over each other in congested areas, contributes to a greater level of snagging, resulting in bathrooms constructed to a poorer quality compared to the offsite equivalent. The influence of the environment on the quality of onsite bathrooms notwithstanding, a significant effect will be the level of quality control exerted onsite, which is professed by interviewees to be less stringent than that performed in a factory.

5.18.2.3 Sub-Factor Three: Quality Achieved Onsite Is Equal to Offsite Standard

Table 5.86: Breakdown of responses/interviewees: quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	1	1
RH	3	3
NBP	4	3
NBO	3	3
MA	4	4
Total	15	14

Interestingly, only one interviewee from the NBSA project considered that '*the quality and final product shouldn't be beyond a competent contractor and designer onsite*' (B3/DT/A). Interviewees from the RH projects added that the quality can be achieved onsite such that '*you wouldn't know the difference*' (D7/DT/A), adding that '*your problems can always be rectified*' (E5/M/NSM), suggesting it is easier to overcome problems onsite compared to offsite. An interviewee from the NBP project considers that '*proper site management means that the workforce can get in to do a high quality job*' (F12/DT/QS). Respondents from the NBO project added that '*you could do it traditionally if you've got the time*' (G12/DT/A), adding the further complication that '*every job's a bespoke job*' (G5/MC/SM). An interviewee from the MA project offered an interesting view of their manufacturer:

> 'Although they were doing it in a factory, the manufacturer for me is just a construction site within a factory. There's no methodology in the way things are moving on and how the efficiency of the productivity can be improved' (H2/MC/SPM).

Even if the offsite bathroom is produced within a factory environment, if the process is not managed effectively and efficiently, the resulting product is not guaranteed to be of a better quality compared to the quality achieved from onsite build.

The main finding from sub-factor 'quality achieved onsite is equal to offsite standards' is that a competent contractor with effective site management that engages with pre-planning and quality control should be able to construct a quality bathroom. Furthermore, some offsite facilities are no more than a construction site within a 'tin shed' and therefore require efficient management not only from the manufacturer but also the main contractor to achieve the required quality.

5.19 Does Effective Communication Improve Interface Management?

5.19.1 Quantitative Analysis

5.19.1.1 Frequency Analysis

Table 5.87: Frequency table – does effective communication improve IM?

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	0	0
Agree (4)	14	17
Strongly agree (5)	68	83

The counts for strongly agree (83%) and agree (17%) add up to 100% demonstrating a clear strong agreement to the question. Worthy of note is that none of the sample disagree nor strongly disagree with the statement.

5.19.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 25A. From a test result of 82, the estimated median is calculated at 5.0, which corresponds with the high result of strongly agree indicated in Table 5.87, which infers from the results that there is a tendency among the population to strongly agree with the statement that effective communication improves IM.

5.19.2 Qualitative Analysis

Table 5.88: Ranking table – does effective communication improve IM?

Rank	Description of Sub-Factor	No. of Interviewees	No. of Responses
1	Clear, concise and continuous communication	22	31
2	Impacts on all aspects of the process	19	24
3	Verbal communication	14	20
4	Inter-relationships between teams	9	9
5	English not first language	2	2
6	Can good communication be taught?	1	1

The qualitative analysis will focus on sub-factors ranked one, two and three:

- Clear, concise and continuous communication (5.19.2.1)
- Impacts on all aspects of the process (5.19.2.2)
- Verbal communication (5.19.2.3).

5.19.2.1 Sub-Factor One: Clear, Concise and Continuous Communication

Table 5.89: Breakdown of responses/interviewees: does effective communication improve IM? – sub-factor one

Classification	Responses	Interviewees
NBSA	14	7
RH	4	4
NBP	4	4
NBO	4	3
MA	5	4
Total	31	22

Interestingly the client from project A, within the NBSA category, summed up his view on communication:

> *'All I need to do is make sure I can tell you what it is that I want, when I want it, how I want it' (A1/C/PM).*

Another interviewee from the same project commented on the use of email and phones and expressed a preference for a greater level of verbal communication:

> *'Everyone now wants to hide behind an email to a degree. Yes, I appreciate that you have to put things in writing, but we are trying to get people to pick up that bloody thing and talk' (A9/M/NSM).*

A further interviewee highlighted the importance of concise communication in managing the team, rather than '*playing tennis with emails bouncing back and forth*' (B3/DT/A).

Another interviewee from the NBSA project emphasised the importance of '*making sure they've got the most up to date drawings … and communicating timescales*' (B5/DT/CCE), while another interviewee explained that this is an important function of the '*project manager's job*' (C1/C/SPM). Interviewees from the RH project also made reference to timescales in the form of '*it's basically down to programmes; programmes is the answer*' (E4/MC/SM), while another respondent emphasised, '*it's about a mindset; it's about a culture*' (E2/MC/ConM), suggesting that management must promote clear concise communication in all forms from the beginning to the end of the project.

An interview from the NBP project expanded on the programme issue as '*sorting out the sequence*' (F9/SC/PM), relating the need for effective communication between trades. This factor was further emphasised by an interviewee from the NBO project who stated that it is '*just as important to deal with the subcontractors as it is with the client and management team*' (G12/DT/A). The importance of documentation was stressed on this project as '*not leaving anything out that is going to come back and bite you*' (G7/MC/BSM), as was the need to hold regular design and co-ordination meetings. The factor of programming was reiterated by interviewees from the MA project, who also commented on '*the way*' (H5/MC/CM) we communicate with people as an important factor, '*straight talking at times*' (H12/DT/A), suggesting that to be clear and concise demands a direct approach.

The main finding from sub-factor 'clear, concise and continuous communication' is that it is important that clients clearly communicate the what, when and how to the design team. It is the project manager that is required to promote a culture of direct and concise communication with all stakeholders. The contract programme and method of recording progress on the project should be disseminated to all parties. While email is now the dominant method of written communication, it should not replace verbal communication and human contact, which is central in building good relationships between actors on a project.

5.19.2.2 Sub-Factor Two: Impacts on All Aspects of the Process

Table 5.90: Breakdown of responses/interviewees: does effective communication improve IM? – sub-factor two

Classification	Responses	Interviewees
NBSA	8	6
RH	4	3
NBP	6	4
NBO	A	3
MA	3	3
Total	24	19

Respondents from the NBSA projects focused on the human aspect of communication, highlighting the detrimental effect of '*human error*' on '*communication that hasn't got through*' (A9/M/NSM) and suggested that '*if people aren't talking correctly then things will fall down*' (B3/DT/A), commenting that architects are '*known to be bad communicators*' (B1/C/PM). On a positive note, two interviewees from projects B and C signalled effective communication as '*improving all aspects of the job*' (B3/DT/A) and allowing '*a better process long term*' (C6/DT/CME). An interviewee from the RH projects caught the general feeling, '*you may as well go home if you are not communicating effectively*' (D10/M/ProM). This was further reiterated by participants associated with the RH, NBP and NBO projects, who all emphasised '*communication is key*' (E3/MC/QS).

Reference was made to the location of the manufacturer's premises in the case of project E, which were in France, and effective communication was implemented from the start resulting in no process problems, whereas for project D the manufacturer was based in Nottingham and despite them being considered more accessible, communication problems resulted. This was further stated by an interviewee from the NBP project:

> '*Generally if things went wrong on this project, it was because someone hadn't communicated something' (F11/DT/A).*

In contrast, with '*effective communication, you can control the process a lot more, can't you*' (G5/MC/SM). Participants from the MA project also highlighted the need to '*speak to each other*' (H5/MC/CM) and how '*you've got to pull together*' (H8/SC/PM) to sort out onsite and offsite problems.

The main finding from sub-factor 'impacts on all aspects of the process' is that effective and efficient communication is extremely important and central to the success of a project. There is a danger that the art of verbal communication is being lost to email, as many stakeholders prefer to avoid face to face contact to resolve disputes. While the industry has become very contractual, often unofficial means of communication are very effective in resolving interface problems that could potentially impact on the project.

5.19.2.3 Sub-Factor Three: Verbal Communication

Table 5.91: Breakdown of responses/interviewees: does effective communication improve IM – sub-factor three

Classification	Responses	Interviewees
NBSA	5	3
RH	2	1
NBP	3	2
NBO	2	2
MA	8	6
Total	20	14

Fourteen interviewees related verbal communication as important to improve IM. Comments from projects A and B of the NBSA projects stress the importance of verbal communication:

> ‘Everybody now wants to hide behind an email. Yes, I appreciate you have to put things in writing, but we are trying to get people to pick up that bloody thing and talk’ (A9/M/NSM);
>
> ‘You’ve got to be able to speak to people’ (B1/C/PM);
>
> ‘So if you don’t talk, you don’t get’ (B2/MC/PM).

An interviewee from project D of the RH projects emphasised the importance of ‘*face to face discussion*’ (D2/MC/PM), and an interviewee from the NBP project offered that, when humans get frustrated, the preferred form of communication is ‘*invariably to pick up the phone*’ (F3/MC/PM). However, it should be noted that stakeholder interpretations can vary at meetings – ‘*some people go away with different impressions*’ (F3/MC/PM) – suggesting that verbal communication requires to be confirmed in writing. Respondents on the NBO project advocate ‘*workshops … open forums*’ (G7/MC/BSM) as verbal forms of communication that benefit the discussion of interfaces, while the MA project favours *‘the likes of co-ordination meetings’ (*H3/MC/APM), both formal and informal, as in-house co-ordination meetings were also viewed as a medium to resolve interface issues.

The main finding from sub-factor ‘verbal communication’ is that informal communications have a part to play in building and maintaining good relationships within the project. Face to face communication can more readily resolve interface problems. However, consideration should be given to the interpretation of verbal communication, as stakeholders do not always identify with the same conclusions. Furthermore, stakeholders must realise that verbal communication does not just mean ‘talking’ but that ‘listening’ is equally important.

5.20 Effective Communication Has More Influence on Offsite than Onsite Bathroom Construction

5.20.1 Quantitative Analysis

5.20.1.1 Frequency Analysis

Table 5.92: Frequency table – effective communication has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	3	4
Disagree (2)	39	48
Neither agree or disagree (3)	25	30
Agree (4)	8	10
Strongly agree (5)	7	8

The results show disagree (48%) and strongly disagree (4%) merge to give 52%, confirming that more than half of the sample disagree that effective communication has more influence on offsite than onsite bathroom construction. Significantly, 30% neither agree nor disagree, and agree (10%) and strongly agree (8%) combining to 18% suggests that nearly three times as many interviewees of the sample disagree rather than agree with the statement.

5.20.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 25B. From a test result of 57, the estimated median is calculated at 2.5, which corresponds with the result of disagree indicated in Table 5.92, which infers from the results that there is a tendency among the population to disagree with the statement that effective communication has more influence on offsite than onsite bathroom construction.

5.20.2 Qualitative Analysis

Table 5.93: Ranking table – effective communication has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Makes no difference	43	43
2	Onsite bathroom construction requires a greater level of communication	14	16
3	Early communication most important with offsite forms	13	15
4	Offsite environment makes for simpler forms of communication	12	12
5	Late decision-making more acceptable in onsite forms	7	8
6	Drawings important form of communication	4	4

The qualitative analysis will focus on sub-factors ranked one, two and three:

- Makes no difference (5.20.2.1)
- Onsite bathroom construction requires a greater level of communication (5.20.2.2)
- Early communication most important with offsite forms (5.20.2.3).

5.20.2.1 Sub-Factor One: Makes No Difference

Table 5.94: Breakdown of responses/interviewees: effective communication has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	8	8
RH	8	8
NBP	5	5
NBO	11	11
MA	11	11
Total	43	43

Forty-three interviewees from the sample of 82 inferred in their comments that effective communication has no more influence in offsite than onsite bathroom construction. Comments from projects A and C of the NBSA projects range from '*if you're not communicating it'll muck things up whether you're onsite or offsite*' (A8/DT/A) to '*if there's good communication, it can work both ways*' (C6/DT/CME). Similar suggestions came from project D of the RH projects, ranging from '*if you are planning things properly and communicating then it doesn't matter whether you're onsite or offsite*' (D5/SC/PME) to '*it applies across the board*' (D9/M/D). A comment worthy of note from the NBP project was, '*you have to be telling these people the right things, whether it's offsite or onsite*' (F8/MC/CM), implying that effective communication with subcontractors and manufacturers is paramount to the success of any project. Of equal importance was the main expression from the NBO project: '*I think they're equal … critical on any stage*' (G12/DT/A). The importance of relationships was emphasised by the interviewees on the MA project with the comment:

> *'As long as you're communicating with the interface and everything I think it doesn't matter' (H16/M/SM).*

The main finding from sub-factor 'makes no difference' is that communication is of equal importance to both offsite and onsite bathroom construction. Regardless of whether the bathroom is constructed onsite or offsite, the correct information and instructions must be made timeously available to suit the method of construction. Furthermore, good communication promotes better relationships, which can have a positive influence on the management of interfaces.

5.20.2.2 Sub-Factor Two: Onsite Bathroom Construction Requires a Greater Level of Communication

Table 5.95: Breakdown of responses/interviewees: effective communication has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	11	10
RH	1	1
NBP	1	1
NBO	2	1
MA	1	1
Total	16	14

Eleven of the 16 responses for this sub-factor came from respondents associated with project B and C of the NBSA projects. The importance of a greater level of communication was stated because 'a *greater volume of work obviously increases the level of communication*' (C1/C/SPM), and '*you're putting a lot of bits and pieces together and it's more onerous*' (B1/C/PM) and are therefore '*communicating with so many more people*' (C4/MC/DM). The increased level of stakeholders' communication was also emphasised by an interviewee from the NBO project, with an interviewee from the MA project suggesting that onsite bathroom construction '*is more problematic here than the factory*' (H8/SC/PM).

The main findings from sub-factor 'onsite bathroom construction requires a greater level of communication' is that onsite bathroom construction requires a greater number of subcontractors onsite compared to offsite and therefore there will be more lines of communication to manage the process. However, the level of communication needed for offsite bathrooms is of equal importance.

5.20.2.3 Sub-Factor Three: Early Communication Most Important with Offsite Forms

Table 5.96: Breakdown of responses/interviewees: effective communication has more influence on offsite than onsite bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	6	5
RH	0	0
NBP	5	4
NBO	2	2
MA	2	2
Total	15	13

Interviewees from project A of the NBSA projects succinctly comment on why early communication is important to offsite forms of bathroom construction: '*if we don't get it right front end we're knackered*' (A9/M/NSM) and '*we want to force the decision-making further up the process chain, so it's really important earlier on*' (A10/M/OM). An interviewee from the NBP project emphasised that '*early communication on offsite is key*' (F5/MC/APM), and this is further emphasised:

> *'Earlier communication is more influential for offsite because everything needs to be designed and all the interfaces need to be designed on the job much earlier' (F6/MC/QS).*

This confirms the importance of early communication between the relevant stakeholders in the resolution of possible interface challenges. The factor of early communication is described by an interviewee from the NBO project as '*upfront design management communication between trades*' (G6/MC/DM), suggesting an important link between early communication and design management.

The main finding from sub-factor 'early communication most important with offsite forms' is that design management and communication are inextricably linked in facilitating early design of offsite forms of bathroom construction. Furthermore, the relationship of design management and communication should be encouraged for onsite bathroom construction, to minimise incomplete design.

5.21 An Effective Project Manager Will Significantly Improve Interface Management in Bathrooms

5.21.1 Quantitative Analysis

5.21.1.1 Frequency Analysis

Table 5.97: Frequency table – an effective project manager will significantly improve IM in bathrooms

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	0	0
Agree (4)	27	33
Strongly agree (5)	55	67

Interestingly, the tally for strongly agree (67%) and agree (33%) combines to 100%, confirming that the sample unanimously agree with the statement that an effective project manager will significantly improve IM in bathrooms.

*5.21.1.*2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 26A. From a test result of 82, the estimated median is calculated at 4.5, which corresponds with the result of agree and strongly agree indicated in Table 5.97, which infers from the results that there is a tendency among the population to agree with the statement that an effective project manager will significantly improve IM in bathrooms.

5.21.2 Qualitative Analysis

Table 5.98: Ranking table – an effective project manager will significantly improve IM in bathrooms

Rank -ing	Description of Sub-Factor	No. of Inter-viewees	No. of Respon -ses
1	The project manager's leadership can improve IM	20	24
1	An effective project manager requires good communication skills	18	24
3	Team work rather than the single influence of the project manager	10	11
4	Project managers vary in the form they take	7	8
5	Project manager's relationship with client	5	6
5	The project manager will input into the design	6	6

The qualitative analysis will focus on the sub-factors ranked joint first:

- The project manager's leadership can improve IM (5.21.2.1)
- An effective project manager requires good communication skills (5.21.2.2).

5.21.2.1 Sub-Factor One: The Project Manager's Leadership Can Improve IM

Table 5.99: Breakdown of responses/interviewees: an effective project manager will significantly improve IM in bathrooms – sub-factor one

Classification	Responses	Interviewees
NBSA	6	5
RH	4	2
NBP	5	4
NBO	7	7
MA	2	2
Total	24	20

The interviewees from the NBSA projects stipulated the importance of an effective project manager in managing the interfaces in bathroom construction. An interviewee from project A commented on the important attribute of leadership, saying '*it's about being an effective leader*' (A2/C/OM). The respondents associated with the RH projects added that leadership is also important within the manufacturer and trade project managers. An interviewee from project E added that the project manager requires leadership to '*coordinate and interface with* *everything*' (E3/MC/QS), emphasising the project manager's leadership in foreseeing interface problems. This characteristic was also echoed by the project manager from the NBP project:

> 'The role of the project manager or leader has changed a little bit to that of trying to have just an overview of what's going on – you're a "problem solver" as opposed to someone who directly influenced the thought process at the start, which is a shame because you have gained a lot of experience' (F3/MC/PM).

This suggests that not including the project manager in the pre-construction stage can dilute the design decisions made by not taking advantage of the project manager's experience.

An interviewee on the NBP project added that strong leadership is required on a project '*to command the design and construction team*' (F12/DT/QS), suggesting that the modern project manager requires to display leadership well before the construction phase. Interviewees from the NBO project added that leadership from the project manager is required '*all the way through the chain*' (G7/MC/BSM) to effectively '*lead the interfaces*' (G9/SC/QS), suggesting that the project manager's leadership skills will impact on all stakeholders. The respondents from the MA project also recognised leadership as having a '*key impact on the project*' (H5/MC/CM), and ultimately that '*the project manager drives the project*' (H14/M/QM). This comment concurs with a comment from the NBP project – '*the project manager is the boss at the end of the day*' (F8/MC/CM) – which unambiguously defines the importance of the project manger's role.

The main finding from sub-factor 'the project manager's leadership can improve IM' is that the attribute of leadership is fundamental to the role of the project manager. Unfortunately, the project manager's problem solving experience is not always utilised at the pre-construction stage, which would help to identify potential interface problems. Also, the leadership trait should be common to the manufacturer's and subcontractor's project managers.

5.21.2.2 Sub-Factor Two: An Effective Project Manager Requires Good Communication Skills

Table 5.100: Breakdown of responses/interviewees: an effective project manager will significantly improve IM in bathrooms – sub-factor2

Classification	**Responses**	**Interviewees**
NBSA	1	1
RH	4	3
NBP	8	5
NBO	5	5
MA	6	4
Total	24	18

A comment from the architect from project A of the NBSA projects related that:

> *'An inefficient project manager is going to cause problems up and down, not just in bathrooms' (A8/DT/A).*

This was also highlighted by a respondent from the RH project – '*someone who's disinterested, there's no coordination going on there*' (D9/M/D) – while the client from project D related the importance of an effective project manager in relation to IM: '*it just goes back to good communication, good communication*' (D1/C/PM).

The project manager from the NBP project said of a communication problem that resulted from the procurement of modular electrical distribution units, '*the guys didn't understand it well enough*' (F3/MC/PM), which resulted in a delay in getting mains power into the building. Another interviewee from the NBP project reiterated the importance of the project manager's communication with staff members: '*that links to whether he is communicating with his construction managers*' (F7/MC/QS). The interviewees from the NBO project related co-ordination as important to the IM of bathroom construction and offered, '*communication is the key to a good project and the project manager sort of leads that*' (G9/SC/QS), while a lack of co-ordination can result in the detrimental effect of '*throwing everyone in on top of each other … it would have been horrendous*' (G6/MC/DM). The architect from the MA project commented on the positive manner adopted by the senior project manager and his assistant in communicating to all staff, while some have experienced others as not so pleasant:

'I mean, I don't think I've ever had them take an angry tone or anything like that. I mean, I've had project managers telling you to 'F' off and stuff like that, such that when the phone rings you say to yourself, "Oh, I hope that it's not that person"' (H12/DT/A).

Therefore, the manner by which project managers communicate can influence the effectiveness of their leadership skills.

The main finding from sub-factor 'an effective project manager requires good communication skills' is that there is a strong link between an efficient project manager and having effective communication skills to co-ordinate and lead a successful project. Project managers should apply their communication skills to all levels of stakeholders connected to the project. Conversely, a project manager lacking in good communication skills will have a detrimental effect on the co-ordination and management of interfaces. Furthermore, project managers should be aware of the tone and manner by which they communicate.

5.22 An Effective Project Manager Has More Influence on Offsite than Onsite Bathroom Construction

5.22.1 Quantitative Analysis

5.22.1.1 Frequency Analysis

Table 5.101: Frequency table – an effective project manager has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	2	2
Disagree (2)	40	49
Neither agree or disagree (3)	22	27
Agree (4)	15	18
Strongly agree (5)	3	4

The counts for disagree (49%) and strongly disagree (2%) combine to give 51%, confirming that slightly more than half of the sample disagree with the statement that an effective project manager has more influence on offsite than onsite bathroom construction. Worthy of note is that 27% neither agree nor disagree, 18% agree and 4% strongly agree combining to 22% agreement, showing that more than twice as many in the sample disagree as agree with the statement.

5.22.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 26B. From a test result of 60, the estimated median is calculated at 2.5, which corresponds with the result of disagree and strongly disagree indicated in Table 5.101, which infers from the results that there is a tendency among the population to disagree with the statement that an effective project manager has more influence on offsite than onsite bathroom construction.

5.22.2 Qualitative Analysis

Table 5.102: Ranking table – an effective project manager has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Project manager influence the same for offsite and onsite	30	31
2	Project manager will have more influence in the onsite bathroom construction	25	26
3	Project manager will have less influence in the offsite bathroom construction	20	20
4	Project manager will have more influence in offsite bathroom construction	9	9
4	Project manager influence will depend on communication	9	9

6	Offsite demands earlier involvement and planning by the project manager	7	8
7	Project manager involved in logistics and onsite co-ordination of offsite	5	6
8	Project manager influence will depend on input by client and design team	4	4
9	Project manager influence dependent on procurement route	2	2

The qualitative analysis will focus on the sub-factors ranked one, two and three:

- Project manager influence the same for offsite and onsite (5.22.2.1)
- Project manager will have more influence in the onsite bathroom construction (5.22.2.2)
- Project manager will have less influence in the offsite bathroom construction (5.22.2.3).

5.22.2.1 Sub-Factor One: Project Manager Influence the Same for Offsite and Onsite

Table 5.103: Breakdown of responses/interviewees: an effective project manager has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	6	6
RH	8	7
NBP	2	2
NBO	6	6
MA	9	9
Total	31	30

The largest number of responses to the statement from interviewees considered that the project manager's influence was of equal importance to both environments. Interviewees from projects A and B of the NBSA projects commented, '*I don't think it's either one or the other*' (A9/M/NSM), '*I think it's vital in both places or it will make your life hell*' (A10/M/OM) and '*I don't think they* *should have any less influence*' (B3/DT/A), all emphasising the important role of the project manager in both offsite and onsite construction.

The comments of the respondents from the RH projects were similar to the NBSA projects, with one interviewee from project E adding that the culture of the two environments may differ – '*you're trying to approach everything the same*' (E2/MC/ConM) – suggesting that the project manager has to be adaptable to the differing environments. This comment was echoed by an interviewee from the NBP project:

> *'Project management is imperative, whether the construction is onsite or offsite and I wouldn't differentiate between the two in terms of the effectiveness of the project manager' (F12/DT/QS).*

However, an interviewee from the NBO project added, '*it's a different role … but you still need him*' (G1/C/PM), suggesting a different skillset, depending on the environment. The interviewees from the MA project reiterated the majority view of the influence of the project manager onsite and offsite as being 'fifty-fifty' (H4/MC/CM) and added, '*if you make a bollocks, whether it's offsite or onsite, it's still a bollocks*' (H8/SC/PM), emphasising the importance of the project manager's role, regardless of project type and environment.

The main finding from sub-factor 'project manager influence the same for offsite and onsite' is that regardless of whether the process is offsite or onsite the effectiveness of the project manager is paramount to the success of the project. However, where the bathrooms are constructed offsite, project managers must adapt their skillset to a manufacturing environment to maintain their effectiveness and not abdicate responsibility for their role to the manufacturer.

5.22.2.2 Sub-Factor Two: Project Manager Will Have More Influence in the Onsite Bathroom Construction

Table 5.104: Breakdown of responses/interviewees: an effective project manager has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	9	8
RH	5	5
NBP	5	5
NBO	4	4
MA	3	3
Total	26	25

Twenty-five interviewees suggested that the project manager has more influence within onsite bathroom construction compared to offsite bathroom construction. Interviewees from the NBSA projects suggested that '*problems are more likely to arise onsite*' (A2/C/OM). An interviewee remarked:

> *'You need to be a good planner and have good planning skills for offsite, which may not be quite so critical onsite' (A8/DT/A).*

This highlights that interface problems that occur with offsite bathrooms are more difficult to resolve in comparison to onsite bathroom construction for which there is a higher degree of flexibility. A comment expressed by project B's design team project manager related to the form of procurement – '*if it was traditional contract, I'd have more hands on influence*' (B4/DT/PM) – explaining that with the particular project being design and build, the client's project manager does not have the same level of direct influence.

Reference was made to the background of the project manager, implying that a project manager from a trades background '*knows how to work them onsite*' (C4/MC/DM) and would focus on the onsite element and transfer responsibility for the offsite bathroom to the manufacturer. An interviewee from project E of the RH projects commented, '*the onsite, it does take a wee bit more management rather than the offsite*' (E3/MC/QS), while an interviewee from the NBP project added, '*it's just slightly more difficult to control*' (F1/C/PM), and a colleague added, '*it's about co-ordination and communication*' (F2/C/PME). These comments were echoed by an interviewee from the NBO project who stated the need for '*more influence on the onsite construction*' (G6/MC/SM).

The factor of 'influence' was further stated by an interviewee from the MA project who stressed the need for '*more influence on an onsite because you're living and breathing it*' (H3/MC/APM). These are all comments that infer project managers have more direct influence with the onsite bathroom construction and that the level of influence can relate to their educational background and the direct contact they have with the trade contractors.

The main findings from sub-factor 'project manager will have more influence in the onsite bathroom construction' suggest that project managers from a trade background are more comfortable with the onsite bathroom process, which has a greater level of flexibility compared to offsite bathrooms. Also, when faced with managing the offsite process, project managers from a trade background tend to transfer the responsibility for the manufacturing process entirely to the manufacturer, whereas project managers from a university education will be more likely to engage with the manufacturer during the process.

5.22.2.3 Sub-Factor Three: Project Manager Will Have Less Influence in the Offsite Bathroom Construction

Table 5.105: Breakdown of responses/interviewees: an effective project manager has more influence on offsite than onsite bathroom construction – sub-factor three

Classification	Responses	Interviewees
NBSA	7	7
RH	5	5
NBP	1	1
NBO	3	3
MA	4	4
Total	20	20

While the previous sub-factor related to the project manager having more influence in onsite bathroom construction, a number of participants conversely commented that the project manager will have less influence with offsite bathroom construction. Comments from projects A and B of the NBSA project suggested, '*if I* *was a project manager I would be comforted in the fact if it was offsite*' (A2/C/OM) and '*then the rest should be fine*' (A8/DT/A), suggesting that once the project manager has placed their order with the manufacturer '*the rest of that is down to the manufacturer*' (B4/DT/PM), and '*he's got no influence on them*' (B7/SC/Con/M). Furthermore, as suggested by an interviewee from the RH projects, '*it's up to the project manager how much they want to get involved to be honest*' (D2/MC/PM), which is exemplified by the manufacturer of project E: '*I never saw any project manager*' (E5/M/NSM).

Interviewees from NBP and NBO agreed that the project manager had less influence: '*because he's physically onsite, he doesn't know what's happening offsite*' (F7/MC/QS), and '*he's not in control when it's an offsite*' (G4/MC/QS). However, interviewees from the NBO project suggested that rather than the project manager having direct involvement with the manufacturer, '*it's more the design manager side that has more influence on the offsite*' (G6/MC/DM). The interviewees from the MA project emphasised the importance of the project manager closely monitoring the manufacturing processes because '*it wouldn't be effective if he's not*' (H2/MC/SPM) and delegating a representative of the main contractor to visit could mean '*he might only be there a day or two a week*' (H3/MC/APM), thus highlighting the importance of maintaining control over the manufacturer as you would with a subcontractor and/or supplier onsite.

The sub-factor 'project manager will have less influence in the offsite bathroom construction' provided a mixed response, from project managers happy to relinquish direct involvement of that part of the project to the manufacturer as they consider that they have no control over the offsite process, to the project managers that consider it important to maintain a level of control by closely monitoring the manufacturing process and delegating a member of the main contractor's team to interact with the manufacturer. The latter is the method that modern project managers should adopt to ensure the quality and timeous delivery of the offsite units.

5.23 A Close Client/Design Team Relationship Will Significantly Improve Interface Management in Bathrooms

5.23.1 Quantitative Analysis

5.23.1.1 Frequency Analysis

Table 5.106: Frequency table – a close client/design team relationship will significantly improve IM in bathrooms

Likert Scale	Count	Percentage
Strongly disagree (1)	0	0
Disagree (2)	0	0
Neither agree or disagree (3)	2	2
Agree (4)	25	31
Strongly agree (5)	55	67

Significantly, the counts for strongly agree (67%) and agree (31%) combine to 98% demonstrating an almost unanimous agreement with the statement that a close client/design team relationship will significantly improve IM in bathrooms. Worthy of note is that none of the sample disagree or strongly disagree with the statement, with the remaining 2% neither agreeing nor disagreeing.

5.23.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 28A. From a test result of 80, the estimated median is calculated at 4.5, which corresponds with the result of strongly agree and agree indicated in Table 5.106, which infers from the results that there is a tendency among the population to agree with the statement that a close client/design team relationship will significantly improve IM in bathrooms.

5.23.2 Qualitative Analysis

Table 5.107: Ranking table – a close client/design team relationship will significantly improve IM in bathrooms

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	Positive and early client/design team involvement	35	49
2	Experience of client can have an impact	20	23
3	Communication between client/design team and main contractor important	16	17
4	Main contractor relationship with client/design team	10	10
5	Commercial benefit	5	5
6	Client/design team influence on offsite methods	3	3
7	Makes no difference to the project	2	2

The qualitative analysis will focus on the sub-factors ranked one, two and three:

- Positive and early client/design team involvement (5.23.2.1)
- Experience of client can have an impact (5.23.2.2)
- Communication between client/design team and main contractor important (5.23.2.3).

5.23.2.1 Sub-Factor One: Positive and Early Client/Design Team Involvement

Table 5.108: Breakdown of responses/interviewees: a close client/design team relationship will significantly improve IM in bathrooms – sub-factor one

Classification	Responses	Interviewees
NBSA	12	9
RH	10	8
NBP	10	7
NBO	11	6
MA	6	5
Total	49	35

Early involvement by the client and design team was considered by a large number of interviewees to improve potential interface problems in bathrooms. Interviewees from projects A and C of the NBSA projects made reference to the conventional approach by the client: '*I'll tell you what I want, when I want it and I expect it there on time*' (A10/M/OM), to '*I mean, the client shouldn't be involved*' (C1/C/SPM).

However, the client for project A emphasised the importance of '*getting design management right early*' A1/C/OM). Comments from projects D and E of the RH projects also emphasised this:

> *'If you can iron out the kinks to the design, you're not going to have any major issues when you get to the actual construction' (D1/C/PM).*

Furthermore, the benefit of '*the client knowing exactly what they wanted*' (D2/MC/PM) and '*a reasonable amount of involvement*' (E1/C/P) suggested that a reasonable level of client involvement benefited both projects.

Comments from interviewees associated with the NBP project suggest that '*there were times when our relationship with the client was not all that direct*' (F11/DT/A), meaning that '*if the design team can't establish what the client is after, you're going to end up messing around*' (F12/DT/QS), suggesting problems that can occur due to a lack of integration, and this in turn means '*your interface problem moves up the pecking order*' (F12/DT/QS). The client from the NBO project commented, '*projects always work best when there is strong co-operation with the team*' (G1/C/PM). Furthermore, '*it's key to get the design nailed down really at the start*' (G9/SC/QS) and '*good relationships between the design team and the client led to them getting the solution they wanted*' (G14/DT/P). Comments from the MA project highlighted the importance of communication: '*they all talk and have a good relationship*' (H3/MC/APM) to '*keep the client involved and kind of keep friendly with them*' (H12/DT/A), suggesting that the client should be considered a part of the team and not isolated from the decision-making process.

The main finding from sub-factor 'positive and early client/design team involvement' is that early integration of the client with the design team can foster good communication and co-operation between the parties, such that the design complies with what the client wants. The client's involvement in the project team should be positively encouraged rather than discouraged by the design team, which would create an inclusive project team, wherein lines of communication are open to all.

5.23.2.2 Sub-Factor Two: Experience of Client Can Have an Impact

Table 5.109: Breakdown of responses/interviewees: a close client/design team relationship will significantly improve IM in bathrooms – sub-factor two

Classification	Responses	Interviewees
NBSA	4	4
RH	6	5
NBP	7	5
NBO	1	1
MA	5	5
Total	23	20

The experience of the clients within the NBSA projects was considered an advantage by the architect for project B: '*they are an experienced client, they knew what they wanted*' (B3/DT/A). This was also confirmed by the professional quantity surveyor from project D of the RH projects as '*both the clients had already agreed the products*' (D8/DT/QS). Interviewees from the NBP commented that '*client-wise, it's very much prescribed the layout of a prison cell*' (F5/MC/APM); however, '*you need a good relationship at the start as an absolute minimum*' (F12/DT/QS), to extrapolate the information that improves the IM in the bathrooms. The MA project highlighted the importance of the client's decision-making and in particular their knowledge of '*the end user*' (H6/MC/BSM). When faced with problems, the experience of communicating with the client, '*speaking to him, showing him the issues – he said I'll accept that*' (H14/M/QM), demonstrates the benefit of engaging with an experienced client, who has the knowledge of the end user's requirements.

The main finding from sub-factor 'experience of client can have an impact' is that it is very important for the design team to forge good relationships with the client, which in turn will benefit the decision-making process. Also important is harnessing the client's knowledge of the end users, which can have an effect on the design and a positive influence in resolving interface issues, and this approach should also be applied to inexperienced clients.

5.23.2.3 Sub-Factor Three: Communication between Client/Design Team and Main Contractor Important

Table 5.110: Breakdown of responses/interviewees: a close client/design team relationship will significantly improve IM in bathrooms – sub-factor three

Classification	Responses	Interviewees
NBSA	4	4
RH	6	5
NBP	1	1
NBO	2	2
MA	4	4
Total	17	16

Communication and good relationships between the client, design team members and the main contractor were highlighted by respondents as significant in improving IM in bathrooms. The close relationship and ease of communication was highlighted by the architect from project A within the NBSA projects when explaining why they would hope to work with the contractor's project manager on another project: '*you just go down and chat it through and work it out and get a solution*' (A8/DT/A). However, the client representative from project C commented on problems within the design team '*who obviously didn't communicate*' (C2/C/PM). Fortunately, the client had knowledge of the product they wanted for the bathrooms, hence the impact of the lack of communication was lessened on this area of the project. *'Having everyone on the same page about what works and what doesn't'* (D1/C/PM) was considered an important form of communication by the client representative of project D.

An interviewee from project E added, '*the key is to get everyone into speaking and communicating, which is your interface management*' (E2/MC/ConM). The benefit of communication between the client, design team and contractor was explained by an interviewee from the NBO project: '*the main contractor knew the cut-off point between us and the M&E subcontractor, so there was no confusion*' (G10/SC/APM), avoiding the phrase 'By Others', which contributes to many interface problems. The interviewee from the MA project considered that one of the main successes of the project was that '*they all talk and have a good relationship*' (H3/MC/APM), so '*we* *kind of talk about it, design it and kind of co-ordinate it all then everyone knows*' (H13/DT/CME), suggesting that an open form of communication between the client, design team and main contractor plays a significant part in the management of interfaces.

The main finding from sub-factor 'communication between client/design team and main contractor important' is that ease of communication between the three parties promotes an open forum for face to face and other forms of verbal communication. Transparent communication between the parties contributes to building good relationships that make interface problems easier to resolve. The phrase 'By Others' should be avoided on drawings, as it is not considered a positive form of communication, and rather it denotes incomplete design.

5.24 A Close Client/Design Team Relationship Has More Influence on Offsite than Onsite Bathroom Construction

5.24.1 Quantitative Analysis

5.24.1.1 Frequency Analysis

Table 5.111: Frequency table – a close client/design team relationship has more influence on offsite than onsite bathroom construction

Likert Scale	Count	Percentage
Strongly disagree (1)	3	4
Disagree (2)	33	40
Neither agree or disagree (3)	17	21
Agree (4)	21	25
Strongly agree (5)	8	10

Interestingly, the counts for disagree (40%) and strongly disagree (4%) combine to give 44%, while the counts for agree (25%) and strongly agree (10%) combine to give 35%, with the remaining 21% neither agreeing nor disagreeing, suggesting a marginal disagreement with the statement that a close client/design team relationship has more influence on offsite than onsite bathroom construction.

5.24.1.2 Wilcoxon Signed Rank Test

Refer to Table 5.10, statement number 28B. From a test number of 65, the p-value is calculated at 0.925 and the estimated median is calculated at 3.0, which infers there is not a tendency among the population to consistently agree or consistently disagree, and instead there seems to be a polarisation of opinions with views divided between agreeing and disagreeing with the statement.

5.24.2 Qualitative Analysis

Table 5.112: Ranking table – a close client/design team relationship has more influence on offsite than onsite bathroom construction

Rank	Description of Sub-Factor	No. of Inter-viewees	No. of Respon-ses
1	No difference/teamwork	33	36
2	Early involvement by client/design team required for offsite bathrooms	24	32
3	Client/design team more influence on onsite bathrooms	9	10
4	Client/design team have little opportunity to make alterations to offsite	8	8
5	Main contractor relationship with client/design team	5	7

The qualitative analysis will focus on the sub-factors ranked one and two:

- No difference/teamwork (5.24.2.1)
- Early involvement by client/design team required for offsite bathrooms (5.24.2.2).

5.24.2.1 Sub-Factor One: No Difference/Teamwork

Table 5.113: Breakdown of responses/interviewees: a close client/design team relationship has more influence on offsite than onsite bathroom construction – sub-factor one

Classification	Responses	Interviewees
NBSA	14	12
RH	5	5
NBP	4	3
NBO	6	6
MA	7	7
Total	36	33

Thirty-three respondents took the opportunity to state that a close client/design team relationship has no more influence on offsite than onsite bathroom construction; however, a number of respondents qualified their response by adding that a close relationships was very important. Interviewees from projects A and B of the NBSA projects added, '*we are all part and parcel of the same team*' (A9/M/NSM) and '*I'd say it's important to both*' (B4/DT/PM), while adding that '*it's important to have a good relationship no matter whether it's offsite or onsite*' (B5/DT/CCE). An interviewee from project D of the RH projects added the importance of working as a team: '*if all these people are working together then it really doesn't matter if it's offsite or onsite*' (D5/SC/PME). An interviewee from the NBO project identified *'better quality'* as a by-product of a close relationship and of working as a team.

The main finding from sub-factor 'no difference/teamwork' is that a good working relationship is important between the client and design team, which should foster a team spirit with the outcome of a quality product regardless of whether the bathroom is constructed onsite or offsite.

5.24.2.2 Sub-Factor Two: Early Involvement by Client/Design Team Required for Offsite Bathrooms

Table 5.114: Breakdown of responses/interviewees: a close client/design team relationship has more influence on offsite than onsite bathroom construction – sub-factor two

Classification	Responses	Interviewees
NBSA	10	7
RH	3	3
NBP	4	3
NBO	11	7
MA	4	4
Total	32	24

Early involvement by the client and design team was considered essential to the success of offsite forms of bathroom construction. Participants from the NBSA projects acknowledged this:

> *'Again, if he is not getting what he wants and he is not involved in the design process and we assume what he wants and it's wrong then serious problems occur' (A3/MC/PM).*

That is to say, the client should not be considered a silent member of the team, but should be encouraged to be proactive. An interviewee from project B commented that the pipe work came too short due to the design team's lack of involvement in the manufacture of the pods, meaning that '*we had to extend them 300 millimetres, every one*' (B7/SC/ConM). The client representative for project C commented that '*the client's priority is to get the brief right in respect of the employer's requirements*' and, furthermore, '*it's the early stage work that makes or breaks a project*' (C1/C/SPM).

An interviewee from the NBP project added that the close design team relationship '*made it easy to drive the early decision-making about the toilets*' (F8/MC/CM). Two interviewees from the NBO project added that '*front end*' involvement by the client allowed them to '*visit the factory to find out exactly what they want*' (G5/MC/SM). Moreover, '*you've got to get that buy in early on from the client and design team*' (G6/MC/DM). The client's representative for the MA project suggested that the clients input into design '*should not greatly affect interface management*' (H1/C/PM). This was further explained by the architect, who commented that the client does not have much interest in the design: '*they just want the bathroom; how it's done is irrelevant to them*' (H12/DT/A).

The main finding from sub-factor 'early involvement by client/design team required for offsite bathrooms' is that early involvement of the client in the decision making process should be encouraged to progress the design early, which is very important when incorporating offsite bathrooms in the design. Of equal importance is encouraging the client and design team to visit the offsite premises, which should help them to visualise the product that will be installed and make any subsequent decisions to allow the design to be finalised.

5.25 Summary

The analysis of the responses from the 82 interviewees from eight projects, which formed five classifications, presented a representative range of ages and work experience in respect to onsite and offsite construction. Analysis of the ranking data resulted in the top nine of the 15 factors being selected for further detailed analysis. The responses given by each interviewee were subject to both quantitative and qualitative analysis. The quantitative analysis used the Wilcoxon signed rank test, to determine the significance of the responses at the 5% level; of the 22 statements analysed, 20 confirmed significance at the 5% level and two were not significant.

The qualitative data for each statement were also analysed, to determine relevant sub-factors and the frequency of responses. The top two to four sub-factors were analysed in detail in order to establish the main findings resulting from the responses. Chapter 6 will discuss these main findings in comparison with the key literature discussed in Chapter 3.

Chapter 6 – Discussion

6.1 Introduction

Chapter 5 presented analysis and findings from the data amassed from the 82 interviews relating to the nine factors. This chapter discusses each of the factors relative to the analysis and findings, with reference to the literature in Chapters 2 and 3. The discussion of each factor identifies sub-factors that can contribute to the satisfactory interface management (IM) of offsite bathroom construction. A conceptual model is proposed and further analysis of all sub-factors is discussed relative to the main problems and solutions identified within the case studies analysed.

The chapter is organised around the following: procurement, design management, supply chain management, health and safety, tolerance, quality, communication, the role of the project manager, and client/design team.

6.2 Procurement

The chosen procurement route can have a profound impact on the management and methods used to construct a project. The focus of the procurement route within this thesis relates to its significance to IM and its influence on the choice of offsite or onsite in situ bathroom construction.

6.2.1 Statement One: The Chosen Procurement Route Can Significantly Affect Interface Management in Bathroom Construction

Eighty-six percent of the interviewees confirmed that the chosen procurement route can significantly affect IM in bathroom construction. Furthermore, 63 percent agreed that the procurement route has more influence on offsite than onsite bathroom construction.

The qualitative analysis identified sub-factor 'design and build/contractor-led' as the preferred method for managing interfaces and incorporating offsite bathrooms. The benefits identified include:

- It is easier to make changes
- Contractors are better skilled in managing interfaces in lieu of the architect
- Contractors able to contribute to design
- There is a single point of responsibility
- Quality is enhanced.

Tam et al. (2007) concur that, from the procurement routes available, design and build is best suited to manage interfaces, in particular when offsite bathrooms are incorporated into the design. However, Pan et al. (2008b) suggest that traditional procurement is still the preferred route by the house-building community and possibly the industry at large for all forms of construction. This discourse from Tam et al. and Pan et al. would suggest that the benefits of design and build and offsite bathrooms have not been communicated to a large section of the construction community, which suggests the need for the industry at large to engage with the contingency theory approach, where by alternatives should be considered (Mullins, 2016).

A further sub-factor, 'early involvement of stakeholders', for example specialist subcontractors and manufacturers, was considered by interviewees as a desirable output of the chosen procurement route in managing the interfaces applicable to offsite bathroom construction. Further findings include:

- Timely contribution to design
- Influence on planning of lead-in times
- The contractor can influence design changes.

Oyegoke et al. (2009) argue that the procurement route will have a significant influence on the methods of construction used, which invariably will preclude early stakeholder input. Larsson et al. (2014) adds that, when offsite bathrooms are included in the design, the procurement route must be modified to allow the manufacturer to input into the design at a stage much earlier than stipulated by the

Royal Institute of British Architect's plan of work (RIBA, 2013), which will aid the building of good relationships between the parties involved. Harty (2008) underlines this discussion with reference to actor-network theory, whereby the inclusion of the manufacturer at an early stage can influence the technical remit of the project.

The relevance of communication was highlighted in relation to sub-factors 'design and build/contractor-led' and 'early involvement of stakeholders'; with comments alluding to more open communication improving relationships between stakeholders. Nadim and Goulding (2011) argue that actors 'on the same side of the fence' are likely to engage in open communication. Furthermore, with design and build, the preferred route to manage interfaces in relation to offsite bathrooms, Tam et al. (2007) concur that communication is a very important people factor to the successful implementation of the chosen procurement route.

6.2.2 Statement Two: The Chosen Procurement Route Has More Influence on Offsite than Onsite Bathroom Construction

Sixty-three percent of interviewees agreed that the chosen procurement route has more influence on offsite than onsite bathroom construction. However, the qualitative analysis identified a further sub-factor from 37 interviewees (45 percent) that 'the procurement route makes no difference to offsite or onsite construction', which would suggest an almost even split on the relevance of the procurement route. Walker and Rowlinson (2008) argue that decision makers do not analyse the advantages and disadvantages of the various routes; rather, lowest cost is deemed the decision maker, which also concurs with Pan et al.'s (2008b) earlier comment.

Pryke (2004) suggests that the existing procurement methods are the main cause of interface problems that occur on construction projects. Morledge and Smith (2013) posit that construction procurement requires modification to integrate innovative practices such as offsite bathrooms, rather than continually utilising the current routes, which were formed to comply with traditional construction. Traditional are converted to outputs (Mullins, 2016). However, Goulding et al. (2012) argue that a root and branch review of construction procurement is required, whereby contingency theory as an offshoot of organisational theory, should demand greater prominence as the way forward. The findings and discussion would suggest that offsite bathroom construction is gaining momentum within the design and build procurement route. However, a substantial proportion of clients and designers remain apathetic about the importance of the procurement route in promoting innovative systems such as offsite bathroom construction, suggesting an overwhelming case for an alternative procurement route that gives parity to offsite and traditional methods of construction, resulting in improved management of organisational and physical interfaces. Figure 6.1 offers sub-factors that have emerged from the analysis of the data and relevant discussion on procurement that are perceived to have a positive influence on IM and offsite bathroom construction.

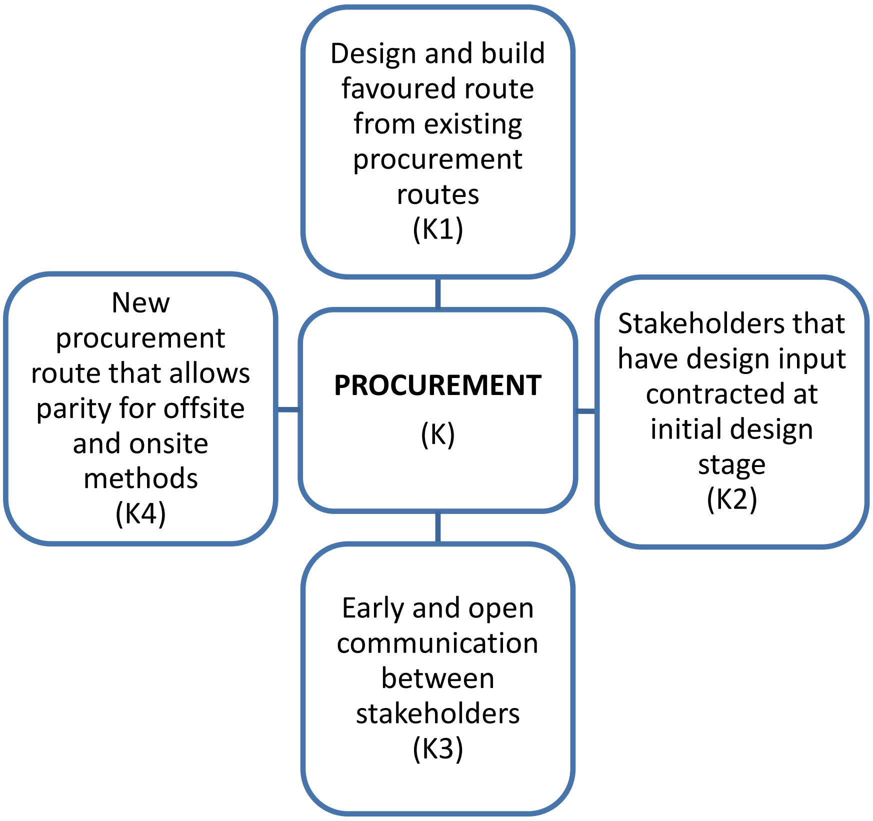

Figure 6.1: Sub-factors that influence procurement

6.3 Design Management

Design management is a process that has emerged in construction due to the introduction of routes of procurement that are alternative to traditional ones, whereby the overall management of the design is the responsibility of the contractor. Design management has been identified in this research as an integral process in the IM of offsite bathroom construction. Three individual statements were offered to the interviewees, and the quantitative and qualitative data from their responses was analysed.

6.3.1 Statement One: Effective Management of the Design Process Significantly Improves Interface Management

The quantitative analysis of the first statement accrued a cumulative total of 98 percent agreement. Furthermore, 60 percent emphasised strong agreement to the importance of the management of the design process in relation to IM, which confirms the strong link between design and IM.

The qualitative analysis identified a number of important sub-factors worthy of discussion. Ranked number one was 'co-ordination of incomplete design is crucial'. Interviewees commented that co-ordination was fundamental to successful design management, particularly in relation to resolving interface problems. Knotten et al. (2015) argue that the process of design management in construction is inferior to the same process used in other industries. This would imply that construction design management is a fledgling discipline worthy of further development. Furthermore, the skillset of construction design managers is subject to debate due to the diversity of professions vying for the right to inherit the position of design manager (Tzortzopoulos and Cooper, 2007). Interviewees identified mechanical and electrical co-ordination as the most prevalent problem area, in particular with offsite/onsite connections and access for maintenance. Jaganathan et al. (2013) are in agreement with this finding, suggesting that little emphasis is placed on the onsite connections when offsite manufacturing is detailed, which would suggest that construction should review the whole construction process through the lens of organisational theory and give equal consideration to both offsite and onsite works (Weick et al., 2005).

The sub-factor ranked number two was 'good communication important to the effective management of design', which reiterates the importance of communication in relation to design management and IM. Interviewees emphasised the need for open communication throughout the design process. Furthermore, they suggested that freehand drawing should not be lost to electronic drawing as a vital communication skill. The importance of the flow of information between stakeholders was identified as was a degree of apathy from stakeholders that manifested in design/interface problems on site. Ahadzie et al. (2014) suggest that this is due to a lack of understanding by stakeholders from other disciplines. Chua et al. (2003) propose the use of their process-parameter-interface model to aid the understanding of all stakeholders of the need to communicate within defined timescales. This approach falls within the context of organisational theory, whereby all parties adopt a transparent and open form of communication (Chua and Godinot, 2006)

'Important to consider buildability' was the sub-factor ranked number three. Interviewees emphasised the need to consider buildability during the design stage and not to view it as an add-on when problems occur on site. A quote from the project manager on project G captures the general view of the interviewees to buildability: *'Solve your problems on the drawing board, rather than onsite'* followed by *'Get the design right first time'*. These are disappointing findings that concur with Alarcon and Mardones (1998) who posit that a lack of communication between designers and specialists culminate in buildability problems that directly affect the design interface. Lam and Wong (2009) suggest that buildability is not given adequate consideration at the design stage, which confirms the need for manufacturers' input at the design stage when offsite bathrooms are included in the design (Isaac et al., 2014).

The final sub-factor of statement one, ‘review design prior to construction’, relates in practice to the three previous sub-factors of the statement. The site manager from project D sums up the premise of this sub-factor: *‘Sort out all the problems before they get to site’*. The architect for project H emphasised the necessity to review the manufacturer’s drawings to ensure compatibility with the design team’s drawings prior to the start of production. El Reifi et al. (2014) and Knotten et al. (2015) suggest that the design should mirror the briefing from the client; otherwise the client will be dissatisfied, even if time, cost and quality are achieved.

6.3.2 Statement Two: Design Management Can Significantly Affect Interface Management in Bathrooms

The second statement accrued a total value of 94 percent agreement, which compared to the 98 percent agreement with statement one, which would suggest that effective management of the design process will have a positive influence on the IM of the project and in particular the bathroom areas. Two sub-factors emerged from the statement that were worthy of discussion. Sub-factor number one was ‘good design promotes fewer interface problems’. Again, the main focus of the interviewees related to mechanical and electrical as the most problematic area, thus emphasising the importance of good relations with members of the supply chain. Sub-factor two, ‘design management not any more important to bathrooms’, could suggest a slight waver from the 94 percent agreement to the statement. However, the respondents acknowledged the importance of the statement but qualified that design management is significant not only to the bathroom areas but also to the project as a whole underlining the role of organisational theory as a platform to resolve unseen interface problems (Weick, 2016).

6.3.3 Statement Three: Design Management Has More Influence on Offsite than Onsite Bathroom Construction

The final statement received less significant agreement at 52 percent, with 32 percent disagreeing and the remaining 16 percent neither agreeing nor disagreeing. The sub-factor ranked first, ‘design management same importance for both’, resonates with sub-factor two of statement two above. The colloquial terms used include, *'It's six or half a dozen of the other'* and *'It's even-Stevens between the two'*, succinctly capturing the view of most of the interviewees. The quantity surveyor from project D detailed an important thread claiming that the design management of offsite and onsite should not be separated. This suggests that the design management of offsite bathrooms is very much interrelated with the design management of the onsite works. Very little was found in the literature that related directly to this sub-factor, which would suggest an area for further research.

The second sub-factor, 'design management more relevant to offsite', elicited responses that focused on the early agreement of the design, less flexibility for change and onsite connections. Particular emphasis was put on the need to have early involvement of the manufacturer and the mechanical and electrical consultants as considerable lead-in time is required for offsite bathrooms. Furthermore, once production starts, any change to the units will have extreme cost and time implications. The project manager from project G succinctly stated the views of the respondents: *'It's as necessary for onsite, but it's very important for offsite'*. It is suggested in a study by Blismas and Wakefield (2009) that clients and designers are inclined to remain with traditional construction. The main reason offered is that they are uncomfortable with the concept of design freeze at an early stage. This problem relates to systems theory, whereby the main components of the process need to be transparent to all parties, to promote a clearer understanding of the system. This argument echoes with the importance of the briefing process in which the design team are required to articulate the client's requirements. However, when the brief includes offsite bathroom construction, it is suggested that designers are ill at ease with the concept, in particular when design management is introduced and the status-quo is breached (El Reifi et al., 2014).

The third sub-factor, 'design of onsite connection critical for offsite units' relates not only to mechanical and electrical connections but also to other trades such as joiner work, tiler work, etc. The sequence of the programme should also be considered as delivery of offsite units may be critical to the progression of the build. The architect from project F summed up the general view of the interviewees: *'You don't realise it's wrong until you try to connect it up. … Also, you get it wrong 240 times'*. This quotation succinctly confirms the need to integrate the onsite and offsite design. Jaganathan et al. (2013) argue that greater emphasis should be given to interfaces during the design of the onsite/offsite installation. With offsite units manufactured to an engineering precision and onsite works to a lower level of precision, consideration should be given to the introduction of a higher level of flexibility and tolerance than is currently allowed where practical, to avoid possible abortive works. Figure 6.4 offers sub-factors that have emerged from the analysis of the data and relevant discussion on design management that are perceived to have a positive influence on IM and offsite bathroom construction.

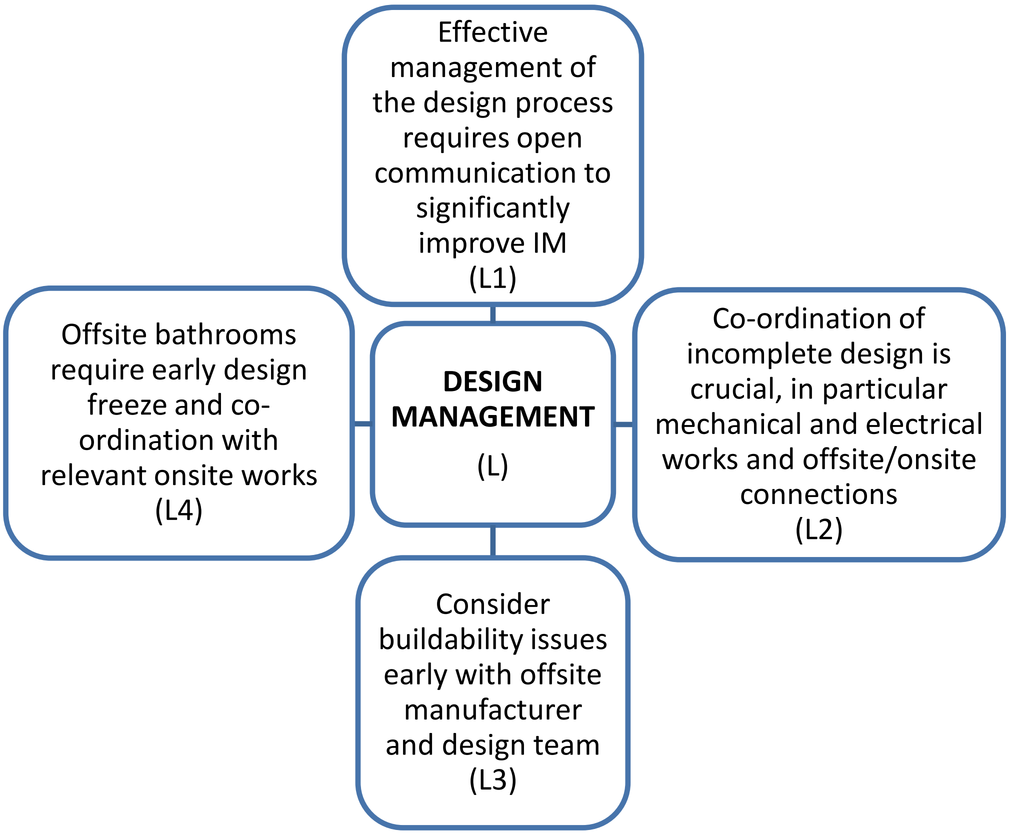

Figure 6.2: Sub-factors that influence design management

6.4 Supply Chain Management

6.4.1 Statement One: Effective Supply Chain Management Significantly Improves Interface Management in Bathrooms

Ninety-three percent of the interviewees agreed that effective supply chain management significantly improves IM in bathrooms. With supply chain management reviewed as a process, it is worth emphasising the importance of people factors in its implementation. The qualitative analysis identified a number of important sub-factors worthy of discussion. The first sub-factor, 'relationship with suppliers' was identified as the most relevant, highlighting the importance of soft factors such as communication and teamwork. Actor-network theory, is now being viewed as a construct that supports the important agenda of soft factors (Hardy, 2008). Wolstenholme (2009) and Annan (2012) argue that main contractors are only recently realising the benefits of building better relationships with subcontractors, through better co-operation and collaboration. Al-Hammond (2000) argues that the literature on supply chain management in construction mainly focuses on two parties, which in practice is not the case, as a ripple effect will normally occur affecting other members of the team, reiterating the importance of relationships not just with suppliers but also with all disciplines involved in the project, to improve IM.

'Requires good management and planning' was also identified as an important sub-factor. Fundamental to this approach was early involvement of specialist contractors and manufacturers. Early involvement of specialists is an anomaly within the construction industry compared to other industries, which concurs with Hardy (2008) that other industries are more familiar than construction with actor-network theory. Tennent and Fernie (2014) argue that construction should resist implementing the manufacturing industry model of supply chain management. Furthermore, a construction supply chain should be grounded in the characteristics that are relevant to construction rather than mirror a strategy from the manufacturing industry. However, Behera et al. (2015) argue that large construction organisations have taken steps to reduce the size of their supply chains, with the view to work more frequently with a select few, thus improving the management and planning, through improved collaboration, similar to the manufacturing industry model of supply chain management. Peat and McCrae (2009) argue that the latter form of supply chain management would favour the integration of offsite bathroom construction.

The sub-factor ranked third, ‘co-ordinated flow of information approach’, highlighted the importance of the issue of up to date drawings and schedules to the relevant parties. Furthermore, communication was stated as integral to the flow of information both in distributing and conveying the design in a manner that can be accurately interpreted by the relevant bodies, to avoid potential interface problems. Central to Akintoye et al.’s (2000, cited in Tong, 2011) definition of construction supply chain management is the management of information flow, which emphasises the importance of the two-way flow of information between organisations, which suggests that the co-ordinated flow of information is dependent on good management and planning and will excel when good relationships exist between the members of the supply chain.

6.4.2 Statement Two: Supply Chain Management Has More Influence on Offsite than Onsite Bathroom Construction

The interviewees were also asked whether supply chain management had more influence on offsite than onsite bathroom construction. The quantitative results confirmed an overall agreement of 48 percent, with 23 percent disagreeing and 29 percent neutral to the question. Furthermore, the 29 interviewees (35 percent) giving the top ranked qualitative responses qualified their response by stating that it was ‘the same influence for both’, identifying sub-factor one and suggesting that the same management of the supply chain was required whether the work was onsite or offsite. Pan et al. (2008b) argue that construction supply chains are immature, which would suggest that they are organised to suit a traditional onsite project and therefore have not developed the maturity of adapting to innovative forms of construction such as offsite bathroom construction. Doran and Giannakis (2011) argue that the offsite sector needs to educate the traditionalists on the merits of adapting the current supply chain to accommodate offsite bathroom as a viable alternative to onsite bathroom construction. The arguments put forward by Pan et al. and Doran and Giannakis allude to the need for the industry to embrace organisational theory as the mechanism to modernise (Farmer, 2016).

'Single modular company advantageous to supply chain management' was identified as sub-factor two of this statement and was considered a significant influence on the supply chain. The single point of contact was considered beneficial as an alternative to the multiple trades contracted to a traditional bathroom construction. However, it was identified by interviewees that a laissez-faire attitude from the main contractor to the manufacturer can result in problems with offsite bathrooms, which can be more difficult to resolve in comparison to traditional bathrooms. Vrijhoef and Koskela (2000) concur with the aforementioned and call for an integrated management of the supply chain, thus encouraging the main contractor to be proactive in the management of the manufacturer. It has also been mooted that main contractors are not in favour of manufacturers as an alternative to the traditional trades, as their power over the supply chain is reduced (Tennant et al., 2012), increasing merit in the argument that the construction industries use of the term 'supply chain management' is no more than a justification for the use of subcontractors, rather than being a process to enhance innovation through actor-network theory and develop the industry (Green, 2011 ; Hardy, 2008). Figure 6.2 offers sub-factors that have emerged from the analysis of the data and relevant discussion on supply chain management that are perceived to have a positive influence on IM and offsite bathroom construction.

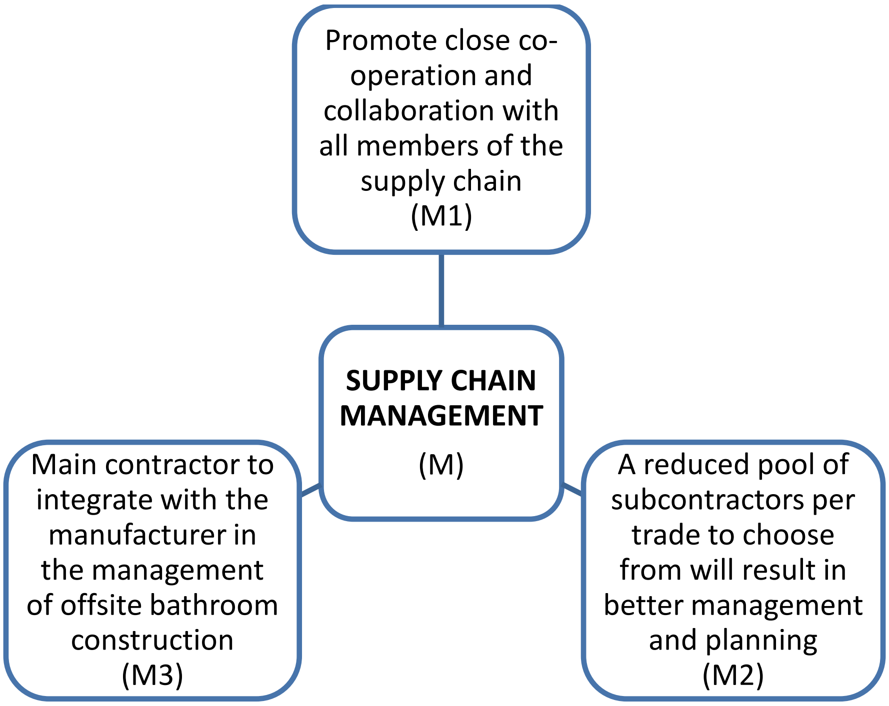

Figure 6.3: Sub-factors that influence supply chain management

6.5 Health and Safety

6.5.1 Statement One: Health and Safety is Significantly Improved through Effective Interface Management

Ninety-nine percent of interviewees agreed that effective IM improves health and safety in construction, confirming the importance of IM to health and safety. Worthy of note is that one interviewee neither agreed nor disagreed. Eighteen interviewees contributed 19 responses in support of sub-factor one, 'good communication and relationships have a positive effect on health and safety and IM'. A study by Smallwood and Venter (2012) found that central to promoting good communication and relationships is the leadership shown by the project manager. This was highlighted by project managers from projects A and B, who emphasised that good relationships with subcontractors led to amiable forms of communication and a positive response from all to health and safety. A study by Kelly and Berger (2006) reviewed the cause of the death of two operatives within an oil refinery, and identified a lack of IM and effective communication as main contributors to the fatalities. Comments from the interviewees consistently referred to the importance of effective communication to build good working relationships that promote good health and safety practice.

Although the question in the context of health and safety did not relate directly to offsite works, surprisingly, a number of respondents qualified their response to configure sub-factor two, ‘reduced site works improves health and safety’, by commenting that if less physical work was carried out onsite, the overall health and safety statistics would be improved. This concurs with the findings of the Health and Safety Executive (HSE, 2016) that construction continues to be one of the most hazardous industries to work in. With the workforce acknowledged as the industry’s most valued asset, it could be argued that the industry has a moral duty to consider offsite construction as an alternative to traditional construction, not just from a cost perspective but with equal consideration given to health and safety (Hinze et al., 2013). The reduction of site works in favour of more work carried out offsite aligns with contingency theory, whereby the traditional approach and the offsite approach require to work in harmony (Mullins, 2016).

Sub-factor three is ‘effective management important to good health and safety’, and synonymous with effective management is planning. Manu et al. (2014) suggest that the inclusion of the main contractor in the pre-construction stage will enhance the planning of the project which will have a positive impact on the health and safety outcome. The findings from the study agree that effective management includes a level of planning whereby an orderly work site is generally a safer environment that avoids trades working over each other. Synonymous with effective management is organisational theory, whereby the safe input of all stakeholders should provide a safe and productive environment for all to work in (Davis, 2015). A further finding relates to a high level of bureaucracy suggesting that it is counterproductive to the effective onsite management of health and safety. Very little evidence exists in the literature to collaborate this finding. However, it is suggested that construction has seen a slight shift away from the traditional blame culture to one that analyses the causes and effects of accidents. From a behavioural safety stance, this would suggest a move from an over-reliance on a paper trail (bureaucracy) to one whereby the discourse with operatives is of equal importance in the pursuit of effective safety management (Kines et al., 2010; Goh et al., 2012; Sherratt et al., 2012).

6.5.2 Statement Two: Good Health and Safety Outcomes Are More Easily Achieved in Offsite Bathroom Construction Compared to Onsite Bathroom Construction

The interviewees were also asked to rate and comment on whether good health and safety was more easily achieved with offsite bathroom construction compared to onsite bathroom construction. Eighty-two percent agreed with the statement. The extremely high agreement to both statements on health and safety would suggest a strong correlation between effective IM and offsite bathroom construction. A study by Nadim and Goulding (2011) concurs with the results above and adds that onsite safety improves in direct proportion to the level of offsite manufacturing executed.

The qualitative analysis identified a number of interesting sub-factors. The top rated of 'factory more controlled environment, fewer hazards' accrued 38 responses from 36 interviewees. A greater level of pre-planning was identified from the consultant civil engineer from project B, not only in relation to the offsite works but also to the interface of the installation onsite. This was also suggested by Nadim and Goulding (2011) as a positive outcome of the manufacture of bathrooms offsite. Common phrases identified to support the sub-factor include: *'controlled environment', 'reduced time spent on site', 'more control of your people'* and *'the more you can do offsite is a benefit to everyone'*. A study by Rubio-Romero et al. (2014) compared the accident rates between traditional and offsite methods and also agreed that time spent onsite should be reduced and as much work should be manufactured offsite as possible. A project manager on project F captured the overall thrust of the sub-factor: *'If they could deliver the whole job on the back of a lorry I would take it'*.

The second highest rated sub-factor, 'they both have safety risks', is exemplified by the unacceptable fatality rates of 43 in construction and 27 in manufacturing for the period 2015/16 (HSE, 2016). The statistics are in agreement with the previous sub-factor; however, they also identify the need to apply appropriate health and safety standards to both environments. A construction manager from project C qualified his statement by confirming that a risk assessment is required regardless of the location. Shahzed et al. (2015) argue that onsite operatives should be trained in the installation of offsite bathrooms, and it is suggested this would contribute to improved accident rates onsite. The senior project manager from project H identified the need to assess the safety practices in the factory environment due to poor standards, emphasising the need for the main contractor to monitor both environments. This conundrum aligns with actor-network theory, such that although the processes are being carried out in different locations, the actors should inter-relate to form a more cohesive approach (Lounsbury and Beckman, 2015).

The third sub-factor, 'onsite more hazards', identified with the high number of trades required to work within the confines of a bathroom onsite, suggesting that the planning and flow of works carried out onsite are more unpredictable compared to the offsite manufacture. Manu et al. (2014) argue that a high level of sub-contracting can have a detrimental influence on accidents onsite. However, a quantity surveyor on project F argued that all operatives onsite are instructed by site management to adhere to safety standards, which is to be expected. It is suggested that the organisational ability of the project manager will have a major influence on avoiding multiple trades working in congested areas, such as onsite bathrooms (Chileshe and Dzisi, 2012). The design manager from project G added that minor accidents (cut fingers, dust in eyes) were more prevalent onsite due to the environment being harder to control compared to the factory environment. Figure 6.3 offers sub-factors that have emerged from the analysis of the data and relevant discussion on health and safety that are perceived to have a positive influence on IM and offsite bathroom construction.

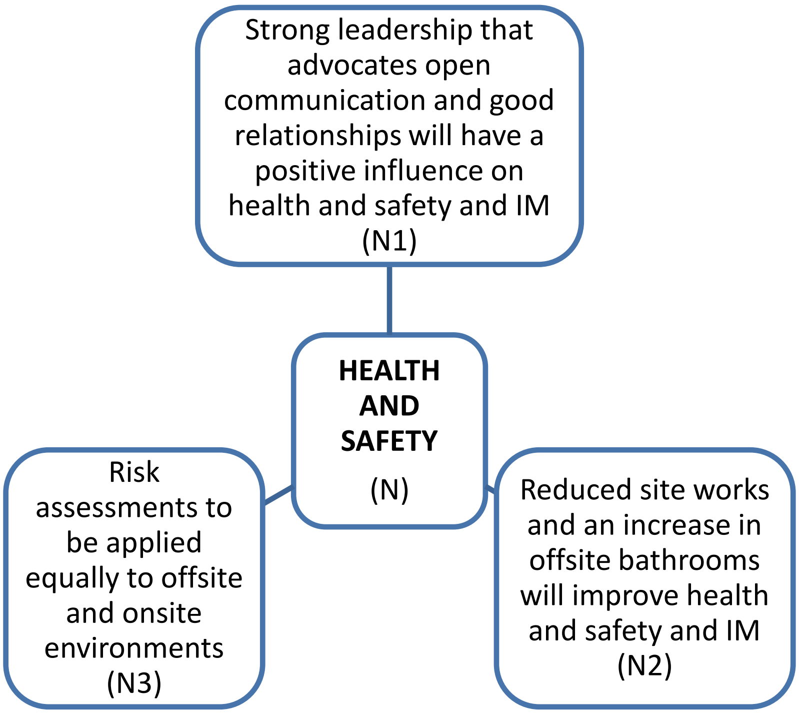

Figure 6.4: Sub-factors that influence health and safety

6.6 Tolerance

6.6.1 Statements One, Two and Three Combined

Three statements were offered to the interviewees to provide quantitative and qualitative data on the theme of tolerance:

1. Tolerances are significantly improved through effective IM
2. Offsite units deliver better tolerances than onsite bathrooms
3. Tolerances would be more problematic with offsite bathrooms than onsite.

The overall agreement to statements one and two was 95 percent and 81 percent respectively. These results confirm a strong association of IM and offsite bathrooms with the theme of tolerance. Statement three accrued an overall disagreement of 55 percent and agreement of 39 percent, which confirmed a level of divergence on the problem of tolerances when comparing offsite and onsite bathrooms.

Interestingly, the sub-factors with the highest number of responses to the three statements, 18, 29 and 24 respectively, were very similar in meaning, such that in the interests of brevity sub-factor one, 'offsite units produced in a factory are manufactured to a higher level of tolerance', will form the discussion. The 'controlled environment' was dominant in the responses from the interviewees, suggesting that a factory environment was more conducive to achieve a more stringent level of tolerance than the onsite environment. This was succinctly stated by the project manager of project C: *'They do better tolerances than onsite bathrooms'*. Also mentioned was the benefit of consistent labour in the factory. The project manager from project H stated, *'The factory labour is used to doing bathrooms day in, day out'*. These findings are supported by Seymour et al. (1997) and Shahtaheri et al. (2017) who suggest that the level of consistent tolerances achieved in a factory environment are unlikely to be achieved onsite.

Sub-factor two, 'offsite units demand a focus on onsite tolerance', in relation to installation works, resonates with the second sub-factors identified in statements one and two. Problems encountered include discrepancy with thresholds levels, out of line drainage pop-ups, entrance door to the pod out of alignment and the incompatibility of traditional materials to a precision engineered unit. While organisational theory is considered the dominant theory to merge offsite and onsite works, consideration will have to be given to contingency theory as the bases for resolving unscripted problems (Lounsbury and Beckman, 2015). The magnitude of the problem with onsite drainage out of position was captured by the project manager of project C*: 'This resulted in digging them all up and moving them to the correct place afterwards; that cost time and money'*. The use of unskilled labour to install pods was identified as a contributor to the problems, as was onsite labour being less stringent in achieving the required tolerance in comparison to factory based labour. These findings suggest that onsite operatives have a different perception of tolerance levels in relation to offsite units and therefore training is required to achieve the required onsite/offsite tolerances, which connects with contingency theory, whereby upskilling of labour is recommended Seymour et al.

(1997) argue that inefficient supervision and ineffective control measures onsite are major causes of out of tolerance site works.

Sub-factor three, ‘design required to be completed and incorporate offsite and onsite tolerance’*,* corresponds to sub-factor three of statement one and sub-factor four of statement three. The operations manager from project A offered the following statement on the need for a complete design*: ‘We can’t have variations, you know. It has to be the first one is the same as the last one’*. The need for early interaction with the design team and timeous flow of information were reiterated as necessary components to reduce the offsite/onsite interface problems. A study carried out by Soetanto et al. (2006) identified that, of all the professions involved in the design process, only engineers considered tolerance to be an important design criteria. Landin and Kampe (2007) suggest that ‘tolerance thinking’ with its roots in organisational theory, requires to be in the minds of all designers and construction personnel and communicated appropriately to site operatives to raise the importance of tolerances.

The importance of the design manager’s role in identifying and resolving interface issues was identified as an important finding. While offsite units are designed to a high level of tolerance, the design must also take cognisance of the entire room or corridor that incorporates the offsite bathroom with respect to materials used and dimensions to avoid onsite adjustments such as moving a radiator or repositioning a door. Lam and Wong (2009) afirm that the aforementioned examples occur as a result of designers giving little cognisance to buildability during the design stage.

Sub-factor four, ‘tolerance issues with offsite units more difficult to resolve onsite’, fits within statement three. It has been acknowledged that not all offsite bathroom pods are immune to tolerance defects, and where this is encountered it may require a complete remake, which has a devastating impact on the project. The project manager for project F summed up the scenario*: ‘They are either all right or they are all wrong’*. Incomplete offsite bathrooms were also prone to onsite completion difficulties, and this was encountered in project C, where pods were installed out of plumb causing difficulty in hanging the permanent door onsite. While, in the main, site management will endeavour to resolve the problems onsite to mitigate the effect, Jingmond and Argen (2015) argue that tolerance issues onsite should not be left at operational level to be resolved. Moreover, tolerance problems should be raised at management level, as designers may be unaware that specified tolerances are physically impossible to achieve. Pan and Gibb (2009) suggest that tolerance issues that relate to offsite bathrooms will manifest in a higher level of maintenance problems.

Sub-factor five, 'tolerance issues with onsite bathrooms accepted and easier to resolve', also relates to statement three. The view of the respondents was that onsite tolerance issues were easier to overcome compared to offsite tolerances. The senior project manager for project H summed up the general view*, 'You have a degree of forgiveness'*, implying that tolerances are less stringent in onsite bathroom construction. Furthermore, clients will generally accept a traditional bathroom if it looks to be built to the specification rather than insist that the tolerances have all been met. A study carried out by Kolarevic (2014) identified that onsite tolerances that are outwith the specified tolerance level but are 'pleasing to the eye' are becoming more acceptable to clients and end users. A concept used in the service industry, 'zone of tolerance', which gauges customers' degree of tolerance satisfaction, may find merit in construction. However, the tolerance issues relevant to offsite bathroom construction incorporated onsite will remain a mainly physical tolerance rather than a purely visual tolerance (Stodnick and Marley, 2013). Figure 6.5 offers sub-factors that have emerged from the analysis of the data and relevant discussion on tolerance that are perceived to have a positive influence on IM and offsite bathroom construction.

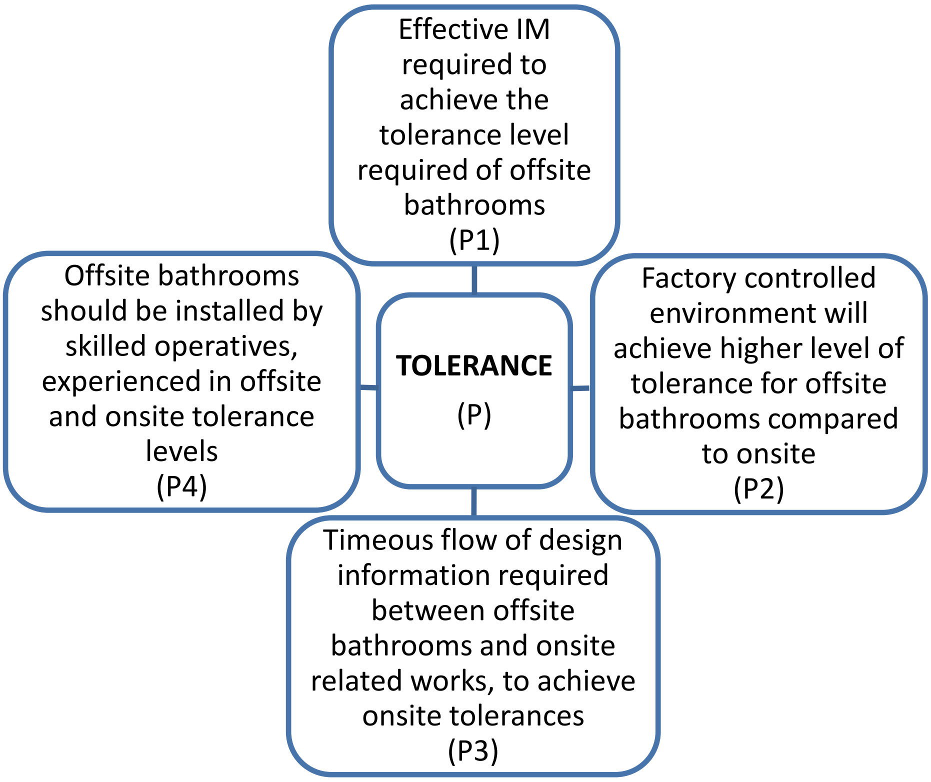

Figure 6.5: Sub-factors that influence tolerance

6.7 Quality

Quality remains a contentious theme in mainstream construction. Within the parameters of the time, cost and quality triangle, quality is generally considered the least important in achieving clients' expectations of a successful project (Hoonakker et al., 2010).

6.7.1 Statement One: Quality Is Significantly Improved Through Effective Interface Management

To gain a clearer appreciation of the relationship of quality to IM, the interviewees were asked to comment on this statement. The quantitative analysis achieved 100 percent agreement, which comprised strongly agree (56 percent) and agree (44 percent), emphasising the important relationship between quality and IM. The qualitative analysis elicited sub-factor one, 'a teamwork co-ordinated IM approach aids quality'. While teamwork may be an overused term in construction, its importance should not be underestimated, as it stems from organisational theory (Davis, 2015). A teamwork approach was emphasised by various participants in the context of 'co-ordinating operations' and 'accountability', suggesting that the various trades involved must take responsibility for the quality of their work and not hide behind the principal contractor. Central to a teamwork co-ordinated interface approach is organisational IM that is founded on an environment that endorses open communication between all members of the team. Mane and Patil (2015) argue that it is incumbent on senior management to have an understanding of a client's quality expectations and communicate this to site staff, who in turn must ensure that all members of the team are informed.

Sub-factor two, 'good management aids quality', was identified by interviewees as it is important to identify the interface issues before they become a problem, which in turn should reduce the level of snagging that occurs. Karim et al. (2006) suggests that reduced interfaces will also reduce defects and relates the offsite process as a method that fits. Conversely, the architect from project A exclaimed that *'Quality can slip very easily if not managed correctly'*. The importance of the project manager's role is emphasised not only in leading the team, but also as a member of the team aspiring to achieve the quality expectation of the client. Altayeb and Alhasanat (2014) are in agreement with the importance of good management and add that training and education, continuous improvement and communication are features that should be incorporated into management to achieve quality.

6.7.2 Statement Two: Quality on this Project Is More Easily Achieved in Offsite Bathroom Construction Compared to Onsite Bathroom Construction

The second statement achieved an 85 percent agreement. This unambiguous finding would suggest that the required quality is best achieved from the offsite environment. The qualitative analysis identified three sub-factors worthy of discussion.

Sub-factor one, ‘offsite environment produces better quality’, achieved 51 responses from 43 interviewees. The reasons given include the factory being a better environment, better protection from the effects of the weather, more robust quality control procedures, less snagging and better control of tolerances. However, a site manager from project E added the caveat that not all offsite facilities are of a manufacturing standard. Furthermore, products produced in a sub-standard environment can equate to an unacceptable level of snagging. It is suggested in the literature that the factory environment is an important attribute to the improvement of quality in construction (Johnsson and Meiling, 2009; Arif and Egbu, 2010). However, it should be a requirement that the main contractor visits the manufacturer’s premises prior to the agreement of a contract and maintains a monitoring brief during the manufacturing process to ensure quality is achieved (AlMaian et al., 2015). This premise is grounded in actor-network theory approach, which advocates a high level of integration between actors (Harty, 2008).

Sub-factor two, ‘onsite environment can result in poor quality’, is the converse of sub-factor one. Twenty-four interviewees gave 25 responses and justified their assertions by including the following: exposure to inclement weather, multiple trades working in a small area, inferior quality control and a greater level of snagging. This is supported by Delgado-Hernandez and Aspinal (2010) who suggest that the current organisational culture of the construction industry is a barrier to achieving quality on construction projects and does not comply with the current organisational theory approaches (Lounsbury and Beckman, 2015). Furthermore, greater awareness of quality through the provision of relevant education and training for management and operatives would contribute to achieving better quality onsite and improve the current onsite culture (Aichouni et al., 2014).

Sub-factor three is ‘quality achieved onsite is equal to offsite standard’. Fifteen responses from 14 interviewees suggested the same standard could be achieved regardless of the work location. A number of the interviewees considered that problems could be overcome more easily onsite compared to offsite. Furthermore, the need for *'proper site management'* was the response from the quantity surveyor on project F. The senior project manager from project H offered a note of caution, similar to the comment from the site manager from project E in sub-factor one, that if the offsite facilities are not managed effectively and efficiently the resulting quality of the bathroom may be no better than what can be achieved onsite. A comparative study of traditional and offsite bathrooms within school projects suggested that the offsite version was built to a superior standard and that it had a positive contribution to the environment of the school (Piroozfar et al., 2012). Thuesen and Hvam (2011) argue that the adoption of 'platform thinking' as used in product-oriented industries can be used to achieve onsite quality. However, this concept, which has been used in the German house-building sector, demands a culture of pride in the completed project. It involves, for example, the plumbing contractor being contracted for multiple projects, which is not always practical in the UK construction context.

A study to compare the maintenance costs of onsite and offsite bathrooms suggests that the offsite bathroom would have lower maintenance costs due to the superior quality of build (Pan and Gibb, 2009). Furthermore, offsite bathrooms are not guaranteed to be built to a better quality compared to onsite, which suggests that the main contractor must manage both environments as required. Figure 6.6 offers sub-factors that have emerged from the analysis of the data and relevant discussion on quality that are perceived to have a positive influence on IM and offsite bathroom construction.

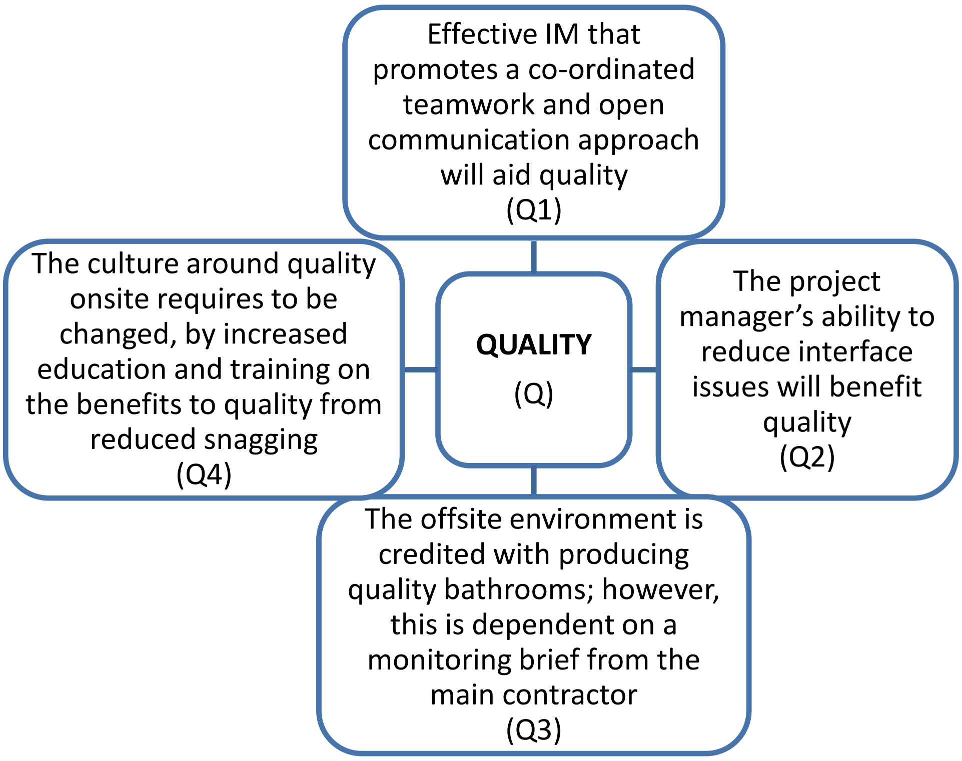

Figure 6.6: Sub-factors that influence quality

6.8 Communication

Communication has been identified as an important people factor in the discussion of the previous process factors. However, its importance in the context of this research merits a specific discussion section on its importance as a people factor.

6.8.1 Statement One: Does Effective Communication Improve Interface Management?

The 82 interviewees were asked, 'does effective communication improve IM?'. The quantitative results of strongly agree (83 percent) and agree (17 percent) accumulate to 100 percent agreement to the question. Although the process factor of quality achieved 100 percent agreement for a similarly phrased statement, it is worth differentiating that the importance of communication achieved 83 percent compared to the importance of quality achieving 56 percent in the strongly agree category. This would suggest that, from the quantitative data collected, communication is considered the most important of all the people and process factors analysed in this research.

'Clear, concise and continuous communication' ('three-C') was identified as the main sub-factor with 31 responses from 22 participants to the question. Three-C communication was deemed essential to manage an effective team, with the consultant civil engineer from project B commenting on the importance of team members having the most up to date drawings and information at the timescales agreed. Emmitt and Gorse (2007) suggest that the complexity and adversarial nature of construction hinders communication, thus emphasising the importance of research into communication and the relevance of complex theory to understand the relationship of adversity and complexity. The significance of trust and good relationships between stakeholders was identified as an important contributor to the three Cs (Emmitt and Gorse, 2007) Ceric (2014) argues that the construction sector is more inclined towards mistrust and poor relationships, resulting in poor communication between the parties. Moreover, the self-interest of the various parties is asserted as hindering open communication (Adriaanse and Voordijk, 2005). Hosmer (1995) argues that trust is fundamental to organisational theory approach, which may indicate why construction is theory adverse in its quest to modernise. The importance of the project manager in promoting a culture of open communication with the client, design team and subcontractors was prominent in the management of interfaces. The project manager is required to understand the various levels of communication skills that exist within the many parties. Xie et al. (2010) contribute that the following six variables require to be applied: accuracy, timeliness, procedures, understanding, barriers and completeness. Furthermore, the six variables should be applied regardless of the communication skillset of the stakeholder to promote three-C communication. Interestingly trust was not included in the six variables.

Sub-factor two, 'impacts on all aspects of the process', achieved 24 responses from 19 interviewees. As has been identified in the discussion of process themes, communication has a significant part to play in the success of individual processes. Dainty et al. (2006) suggest that effective communication underpins all the processes that exist in the construction sector. Furthermore, the many facets linked to communication, underline its importance in systems theory as its input if not interpreted correctly can result in a negative output (Dianty et al., 2006). Interviewees highlighted the harmful effect of miscommunication in verbal and written forms, which was summed up by the production manager of project D: *'You may as well go home'*. Furthermore, mistrust among stakeholders, due to their self-interest, will compromise open communication (Adriaanse and Voordijk, 2005). Equally, interviewees exclaimed the positive influence of communication. This was captured succinctly by the quantity surveyor from project E: *'Communication is key'*. Shokri et al. (2016) add that communication is important to IM. With the formal lines of communication determined by the procurement route and form of contract, interviewees advised that informal verbal communication has a place in resolving process issues, in particular the offsite/onsite interface of bathroom construction. Xie et al. (2010) suggest that the early involvement of manufacturers will benefit the interface problems that result from design changes, thus avoiding the over-reliance on informal communication to resolve design issues.

Although verbal communication has been mentioned in the previous two sub-factors, 14 interviewees contributed 20 responses to merit sub-factor thee, 'verbal communication'. Formal and informal verbal communication was identified by the interviewees as inextricably linked to identifying and resolving interface issues. Hedman and Valo (2015) argue that informal communication has a worthwhile part to play in the success of a project. The project manager from project B simplified the attribute: *'You've got to be able to speak to people'*. The project manager from project D was more specific and emphasised the importance of *'face to face discussion'.* The project manager from project F acknowledged the importance of verbal communication but added that it required to be confirmed in writing. The national sales manager from Project A summed up the general response – *'Everybody now wants to hide behind an email'* – suggesting that advances in technology have swayed email communication in favour of the spoken word, thus relegating the art of 'listening', which is a very important aspect of verbal communication. Otter and Emmitt (2007) suggest that telephone conversations normally occur in the same time zone between different locations. Email's popularity stems from its use in different time zones in different places. Furthermore, verbal and electronic forms of communication each have an important role to play in resolving interface problems, with one no more important than the other (Lin, 2013).

6.8.2 Statement Two: Effective Communication Has More Influence on Offsite than Onsite Bathroom Construction

The nature of the questions and statements followed the format of previous factors, with the second statement being 'effective communication has more influence on offsite than onsite bathroom construction'. The quantitative data resulted in a cumulative score for disagree of 52 percent, neither agree nor disagree of 30 percent and agree of 18 percent. The qualitative data concurred with the former, to establish sub-factor one, 'makes no difference', with 43 responses from 43 interviewees inferring effective communication is required for both offsite and onsite bathroom construction. The project manager for electrical on project D stipulated that good planning and communication apply to both. *'Of equal importance'* was the common phrase used, with the site manager from project H adding that a good relationship with subcontractors and manufacturers fosters good communication. Martin et al. (2014) point out that how well a project is organised will have a significant influence on the relationships between actors and the effectiveness of the communication regardless of whether offsite or onsite construction is adopted.

Sub-factor two is 'onsite bathroom construction requires a greater level of communication'. Fourteen interviewees contributed 16 responses to this sub-factor. The general comments related to a comparison of the increased number of subcontractors required to construct onsite compared to offsite bathroom construction, resulting in a substantial increase in the level of communication between the actors of onsite bathroom construction. The project manager from project H commented that an increased volume of communication should not be seen as a positive attribute due to the industry's inability to communicate effectively. Emmitt (2010) suggests that the project manager does not have direct control of the employees of the many subcontractors engaged in onsite bathroom construction. Each subcontractor will have their own agenda, which makes efficient communication difficult to achieve.

Sub-factor three is 'early communication most important with offsite forms'. Thirteen interviewees offered 15 responses. Interestingly, sub-factors two and three have very similar levels of responses, which would suggest communication is of equal importance to both forms. However, early communication is considered more important to offsite bathroom construction. A strong relationship between communication and design management has been reported in the literature. Johnsson and Meiling (2009) suggest that poor levels of communication at the design stage can lead to defects in offsite bathrooms. The quantity surveyor from project F commented that physical interface problems require to be identified early, suggesting a link between early communication and design management. Goulding et al. (2015) suggest that designers involved in offsite design, and in particular the offsite/onsite interface, require training on the manufacturing processes that incorporate offsite bathrooms. The training would give designers a better appreciation of the importance of early communication, the required flow of information, the offsite/onsite interface and the effects of miscommunication on the process. Figure 6.7 offers sub-factors that have emerged from the analysis of the data and relevant discussion on communication that are perceived to have a positive influence on IM and offsite bathroom construction.

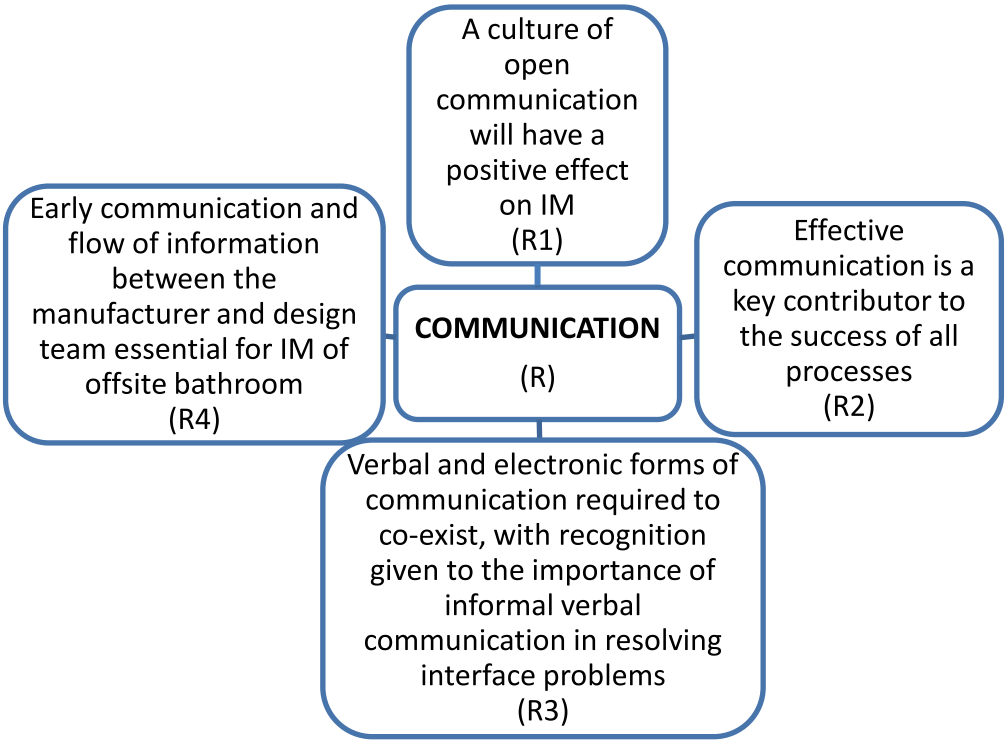

Figure 6.7: Sub-factors that influence communication

6.9 Role of the Project Manager

The role of the construction project manager is fundamental to the construction complex and fragmented industry. This has resulted in the project manager being categorised as a 'problem solver' to manage the complexity. Furthermore, project managers' requires to upskill their soft skills, to enhance collaboration and integration in a fragmented industry, none more so when managing onsite and offsite construction.

6.9.1 Statement One: An Effective Project Manager Will Significantly Improve Interface Management in Bathrooms

The interviewees were invited to respond to this statement with strongly agree (67 percent) and agree (33 percent) combining to 100 percent agreement on the importance of the role the project manager has in managing the interfaces of bathroom construction.

The qualitative data identified two sub-factors both with 24 responses. The first to be discussed, 'the project manager's leadership can improve IM', was highlighted by 20 interviewees. Interestingly, this sub-factor gives credence to the removal of leadership as a stand-alone factor from the original 16 factors. Furthermore, it is suggested that leadership is inextricably linked to the role of the project manager (Burke, 2013). A number of participants clarified that their comments included not only the main contractor's project manager but also subcontractor and manufacturer project managers. However, the project manager from project F added that the role of the project manager has changed from having a direct influence on the work sequence to that of being a 'problem solver' of both physical and operational interfaces, which aligns with complex theory being a component theory of organisational theory (Mullins, 2016) Hwang and Ng (2013) and Walker (2015) argue that the project manager in the twenty-first century not only has to deal with the trade-off of time, cost and quality but also has to manage environmental and sustainability issues, project safety, internal and external stakeholders and possess the attributes of a problem solver and decision maker. Respondents from project H summed up the role of the project manager – *'The project manager drives the project'* and *'The project manager is the boss at the end of the day'* – acknowledging the organisational and leadership skills required to manage the many physical and organisational interfaces that occur on projects, with specific reference to bathroom construction.

The second sub-factor, 'an effective project manager requires good communication skills', generated 24 responses from 18 interviewees. Within the comments from the NBSA and RH projects, participants also focused on inefficient project managers and the problems that resulted. Tong (2011) argues that some project managers find themselves in the role having been promoted from their original profession without acquiring the necessary skillset, emphasising a lack of communication as a significant contributing factor. The client from project D emphasised the importance of good communication between the project manager and the client, never more so than when the project manager has to communicate positive or negative aspects of the project to the client. Moreover, the quantity surveyor from project F added the importance of the project manager effectively communicating with his staff, to foster effective sequencing of tasks. Jha and Iyer (2006) suggest that the primary skill of the project manager on a complex project is not technical but centres on communication, that is, the ability to effectively communicate with all stakeholders, which aligns with the fundamental premise of organisational theory (Loundsbury and Beckman, 2015) The architect from project H added that the manner and tone of communication can also have a positive or negative impact on communication, dependent on what the form of communication is aiming to achieve.

6.9.2 Statement Two: An Effective Project Manager Has More Influence on Offsite than Onsite Bathroom Construction

The second statement relative to the role of the project manager asked the interviewees to comment on 'an effective project manager has more influence on offsite than onsite bathroom construction'. The quantitative results based on the analysis of the data confirmed that 51 percent disagreed, 22 percent agreed and 27 percent neither agreed nor disagreed. The Wilcoxon signed rank test resulted in a median of 2.5, which suggested that the general population disagrees with the statement. The qualitative analysis will focus on three sub-factors:

1. Project manager influence the same for offsite and onsite
2. Project manager will have more influence on onsite bathroom construction
3. Project manager will have less influence on offsite bathroom construction.

Sub-factor one, 'project manager influence the same for offsite and onsite', accumulated 31 responses from 30 interviewees. The respondents' comments were consistent in their assertion that an effective project manager is required for both onsite and offsite bathroom construction. The PMBOK (2013) argues that a project manager requires a mix of technical and interpersonal skills to be effective. The operations manager from project A clarified, *'I think it's vital in both or it will make your life hell'*. The contracts manager from project E qualified his response by stating that both forms will have different ‘cultures’. The project manager from project G added, *‘It’s a different role’*, suggests a variation in skillsets applicable to both. Ramazani and Jergeas (2015) argue that the culture of offsite is more suited to project managers educated to degree level, with a skillset that embeds interpersonal skills. However, both interviewees generally agreed that the effectiveness of the project manager is required in both forms of bathroom construction regardless of their background. The project manager from project H clarified the general view, *‘If you make a bollocks, whether it’s offsite or onsite, it’s still a bollocks’*.

Sub-factor two, ‘project manager will have more influence in the onsite bathroom construction’, accrued 26 responses from 25 interviewees. *‘More influence’* was the phrase that captured the general opinion. It is suggested that the project manager has a greater level of involvement in the planning, sequencing and technical aspects of onsite bathrooms. Sommerville et al. (2010) suggest that, while no definitive training route exists to develop efficient project managers, age and experience gained on a variety of projects are the main contributors. The design manager from project C qualified his response by adding that the trade or educational background of the project manager can influence their effectiveness, implying that a project manager from a trade background would be more adept within the onsite environment and likely to leave the management of offsite to the manufacturer. Santos and Eisenhardt (2005) argue that the increase in the organisational boundary, that is involved in both onsite and offsite construction will have a positive effect in the development of organisational theory through the process of eliciting a sub/alternative theory to guide the project manager in the overall processes.

Sub-factor three, ’project manager will have less influence in the offsite bathroom construction’, can be interpreted as the converse of sub-factor two. Twenty responses were received from 20 interviewees. Responses were mixed about the level of input by the project manager in the offsite process. The contracts manager for a subcontractor on project B commented, *'He's got no influence on them'*, with the project manager of project D suggesting, *'It's up to the project manager how much they want to get involved to be honest'*. The quantity surveyor from project G commented, *'He's not in control when it's offsite'*. However, Harris et al. (2013) argue that where the procurement route allows the early involvement of project managers, they must possess the skillset to objectively influence the use of onsite or offsite bathroom construction.

The design manager from project G suggested that it is more prudent for the design manager to monitor the manufacturing process. The senior project manager and assistant project manager from project H were both of the opinion that it is important to delegate responsibility to a member of the construction team to liaise directly with the manufacturer. Less influence in offsite bathroom construction should not be interpreted as the project manager having no influence or abdicating responsibility, but rather the project manager should maintain a level of control over the manufacturer as they would over a domestic subcontractor. Emmitt (2010) argues that the main function of the project manager is to manage the many individual and organisational interfaces regardless of the form of construction, which suggests a holistic approach to onsite and offsite bathroom construction in line with organisational theory.

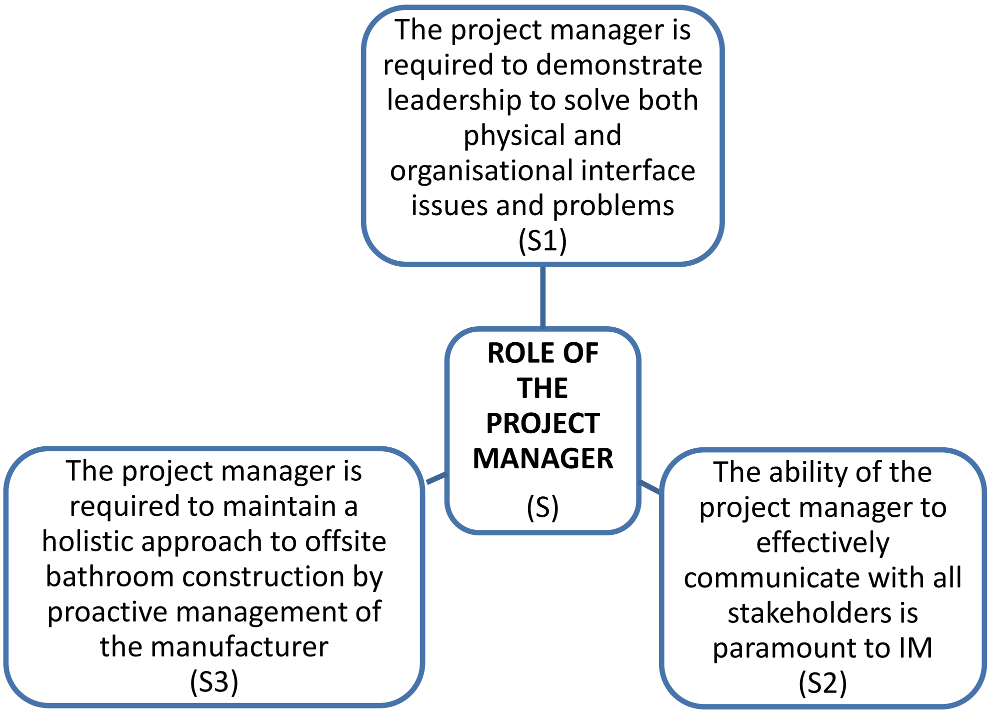

Figure 6.8: Sub-factors that influence the role of the project manager

6.10 Client/Design Team

The client/design team relationship for a project starts at the initial briefing stage and should continue until the end of the defects period. As with any relationship, the initial meetings can indicate how effective the relationship will become in the interests of the project.

6.10.1 Statement One: A Close Client/Design Team Relationship Will Significantly Improve Interface Management in Bathrooms

The quantitative analysis of this statement accumulated a 98 percent agreement to the statement (67 percent strongly agreed and 31 percent agreed). The remaining two percent neither agreed nor disagreed. The result of the Wilcoxon signed rank test estimate a median of 4.5, which indicates agreement from the wider construction population with the statement.

The qualitative analysis of the comments offered by the participants about the statement indicated a number of interesting sub-factors. This discussion will focus on the top three. Sub-factor one, 'positive and early client/design team involvement', amassed 49 responses from 35 interviewees, with a positive influence on IM acknowledged by the participants. The importance of the briefing process underpinned the interviewees' responses. The quantity surveyor from project F exclaimed, *'If the design team can't establish what the client is after, you're going to end up messing around'*. Khosrowshahi (2015) suggests that construction should look to incorporate a level of automation into the briefing process. This structured approach will enhance the briefing process and ensure the client's requirements are communicated. Emmitt and Ruiker (2013) argue that all clients should be involved in the briefing stage, and thereafter their involvement will be determined by the procurement route and their experience. This suggests the importance the procurement route has in integrating the client and design team. The importance of having design management in place early was identified. Gray and Hughes (2001) suggest that, regardless of the experience of the client, the flow of information should be managed by a design manager. The people factor of 'integration' was alluded to, with the emphasis on not isolating the client, but rather developing good communication channels and co-operation as postured in organisational theory (Davis, 2015).

Sub-factor two is 'experience of the client can have an impact'. Twenty-three responses from 20 interviewees identified with this sub-factor. The inherent experience of the client was considered an advantage to the project. The respondents from the NBSA and RH projects acknowledged that their clients were experienced in their chosen form of bathroom construction. Levander et al. (2011) suggest that inexperienced clients are more likely to be directed to traditional bathroom construction by the design team. Hardy (2008) argues that the underlining principle of actor-network theory is that all parties should communicate pertinent information and not hinder the decision making process for their own selfish ends. Furthermore, the need to build good relationships was emphasised by the quantity surveyor from project F: *'You need a good relationship at the start as an absolute minimum'*. Moreover, the client's experience of the end user's requirements was highlighted by the quality manager for project H: *'Speak to him, show him the issues; he said, "I'll accept that"'*. The decision-making attribute of the client is important, never more so than in relation to the end user's maintenance of the bathrooms. Pan and Gibb (2009) argue that when offsite bathrooms are used, the design team should be involved with the manufacturer to ensure the client's maintenance strategy is achieved. This confirms the importance of building good relationships among experienced and inexperienced clients and their design team.

Sub-factor three is 'communication between client/design team and main contractor important'. Seventeen responses from 16 interviewees give significant relevance to this sub-factor. The architect from project A gave an example: *'You just go down and chat it through and work it out and get a solution'*. This good working relationship between the design team and the main contractor's project manager emphasises the importance of open communication. Cheng et al. (2006) suggest that effective communication between the main parties contributes to the overall satisfaction of the client with the design team and main contractor. Furthermore, although formal communication channels will have been established by the procurement route, informal communication can also be seen to contribute in a pragmatic way to the building of good relationships between the many work packages (Emmitt, 2010; De Blois et al., 2011).

A lack of coherent communication within the design team of project C caused avoidable problems with the bathrooms, resulting in incomplete offsite bathrooms being delivered to site. Senaratne and Gunawardane (2015) posit that the design team is generally made up of consultants with a technical remit. Little or no emphasis during the selection of the consultants is placed on their soft skills abilities, for example communication, which suggests little to no cognizance of organisational theory. This can result in repeated use of the phrase 'by others'. Furthermore, the experience of the client from project C aided the solution as they engaged in open communication with the main contractor. The consultant mechanical engineer for project H attributed the good relationships and open forums of communication between the parties as a primer to resolving interface issues with modular bathroom construction.

6.10.2 Statement Two: A Close Client/Design Team Relationship Has More Influence on Offsite than Onsite Bathroom Construction

In keeping with the comparison of offsite and onsite bathroom construction, the interviewees were asked to comment on the idea that 'a close client/design team relationship has more influence on offsite than onsite bathroom construction'. The quantitative analysis resulted in a cumulative total of disagree at 44 percent, agree at 35 percent and neither agree nor disagree at 21 percent. The Wilcoxon signed rank test with a median of 3.0 indicates that the predisposition of the population is to neither agree nor disagree with the statement. This was also confirmed by Arif and Egbu (2010) in their study, where the majority of participants were undecided.

Sub-factor one, 'no difference/teamwork', accumulated 36 responses from 33 interviewees. The general response, captured by the consultant civil engineer from project B, was *'It's important to have a good relationship no matter whether it's offsite or onsite'*. The importance of the client, design team and main contractor working as a team was qualified by participants from project D. Taylor (2010) argues that it is incumbent on government sponsored bodies, for example 'Buildoffsite'[2], to promote the benefits of offsite construction to teamwork and the promotion of better relationships. Moreover, interviewees from project H added that better quality was achieved as a result of team working and good relationships.

Sub-factor two, 'early involvement by client/design team required for offsite bathrooms', accrued 32 responses from 24 interviewees. The overwhelming view of the interviewees related to the importance and benefit to the decision-making

[2] The thesis author notes that Buildoffsite is no longer a government sponsored organisation, although it was initially supported by the Department of Trade and Industry.

process of having the client's early involvement with the design team. Davidson (2009) and Emmitt (2010) suggest that early interaction between the client and design team can foster innovative practices, such as offsite bathrooms in lieu of traditional. The senior project manager from project C summed up the general response: *'It's the early-stage work that makes or breaks a project'*. The design manager from project G added the need to get the client and design team's *'buy-in to offsite bathroom construction'*, with the added advantage of both parties able to visit the manufacturer's factory.

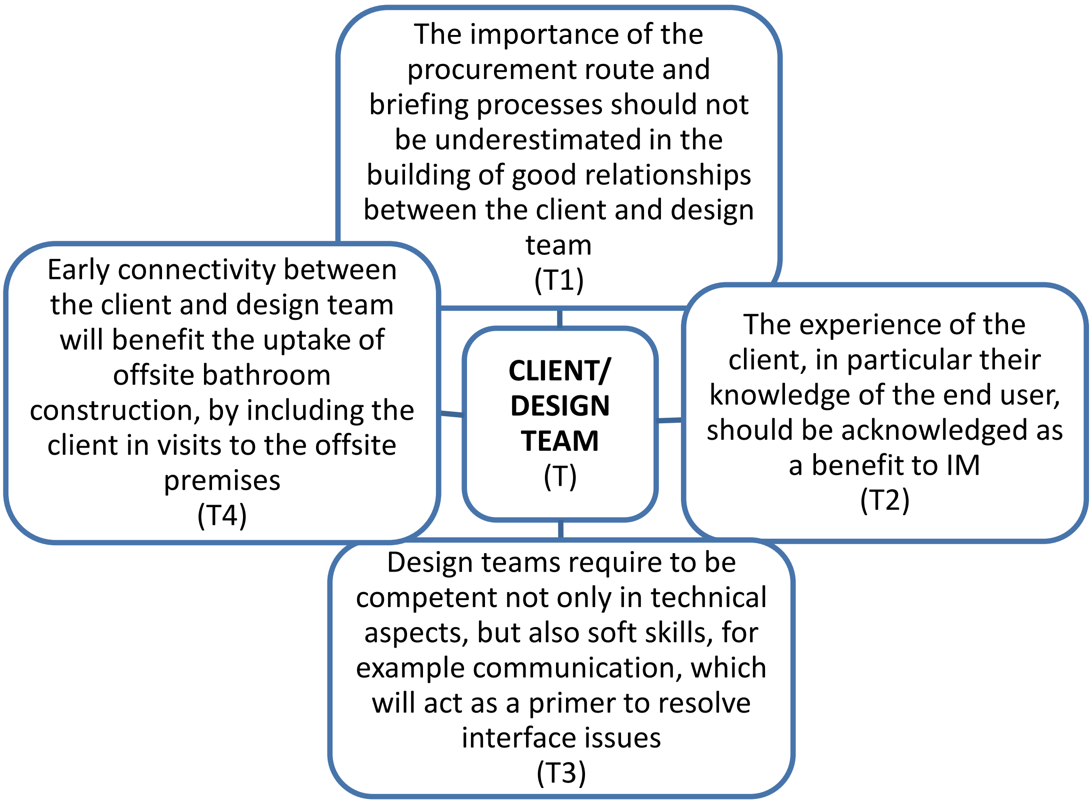

Figure 6.9: Sub-factors that influence the client and design team

6.11 Conceptual Model of the Relationship of IM to Offsite Bathroom Construction

The summation of figures 6.1 to 6.9 culminate in a conceptual model (Figure 6.10), which shows the main factors and associated sub-factors that contribute to the IM of offsite bathroom construction.

6.11.1 A Guide to the Conceptual Model

The conceptual model adopts the premise that interface management is a complex array of factors that must be systematically managed to achieve the successful outcome of the manufacture and installation of offsite bathrooms. The model can be viewed in two main sections process factors and people factors.

The top half of the model identifies the six process factors. The process factors have been arranged from left to right, each with their own prefix code, to represent their order in the overall construction process. Each factor has a number of coded subfactors, which have been abbreviated. The full version of the sub factor can be viewed by making reference to the legend included in the figure. The sub factors have been identified from the analysis of the data and a comparison of the findings of the analysis and the literature. A further review identified that each factor contained at least one sub factor which related to a people factor, thus reiterating the importance of people factors in the successful execution of process factors.

The bottom half of the model displays the three main people factors and sub factors, arranged from left to right. Each of the three people factors and their sub factors should be viewed as having a positive influence on all of the six process factors. Worthy of note is that all of the people sub factors related to soft factors, with the exception of process sub factor 'procurement route' that related to the client/design team factor. Emphasising the part played by the procurement route in building effective relationships between the client and design team.

The model has adopted the 'fishbone diagram' for ease of illustration, to demonstrate that good practise in interface management requires a review of each of the process factors and their sub factors, in tandem with the three people factors and their sub factors to mitigate the practical and organisational interface challenges that can impede the successful manufacture and installation of offsite bathrooms.

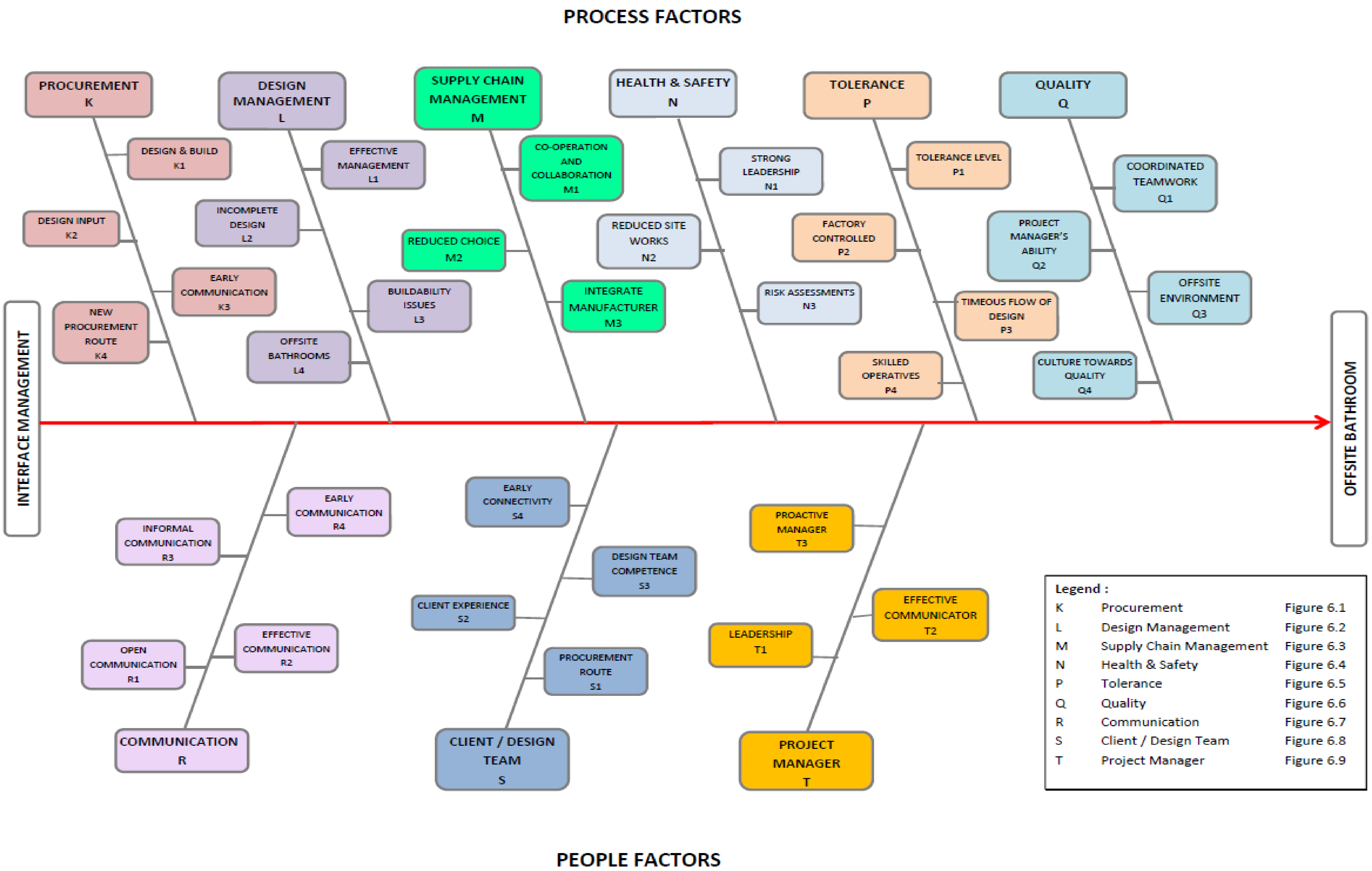

Figure 6.10: Conceptual model of the relationship of IM to offsite bathroom construction

6.12 A Review of Sub-Factors to Identify Problems and Solutions Which Relate to IM of Offsite Bathroom Construction Inferred from the Data Analysis

The analysis of each of the preceding questions and statements has focused on the top two, three or four sub-factors. As well as these, a thematic analysis of the whole data set identified cross-cutting problems and solutions regarding IM of offsite bathroom construction. These problems and solutions are described in the following sections. The relevant statements along with the questions and respondents to which they are linked are provided in Appendix F.

6.12.1 Problems

The main problem themes identified from the eight case studies analysed include the following:

- Design
- Procurement
- Manufacture
- Client/project manager
- Communication
- Onsite preparation

6.12.1.1 Design Problems

From the statements that relate to procurement, it was clear that allowing adequate time to develop and complete the design was considered a concern. Furthermore, the responses to the statements that were associated with design management added that poor design was expensive in terms of both time and money. Moreover, the co-ordination of incomplete design ('by others') is crucial when engaging offsite methods as is the early completion of the design. Added to the lack of design management, all of these are factors that hinder the successful outcome of a project. Relationship problems were also identified in the form of a lack of support for offsite bathroom construction from the client and design team;

this may be attributed to the parties being unable to make alterations to offsite methods. The design of onsite connections was considered critical to the installation of offsite units, which is influenced by the compatibility of offsite and onsite tolerances which must be incorporated by clearly defined interfaces.

The theme of supply chain management identified design and project type as having an influence on the form of supply chain management, while the theme of procurement suggested that the type of project can influence the use of offsite methods, implying that offsite bathroom construction is restricted to certain types of projects, such as student accommodation and hotel construction. The statements relating to the theme of health and safety suggested that design has a major impact on the level of accidents that may occur on a project, which may in part be due to a lack of IM being incorporated into the design, emphasising the need to manage the design not just for onsite construction but equally, if not more, for offsite construction. The statements related to the themes of quality and communication identified the importance of design in achieving the required quality and the relevance of drawings in communicating the requirements of the project.

The main problems identified relating to design suggest that the procurement route can affect the time allowed to complete the design, which will have an effect on designing out interface problems. Furthermore, the type of project can influence the chosen procurement route, which may in turn influence the relationships between the actors involved, with the detrimental effect of not considering the use of offsite bathrooms.

6.12.1.2 Procurement Problems

The statement 'using offsite solutions improves IM on this project' highlighted the importance and influence the procurement route has in adopting offsite methods to improve IM. The statements relating to the theme of procurement added that the procurement route is established before the method of construction is designed. Furthermore, cost and time will have a major influence on the procurement route chosen, while the views are split equally as to whether the procurement route has an influence on interfaces or not. The chosen procurement route was identified as having an influence on the form of supply chain management adopted and also the influence the project manager will have in the adoption of offsite bathroom construction. Construction management was not seen as strong in the co-ordination of the design, while design and build was the route considered most compatible to allowing the project manager to influence the use of offsite and subsequently the direction of the supply chain.

In summary, the main problems associated with the procurement route suggest that, as it is established before the design, this will affect the form the supply chain will take, which may restrict the project manager's influence on the choice of offsite bathrooms. Design and build was considered the only current procurement route aligned to allowing the project manager to influence incorporating offsite bathrooms in the design.

6.12.1.3 Manufacturing Problems

The diminished role of the architect's involvement in the manufacturing process is considered a problem due to the high level of design management demanded of manufactured units. Offsite manufactured units are deemed to be less flexible to design changes, and furthermore they do not lend to possible alterations onsite, which in turn can cause buildability issues. Not all interviewees agreed that using offsite solutions on their site improved IM, with five maintaining that it was more problematic than if traditional methods had been used. To reduce the possible problems encountered from offsite manufacture, in depth planning and a good level of organisation must be embedded in both the offsite and onsite processes. The project manager needs to manage the offsite similarly to the onsite process and not adopt an 'out of sight, out of mind' attitude, whereby problems will occur among supply chain members. The offsite environment does not necessarily produce better quality compared to onsite and therefore the management procedures need to be in place, in particular in relation to health and safety as standards vary between offsite and onsite environments. Tolerance issues can be problematic, in particular when matching offsite to onsite tolerances. With no flexibility in the offsite tolerances, it is paramount that tolerances are identified early and managed, to avoid possible quality issues.

The main problems relating to the manufacturing process identify with the architect's lack of involvement in the manufacturing process, suggesting it can have an effect on the offsite/onsite co-ordination. The strict tolerances on manufactured units can aggravate the resulting interface problems onsite. If the project manager does not manage the manufacturing process as diligently as the onsite works, problems such as issues with health and safety can result.

6.12.1.4 Client/Project Manager Problems

Non-participation by the client is considered to have a negative impact on a project. The client's relationship with the manufacturer is considered beneficial in promoting offsite forms of bathroom construction. Equally, the client can have a positive influence on the supply chain by demonstrating commitment to the project team. A poor client/project manager relationship, and similarly a negative design team/project manager relationship, will have a negative impact on the IM and the overall success of the project. Poor relationships between the project manager and client and design team will reduce the influence the project manager could have with particular regard to the adoption of offsite methods. Consideration must be given to the management style of the project manager when implementing offsite methods, as project managers whose experience may be solely traditional construction may not possess the skills required to manage the supply chain which includes an offsite manufacturer.

The main problems identified in the client/project manager connection can result when the client takes a silent role and does not engage as a member of the team. Moreover, poor relationships between the parties will have a negative effect on the adoption of offsite bathrooms.

6.12.1.5 Communication Problems

Communication was implicated as having a key impact on all aspects of the process throughout the lifecycle of the project. Conversely, a lack of meaningful communication among stakeholders can create problems which could otherwise be avoided by adopting a more open form of both written and oral communication. It was questioned by one interviewee whether good communication can be taught. While we all have an inherent level of communication skills, it is accepted that levels vary and therefore a degree of tuition is required, to avoid the problems encountered from a lack of communication skills.

In summary, the main problem identified in relation to communication is that, while communication is a key component of all factors, the level of meaningful communication can vary considerably among actors on a project such that many consider communication to be solely verbal or written, whereas the ability to listen is of equal importance but is often ignored.

6.12.1.6 Onsite Preparation Problems

The onsite preparation works required for the installation of offsite forms of bathrooms are crucial to the overall success of the process. Achieving the required tolerance onsite is considered more problematic than achieving the tolerance requirement offsite. Due to the onsite environment, rectifying tolerance problems with offsite units is extremely difficult to achieve onsite. While the factory environment is considered less hazardous than the site environment, consideration must be given to potential safety problems that could result from the increased use of mobile and tower cranes installing the units onsite. Late decision-making is more acceptable in onsite bathroom construction in comparison to the early decision-making requirements for offsite bathrooms, and consequently the early decision-making and co-ordination of the process must apply to the onsite works associated with the offsite bathroom, otherwise problems will result.

It is the expressed view of a number of interviewees that the onsite environment is less conducive to achieving the quality standards that can be achieved in the factory environment; this generally results in a higher level of snagging associated with the onsite works. The level of IM is deemed by interviewees to also affect quality, and this can be attributed to the higher number of interfaces within the supply chain potentially causing more problems, emphasising the importance of good relationships between the members of the supply chain.

The main problems with the onsite works associated with offsite bathrooms suggest that onsite tolerances are required to be compatible with offsite tolerances; however, the onsite environment makes this difficult to achieve. Furthermore, the early decision-making required for offsite bathrooms is required of the corresponding onsite works. With a greater number of interfaces between supply chain members onsite, the importance of good relationships cannot be underestimated.

6.12.2 Solutions

The approach used to identify solution themes was similar to the method used in Section 6.12.1 to identify problem themes, and the solution themes have been classified under the following:

- Design
- Manufacture
- Management

6.12.2.1 Design Solutions

While design has been identified as a problem theme, it has also been considered by interviewees as fundamental in providing solutions to the various problem areas, not least within the theme of design. Promoting early input by the client was seen as a positive step in producing good design, as was allowing sufficient time for the design process. A further step change was the early co-ordination of design to improve the management of the interfaces associated with the project, in particular when the project involves offsite solutions such that all parties are involved in the design, and this should include the client and manufacturer as well as the design team. While it is acknowledged that good design promotes good sequencing and fewer interface problems, it is equally important to recognise the important role of the design manager in the co-ordination of the design and flow of information, which in turn will have a positive impact on IM and the resulting quality achieved with particular reference to the tolerances required of offsite bathrooms.

The process of design does not stand in isolation and therefore it is important to integrate the design process with the other processes that impact on the overall construction process, one of which is procurement and the route stipulated for the project. To adopt the aforementioned solutions, it is suggested that the design should be contractor-led. Design and build is seen as the preferred procurement route in which offsite bathroom solutions are an integral part of the project. Design and build offers the opportunity to make the design buildable and make use of standardisation, while promoting open communication throughout the management of the design. A contractor-led design approach would instigate a review of design prior to construction, with the issues of buildability and constructability foremost in the design methodology, while allowing for the construction of prototypes to benefit the management of potential interface problems during the construction.

In summary, the main solution offered with regard to design is that the client should be incorporated early as a member of the project team, such that adequate time can be allowed for the design of the project. While the architect may be the design leader, the design should be managed independently by a design manager, with the mandate of focusing on interfaces. The strong connection between procurement and design should promote design and build when using offsite bathrooms.

6.12.2.2 Manufacturer Solutions

The expertise and experience of the manufacturer was seen as a positive attribute of the offsite environment. However, caution should be exercised in the classification of expertise as not all manufacturers adopt a production process that is synonymous with manufacturing. The manufacturing process demands a greater level of pre-planning, which along with stage inspections can lead to a faster production process. Pre-planning should not only include the designers involved in the offsite bathrooms but also the client, to ensure their requirements are being met in relation to quality and the maintenance of the product. Manufacturing promotes better control of tolerance and quality resulting in less snagging compared to traditional construction. The promotion of a single modular company manufacturing the offsite bathroom solutions will have an influence on the supply chain management of the project in simplifying the lines of communication and in promoting the building of mock-ups, and providing samples to aid the understanding of interfaces before the actual installation process takes place on site.

The manufacture of offsite bathroom solutions leads to fewer interfaces and improves IM of the overall process. The manufactured units can contribute to a more precise and shorter overall programme for the project. A more controlled environment promotes better control of safety hazards and results in less manual handling. Conversely, less labour onsite will have a positive impact on health and safety.

In summary, the main solutions identified in relation to the manufacturer suggest that the main contractor should inspect the manufacturer's premises before contracting the manufacturer to satisfy that a manufacturing process will be used. With the client being part of the project team they should engage with the manufacturer during the early stages of design. The use of offsite manufactured bathrooms should allow the concurrent progress of the onsite works, promoting better health and safety and less snagging with the manufactured product.

6.12.2.3 Management Solutions

The management of any project starts with the client, and central to the management of a project is the positive relationship that is built up between the main contractor, client and design team. The experience of the client can influence the project, such that an experienced client will be aware that good communication between the design team, main contractor and themselves will aid the quality achieved. The procurement route and form of contract are both seen to have an influence on the level of IM required within a project. The form of contract is deemed by some interviewees to have more of an influence than the procurement route, while it is considered necessary when using offsite bathroom construction that they both allow early involvement of the manufacturer. Contractor-led design and build and construction management are considered the preferred procurement routes when considering offsite solutions. Both routes have the potential to foster strong partnerships within the supply chains. However, regardless of the procurement route or form of contract, if good open communication does not exist between all stakeholders then the IM of the offsite bathrooms will be disadvantaged.

Clear, concise and early communication is most important in the management of offsite bathrooms. Good communication has a positive influence on health and safety and the management of the supply chain. Where co-operation and open communication exists within the supply chain the management of tolerances that affect the interface between components will be more easily achieved. Good open verbal communication can promote a spirit of teamwork within the supply chain, which when co-ordinated within the team will aid the achievement of the required quality. Central to the teamwork approach is the influence of the project managers and their approach to communication and co-ordination in resolving interface issues.

A number of interviewees argued that IM is about understanding the tolerances that influence the completed design. Achieving the required tolerance levels requires good management, planning and early involvement. Pivotal to managing the tolerance issues is the main contractor and while it is important to manage the processes that impact on the IM of offsite bathrooms, the effective management of the people involved should not be underestimated in achieving a quality offsite bathroom. While a teamwork approach is recommended within the supply chain, the influence of the project manager cannot be understated. The project manager needs to be actively involved in the onsite works associated with offsite bathrooms and the offsite manufacture including logistics of transporting and installing onsite. To achieve this, the project manager must demonstrate strong leadership and good communication skills, which promote the required inter-relationships between the teams that make up the supply chain, resulting in the successful co-ordination and installation of offsite bathrooms within the project.

In summary, the main findings relating to management solutions would suggest that the promotion of good relationships between the main stakeholders can influence the ease of resolving interface problems. The management of the client is important, as is the communication between the client and the other members of the project team. While the procurement route can influence the early involvement of the main contractor and contractor-led design, consideration should be given to the form of contract to ensure the same compliance. The strong leadership and influence of the main contractor's project manager is considered pivotal to resolving interface issues connected to offsite bathrooms. The project manager should instigate a culture of co-operation and teamwork to benefit the management of the offsite bathrooms and the project as a whole.

6.13 Summation of All Findings

The construct of the conceptual model (Figure 6.10) was based on the findings and discussion of the questions and statements that related to the nine factors analysed. It was considered prudent to analyse all findings (see the statements in grey boxes) that emerged from the analysis and discussion of sections B, C and D of the pro forma and the findings that emerged from the analysis of the problems and solutions. A total of 70 findings were analysed (refer to appendix G) to determine the connection to a factor or factors. Table 6.1 denotes the ranked order of the results.

Table 6.1: Summary of all findings

Ranked Order	Factor	Total
1	Role of the project manager	25
1	Communication	25
3	Design management	22
4	Client/design team	17
5	Tolerance	11
5	Quality	11
7	Procurement	10
8	Supply chain management	9
8	Health and safety	9

Worthy of comment is that three of the top four factors and the two ranked joint first are people factors. Conversely, the bottom five factors are process factors with total scores between 9 and 11. The joint first factors of 'the role of the project manager' and 'communication' highlight the importance of the contractor's project manager in managing all aspects of the IM of offsite bathroom construction, linked with their ability to communicate in all forms with all stakeholders. Interestingly, design management and the client and design team ranked third and fourth respectively, which could suggest a strong link between the input of the client and design team and the management of the design. Moreover, this emphasises the importance of the project manager in communications with the client and design team, to effectively manage the design process.

The correlation between the process factors of quality and tolerance is evident in them being ranked joint fifth, suggesting that both have an equal influence on each other. The remaining three process factors of procurement, supply chain management and health and safety, ranked seventh and joint eighth respectively, suggest that adopting a mainly offsite form of bathroom construction, whereby a manufacturer is in full control of the process, removes a lot of the health and safety, supply chain management and procurement issues that prevail in traditional bathroom construction.

A comparison of Table 5.6, ranking of factors for IM of offsite forms of bathroom construction, with the ranking in Table 6.1 above, shows that most factors fall within an acceptable variation of plus or minus a maximum of three places. Notably, the ranking of the role of the project manager has risen from seventh in Table 5.6 to joint first in Table 6.1, which would suggest that the project manager's role in the IM of offsite forms of bathroom construction is considered implicit rather than explicit among the population of the sample. Furthermore, the procurement of offsite bathrooms from a manufacturer does not diminish the contractor's project manager's role, but rather they must adapt to the changes in working that they bring.

6.14 Test and Validate Conceptual Model

Four construction professionals agreed to test and validate the conceptual model (Fig 6.10). To comply with anonymity each interviewee will be coded as follows:

Table 6.2 Validation Interview Sample

Interviewee	Role	Organisation	Years of experience of offsite bathroom construction	Types of offsite bathroom construction
V1	Project Manager	Project management organisation	6 years	Modular and Pods
V2	Senior Project Manager	Main Contractor	12 years	Flat pack and pods
V3	Project Director	Main Contractor	8 years	Modular and pods
V4	Associate Director	Project Management Organisation	20 years	Pods

The format of the conceptual model was explained to the interviewees, which allowed them to test the validity of the model as an aid to the successful interface management of offsite bathroom construction. All interviewees agreed with the importance of all the process and people factors stated. V1 commented that with her experience of the contractor and client side, the six process and three people factors were "*absolutely important*". V3 qualitied his response with the phrase '*very relevant*". V4 used the word "*truism*", to emphasise the relevance of all the factors. All interviewees agreed with the relevance of the people factors to the process factors. Communication was highlighted as vital to the overall process. V3 emphasised the importance of "procurement", suggesting that the design team required to inform the client of the alternative use of offsite construction, prior to procurement.

The four interviewees also agreed with the inclusion of the sub-factors, V1 suggested that some had particular relevance, for example offsite environment, reduced site works, buildability and incomplete design to name but a few. V2 highlighted incomplete design and the importance of communication. Otherwise "you *could be flogging a dead horse*". V3 countered his response that all the sub-factors were very relevant. While V4 exclaimed " *I didn't fine anything that doesn't belong in there*".

The interviewees were asked to identify factor/factors that they considered most significant of the nine. V1 suggested that design management and communication were both key factors. V2 concluded all to be of equal importance. V3 stated procurement and V4 explained that it was difficult to single out any, but chose quality. The variations in the responses suggest all factors are of equal importance.

The five disciplines included in the study comprise of clients, main contractors, sub-contractors, design teams and manufactures. The interviewees were asked to comment on which of the five the model would be most useful too. V1 and V2 suggested that it would be beneficial to all disciplines. V1 added that it should be included in the project execution plan. V1 also added that it would be of particular benefit to management with little or no experience of offsite construction and included in the agenda of a pre-start meeting. V3 and V4 considered the model most useful at the start of the project and therefore the client would particularly benefit with it included in the employer's requirements.

The review of the four interviewees' responses confirms that the conceptual model has unanimously achieved approval as a valid document to manage the interfaces associated with offsite bathroom construction. Furthermore, V2 and V4 considered the model to be very relevant to all forms of offsite construction.

6.15 Summary

The nine factors and their corresponding sub-factors identified in the previous chapter have been further discussed in this chapter with reference to the literature contained in chapters two and three. The discussion has resulted in the syntheses of new sub-factors that succinctly contribute to each factor. A conceptual model has been offered, which encapsulates the nine factors and their sub-factors. A further analysis and discussion relative to the problems and solutions of the IM of offsite bathroom construction resulted in a further array of findings, worthy of further discussion. In keeping with the pragmatic paradigm of the study a further analysis of all findings took place (refer to appendix G). The resulting summary of the findings allowed the importance of the nine factors to be identified (Table 6.1). The role of the project manager and communication were considered joint top in terms of importance to the IM of offsite bathroom construction. The next chapter will conclude the thesis.

Chapter 7 – Conclusions and Recommendations

7.1 Introduction

Chapter 1 introduced this thesis and Chapters 2 and 3 reviewed the existing literature. Chapter 4 justified the methods of analysis, which were carried out in Chapter 5, the analysis chapter. Chapter 6 discussed the findings from Chapter 5 with comparisons with the literature review chapters. This chapter concludes the thesis, with a review of the research questions, aim and objectives. Also included in this chapter are a review of the thesis' contribution to knowledge, recommendations for further study, and finally a personal reflection on the PhD experience.

7.2 Review of Research Objectives and Aim

7.2.1 Objective 1

> *To determine and critically review the process and people factors that relate to the management of interfaces, focusing on offsite bathroom construction.*

A four-stage review (Chapters 2, 3, 4 and 5) was used to fulfil this objective. The first stage (Chapter 2) critically reviewed literature that related to traditional and offsite construction and IM. The review of the literature identified and justified the inclusion of the following process factors: procurement, supply chain management, whole life costing, health and safety, design management, lean construction, sustainability, tolerance, and quality. The people factors also identified include the following: communication, role of the project manager, leadership, culture, client and design team, perception, and integration. The nine process and seven people factors were identified as factors that could have an influence on the IM of offsite bathroom construction, including the associated onsite works.

The second stage (Chapter 3) critically reviewed the literature applicable to each of the process and people factors with specific relevance to offsite bathroom construction and IM to gain a more in-depth appreciation of the impact of the individual factor on the relationship of IM to offsite bathroom construction. The third stage (Chapter 4) involved the pilot study of the original 16 factors, resulting in the removal of the people factor of leadership from the analysis, due to the six participants' overwhelming conclusion that leadership is inherent in the role of the project manager. Prior to the main analysis of the remaining 15 factors (stage four, Chapter 5), an analysis of three sets of ranking questions was carried out. A cumulative ranking of all 15 process and people factors was formulated (Table 5.7) in order of importance. The cumulative ranking process resulted in those factors scoring a cumulative weighting of 112 or less not being included in the remainder of the analysis, leaving the nine factors of design management, communication, quality, procurement, supply chain management, client and design team, health and safety, role of the project manager and tolerance determined as worthy of further analysis. It can be concluded from the review of objective 1 that there is a propensity within the literature and data to focus more on the process factors and less on the people factors, with the exclusion of culture, perception and integration from the detailed analysis.

7.2.2 Objective 2

To evaluate the interrelationships and interdependencies that result from the design, manufacture and construction of offsite bathrooms.

Objective 2 was derived from the literature review in Chapters 2 and 3. The review of traditional construction identified a lack of interrelationships within the process, in particular between the design and construction phases. This was further exacerbated by the inclusion of the manufacturing process, with procurement and design management cited as process factors that can both hinder and improve the interdependencies and interrelationships that result, with particular reference to the onsite works associated with offsite bathroom construction. A finding from the literature identified that incorporating offsite bathroom construction into the traditional adversarial form of construction does not enhance the interrelationships and interdependencies required. It has been identified that greater emphasis needs to be placed on the interpersonal skills of the project manager in tandem with the required technical skills to manage the design, manufacture and construction of offsite bathroom construction. This would allow a more holistic integrated approach to be developed whereupon complex interfaces and their tolerances are identified early in the design of offsite bathrooms and a more open and effective form of communication is endorsed between the management of the manufacturer and the onsite contractor.

To manage the interrelationships and interdependencies associated with the design, manufacture and incorporation of offsite bathrooms onsite requires an understanding of the interrelationships between the process and people factors identified in Objective 1. The chosen procurement route has been identified as crucial to allow manufacturers and specialists with design input to engage with the design at the appropriate stage. A design manager included to co-ordinate the design process must give equal consideration to the offsite and onsite elements of the process and none more so than promoting early inter-organisational communication to identify and resolve buildability and constructability problems. Furthermore, the design manager must not only integrate with the design team but also with the client to foster a culture of interdependency and good interrelationships.

The chosen procurement route and design process will influence the interdependencies that form within the supply chain. The parties implicated not only include the main contractor and subcontractor but also the client and design team. The importance of the client's role in the design and construction process is constantly overlooked. However, when integrating offsite bathroom construction it is pertinent to engage the client as an equal member of the supply chain, never more so than at the design stage. While traditional construction tends to isolate the client, offsite bathroom construction promotes the inclusion of the client as an important contributor to the overall process.

A process that promotes interrelationships and interdependencies between the many stakeholders involved, such as offsite bathroom construction, will integrate a culture of effective health and safety into all stages of the lifecycle of the process, not just the construction stage, thereby being mindful of health and safety from the early design stage. Central to the promotion of good interrelationships is the project manager. The project manager must demonstrate leadership to promote an effective health and safety strategy, not only onsite but also offsite during manufacture. Although sustainability has not been included in the final analysis of the data, it has been acknowledged that the client, design team and project manager, through the design decisions made, the materials chosen, the management of waste and the use of energy efficient mechanical and electrical systems, consider offsite bathroom construction a more sustainable process compared to traditional bathroom construction.

The integration of the previously discussed process and people factors can result in a quality offsite-constructed bathroom. However, consideration must be given to the environment of the premises and the integration of the offsite and onsite works. It is prudent of the project manager to monitor the progress and quality of offsite bathrooms during manufacture as some offsite premises resemble onsite conditions with a roof-covering in comparison to manufacture premises, thus endangering the resulting quality of the bathroom. Moreover, consideration must be given to the tolerance levels achieved offsite, which should be more precise than the tolerance level of the onsite works, emphasising the need for the design team and the project manager to effectively communicate the compliant deviation of tolerance acceptable to the integration of the offsite and onsite processes. To conclude objective 2, the designers, manufacturers and contractors involved in offsite bathrooms, should be introduced during the design stage and not left until the construction phase. This is a common recommendation for the successful implementation of an offsite approach (Gibb and Isack, 2001; Blismas et al., 2005) A design manager under the direction of the project manager should promote a team ethic, whereby interrelationships and interdependencies enhance the overall offsite bathroom process.

7.2.3 Objective 3

> *To establish existing industry practices, in relation to IM, around the process and people factors which affect the offsite manufacture and onsite installation of offsite bathroom construction.*

The validity of establishing the current construction industry's practices in relation to the IM of the process and people factors which affect offsite bathroom construction was identified mainly from the quantitative analysis of the 82 interviews carried out. As has been previously stated in Objective 1, the original 16 factors were reduced to nine for the purpose of the detailed quantitative and qualitative analysis. The five-point Likert scale provided the frequency applicable to each scale and also provided the data to apply the Wilcoxon signed ranked test to each statement or question, to determine its significance at the 5% level. Two statements in section B of the pro forma (refer to appendix A) relate to the general association of IM to offsite construction. The responses to both confirmed strong agreement, and significance at the 5% level, with the importance of IM when using offsite construction.

A similar approach to the 20 statements and questions (refer to Table 5.10) related to the nine process and people factors confirmed 18 as significant at the 5% level, with two not significant at this level. The sample mainly disagreed with the statements that 'tolerances would be more problematic with offsite bathrooms than onsite' and that 'a close client design and team relationship has more influence on offsite than onsite bathroom construction', suggesting that they do not consider that tolerance and the client and design team relationship should be given any more significance when considering the use of onsite or offsite bathroom construction. The 18 statements that were significant at the 5% level confirmed the industries' view that procurement, supply chain management, health and safety, design management, quality, communication, role of the project manager and in part tolerance and the client and design team have a significant part to play in the importance of IM to offsite bathroom construction. Although not included in the detailed analysis, the factors of integration, perception and culture would suggest that the construction industry has not fully embraced the importance of the influence of people factors on process factors and still remains mainly traditional in its approach. Furthermore, architects remains the dominant influence in the client and design team and, with their mainly traditional approach to construction, inexperienced clients are unlikely to be advised to incorporate offsite bathroom construction into the project. To conclude the main finding of objective 3, the industry remains fairly traditional in its approach to the IM of offsite bathroom construction. The emphasise remains with the process factors, with people factors perceived as aiding the influence of the process factors.

7.2.4 Objective 4

To identify key problems and solutions for offsite bathrooms construction.

The final question on the pro forma asked the interviewees to identify the main interface problem in relation to offsite bathroom construction on their project. However, the analysis of the responses determined that the data did not give a true reflection of the interface problems encountered. An alternative approach was adopted, which resulted in analysing all the sub-factors contained in all the ranking tables applicable to the questions and statements of sections B, C and D of the pro forma, adopting a thematic analysis approach (refer to appendix F).

The thematic approach to organisational IM in offsite bathroom construction identified the following *problematic* themes and sub-themes:

- Design problems – onsite connections, non-clearly defined interfaces and incomplete design (6.12.1.1).
- Procurement problems – the chosen procurement route may stifle open co-operation within the supply chain, the procurement route may hinder the influence of the project manager and most procurement routes are not compatible with incorporating offsite bathroom construction and subsequent management of resulting interfaces (6.12.1.2).
- Manufacturing problems – offsite bathrooms less flexible to change, can cause buildability issues due to lack of architect involvement and tolerance issues with offsite/onsite installation (6.12.1.3).
- Client/project manager problems – poor relationship between client and project manager, non-involvement of the client in the construction process and a lack of understanding of the client's brief by the project manager (6.12.1.4).
- Communication problems – lack of meaningful communication can impact on all processes (6.12.1.5).
- Onsite problems – onsite environment can result in poor quality, poor onsite tolerance levels for offsite bathrooms and incompatible relationships between members of the supply chain (6.12.1.5).

A similar thematic approach was carried out for the *solutions* identified within the data, leading to the following factors and sub-factors:

- Design solutions – positive and early client and design team involvement, early co-ordination of design to manage interface issues and promote open communication and good design to reduce interface problems (6.12.2.1).
- Manufacture solutions – main contractor to inspect offsite environment to ensure a quality bathroom will be manufactured, early involvement of client with the manufacturer to ensure brief is understood and concurrence of manufacture and onsite works should result in less time onsite, better health and safety overall and fewer snagging works (6.12.2.2).

- Management solutions – clear, concise and early communication between client, design team, main contractor and manufacturer, strong leadership from the project manager in the planning, co-ordination and communication of the project and the chosen procurement route should not hinder offsite bathroom construction (6.12.2.3).

To conclude objective 4, it has been identified from the data analysed that a theme can be both a problem and a solution, for example design and manufacture. Ultimately it is the management of the project which will influence whether a factor can be transformed from a problem to a solution.

7.2.5 Objective 5

To develop test and validate a conceptual model to better understand the IM of the manufacture and onsite installation of offsite bathrooms.

Objective 5 was realised through the analysis of the data in Chapter 5 and the discussion in Chapter 6. The data applicable to each of the nine factors in Chapter 5 was analysed to identify relevant sub-factors. The qualitative data of the top two, three or four sub-factors relevant to each question or statement for each of the nine factors was analysed to determine relevant findings. Chapter 6 discussed each factor and sub-factor, and findings from Chapter 5 with the relevant literature, to formulate a maximum of four sub-factors that emerged to support the particular factor in the successful execution of the IM of offsite bathrooms.

The Ishikawa diagram (refer to Figure 6.10) was considered appropriate to display the flow of factors and sub-factors, which have an influence on the IM of offsite bathroom construction. The top half of the diagram shows the six process factors and 22 sub-factors. The bottom half indicates the three people factors and 11 sub-factors. The flow of the factors from IM to offsite bathroom (left to right) represents an order which is appropriate for the manufacture and onsite installation of offsite bathrooms. Interesting findings from the conceptual model include:

- Factors that emerged as sub-factors in an alternative group demonstrating interrelationship between factors, for example:

  Procurement → early communication

  Quality → project manager's ability

  Client and design team → procurement route
- Leadership, which was discounted from the original 16 factors after the pilot study, was identified as a sub-factor to the role of the project manager and health and safety, which concurs with the reasoning for its omission.
- Two factors that were not included in the full analysis have been associated with factors as sub-factors, suggesting that the six factors not included in the full analysis have relevance to the study as possible sub-factors, for example:

  Supply chain management → integration

  Quality → culture

An important note to conclude objective 5, is that, while the contribution of the nine process and people factors has been established in the IM of offsite bathrooms, equal consideration should also be given to the sub factors that support the realisation of each factor.

Overall, the five objectives set out in chapter 1 have been successfully met.

7.2.6 Review of Aim

The successful achievement of the objectives has contributed to the realisation of the aim set out in chapter 1, '*To identify and understand the interconnectivity between the main process and people factors that influence IM in relation to the offsite manufacture and onsite installation of bathrooms in construction*'. From an original total of 16 factors identified from the literature review, the data analysis confirmed the importance of nine factors (six process and three people factors). The review of the aim has enlightened the researcher to the individual importance of each factor and equally to the important contribution that the people factors have on the achievement of the process factors, confirming with existing knowledge (literature) that factors do not operate in isolation. A further review carried out of all the findings identified in Chapters 5 and 6 confirmed that communication and the role of the project manager were the joint top main factors which influenced the successful IM of offsite manufactured bathroom installation on site. One process factor worthy of special mention is 'procurement'; although design and build was considered by the data as the most relevant of the routes available, the literature recommend the formation of a new procurement form that would give equal parity to offsite and onsite construction.

7.3 Review of Research Questions

The research was carried out to address the main research question as stated in chapter 1:

> '*What is the relationship between offsite construction and IM in the context of offsite bathroom installation?'*

To contribute to the answer of the main research question, two secondary questions were asked. For the first, *'What are the main process and people factors that significantly influence the IM of the manufacture and onsite installation of offsite bathrooms?'* Table 1.1 indicates connectivity between objective 1 and secondary question 1. In the interest of brevity reference can be made to 7.2.1. However, it should be added that although process factors are dominant in the IM of the manufacture and onsite installation of offsite bathrooms, the analysis of all the findings (6.13) suggest that the people factors of communication, the role of the project manager and the client/design team are particularly influential in the outcome of the process factors.

For secondary question two, '*How do process and people factors affect the relationship between offsite and IM?'* Table 1.1 again shows the connectivity of this question to objective 2 (7.2.2). Furthermore, the data analysis contained in sections 5.3 and 5.4 confirm the importance of co-ordinating the design early, clearly defining interfaces, making use of the manufacturer's expertise and good communication.

The two secondary questions have contributed in part to answering the main research question by highlighting the complexity that exists in the relationship of IM and offsite bathroom installation. The complexity is illustrated in the conceptual model (Figure 6.10). While the justification of the nine factors has been discussed earlier, the importance of the subfactors for each factor should not be understated. Furthermore, the relationship of IM to offsite bathrooms is of importance to all stages of the life cycle of a project, with a particular influence at the design stage. Manufactured offsite bathrooms are perceived in the literature and data analysis to reduce the management of interfaces in comparison to traditional bathroom construction. However, the management of the pertinent interfaces demands a higher focus of management, both in relation to the offsite and onsite associated works, due to the little flexibility available from the manufactured bathrooms.

7.4 Contribution to Knowledge

The two main themes that contribute to this research are IM and offsite construction, with an emphasis on offsite bathroom construction. IM has been subject to very little research, and offsite construction only marginally more. However, offsite *bathroom* construction has seen very little research within the construction management community. It is considered reasonable to assert that a study which embodies the relationship of IM to offsite bathroom construction has elements of originality that are worthy contributors to the body of construction project management knowledge.

As has been stated on a number of occasions within this thesis, IM (and in particular organisational IM) has not been researched significantly within general management literature and construction in particular. With the lack of a standard definition of IM (and organisational IM in particular) this thesis offers an original definition of organisational IM.

Offsite bathroom construction does not exist in isolation from the rest of construction, such that the literature review analysed traditional construction, offsite construction and IM to determine the process and people factors that would have an influence on the IM of offsite bathroom construction. The researcher's experience and contacts within the construction industry contributed to gaining access to 82 interviewees from a broad spectrum of disciplines within the current construction community. The normal practice in construction management research is to adopt either a quantitative or qualitative method of analysis. However, this research used a mixed method combination of quantitative and qualitative to analyse the data. The quantitative data were analysed using frequency tables and the Wilcoxon Signed Rank Test, to give a level of agree/disagree to the statements. The top two, three or four sub-factors identified were insightfully analysed qualitatively, also taking cognisance of the quantitative result to identify emerging findings. The findings were further reviewed by comparison to the existing literature, to substantiate sub-factors that influence the nine factors, resulting in validation of the data through triangulation. An original conceptual model has been formed to show how the flow of factors and their sub-factors contributes to the successful IM of offsite bathroom construction.

As a theoretical contribution, it is considered the content of the thesis and the conceptual model in particular provides a theoretical base for the management of organisational IM in relation to offsite bathrooms. For the offsite community, the findings and conceptual model provide the factors and sub-factors for each discipline to consider within their particular contribution to the offsite bathroom process. For the wider construction community, it is considered that general IM could be improved by making reference to the factors and sub-factors denoted in the model.

7.5 Limitations of the Research

All research has its limitation and this thesis is no exception. The first limitation identified with the sparse amount of literature on interface management and in particular construction interface management. While the lack of peer reviewed literature contributed to the difficulty of identifying underpinning theory relating to interface management, it also confirmed the relevance of the need for further research.

Although the 82 interviews carried out amassed a substantial amount of data, due to time and word count constraints, limitations were placed on the diversification of the areas of analysis. Areas that would be worthy of further research are comparing the data of the various disciplines and age ranges to determine any significant change to the finding identified in the overall analysis.

A further limitation related to the identification and access to live projects that included alternative forms of offsite bathroom construction. Although five classifications were identified, three classifications only had one case study per classification. Access to projects utilising pre-cast concrete, pre-engineered and full modular incorporating bathroom construction, would have ensured a minimum of two projects per classification, which may have enhanced the analysis.

7.6 Recommendations for Further Study

It is important that research is continued in the areas of IM and offsite construction either separately or in combination, and none more so than the contribution that offsite construction could make to the current housing shortage within the UK. The following are recommended for further investigation:

- To carry out research into the aptitude of the categorical variables identified in this research, for example background, age range and experience to determine their position to the relationship of IM to offsite bathroom construction

- Although there is a lack of research on IM, physical and organisational interfaces are dominant in the construction process. It is the researchers experience that a typical construction manager will spend approximately 70 percent of his or her working day dealing with interface issues. Further research should be carried out into the IM of subcontractors within traditional construction.
- Offsite construction is underutilised in the construction industry. It is argued that procurement is one of the main protagonists inhibiting greater use of offsite systems (Nadim and Goulding, 2011). Further research should engage with the professions to identify and implement a new procurement route that will give equal consideration to both offsite and traditional construction methods.
- While offsite bathroom construction is gaining popularity in the hotel and student accommodation sectors, its use in other categories remains low. A future study could be carried out to identify the barriers and constraints to the uptake of offsite bathroom construction within other sectors, for example social and private housing.
- The design team is central to resolving physical interface problems within construction. However, this research has identified that, while designers are robust in technical aspects, they can often lack soft skills attributes. A study could be instigated to identify the soft skill requirements for designers and the consequent training required to address this need.
- Mechanical and electrical works are considered the main physical interface problem areas within the offsite bathroom sector. Furthermore, mechanical and electrical works are estimated to account for approximately 30 percent of the cost of a new hospital project. A study could be implemented that attempts to determine the main physical and organisational interfaces when using offsite forms of mechanical and electrical services within a hospital project.
- The offsite manufacturing environment is generally perceived as similar to a factory production line set-up and the domain of the manufacturer.

However, this researcher has viewed offsite environments that more resemble a construction site environment, but with a roof. A study could be conducted to identify the minimum requirements of an offsite manufacturing premises to deliver a quality product and to determine if the 'flying factory' approach discussed in Chapter 2 is a viable option.

7.7 Reflection on the PhD Experience

As I come towards the end of this both arduous and fulfilling journey, I am reminded of a favourite Beatles song, 'The Long and Winding Road'. The title of the song captures succinctly the devotion required of a part-time PhD student and the many turns you face along the way. I feel privileged to have been given the opportunity to research the topic of this thesis at Loughborough University, some miles south of my place of work, Glasgow Caledonian University. On reflection, the benefits of being a part-time student at Loughborough University have far outweighed the disadvantage of the travel to Loughborough, one of the main benefits being the opportunity to focus wholly on my research when down in Loughborough.

The process of research exposes you to many facets, such that it is a true learning experience. The skills I have acquired along the way have given me more confidence and a greater knowledge of the research process, which have been and will continue to be put to effective use in my career as a lecturer in construction management. I have become more proficient in the skills of searching and evaluating relevant literature and it has also enhanced my computer skills, although there is still room for further improvement in the latter. The opportunity to engage with fellow PhD students in the 'Hub' at Loughborough University and at conferences both inspired and motivated me to progress my research.

My considerable experience in the construction industry proved to be a benefit during the interview process. However, I also learned the importance of being a good listener when carrying out interviews. My numerous site visits to identify appropriate case studies using offsite forms of bathroom construction both confirmed and challenged my belief that the construction industry has made progress in the 15 years since I last had to put on my safety hard hat and boots for my day job. I am inspired that the construction industry has slowly moved to adopt offsite bathroom construction but dismayed that the physical, contractual and organisational interface problems that I experienced in the industry are still very much in existence. I hope that this research will contribute in a small incremental step to the increased use of offsite construction methods and a reduction in the interface challenges that blight the construction industry. My overriding reflection is of a very positive experience, which has allowed me to engage with numerous staff members at both Loughborough and Glasgow Caledonian Universities on the subject matter of my research.

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Appendices

Appendix A – Interview Proforma

Loughborough University

The aim of this interview is to review the effect of **process** and **people** factors on interface management in relation to offsite forms of bathroom construction.

I would like to record the interview – only for my own purposes – the notes will be anonymised and the recording deleted once the notes have been extracted – is this ok?

I am happy to give you a copy of the notes from this interview – would you like this?

Section A - General Questions

1. What is your name?

2. Please confirm if you are from a **trade** or **graduate** background and any **qualifications** you have?

3. What is the name of the company you are employed by?

4. What is the name of your current project?

5. What is the value of the project?

6. What is the duration of the project?

7. Please indicate the age range which best applies to you:

16-19 20-29 30-39 40-49 50-59 60-65.

8. What is your current position within the company?

9. How many years of experience do you have in the construction industry?

10. Of your response to Q 9, how many years would you estimate relates to **onsite bathroom/wet room construction**?

11. Of your experience in the construction industry, how many years of it would relate to **offsite methods of construction**?

12. What **areas of offsite construction** would this relate too? Please give examples if possible.

13. Of your experience of offsite construction what level of it would relate to any form of **offsite bathroom/wet room construction**? Please give examples.

Section B – Interface Management

In the context of this research IM is defined as: The management of the interrelationships between organisations. I'm now going to make some statements and would like you to comment as to whether you: **Strongly Agree/Agree/Have no view/Disagree/Strongly Disagree** – Please feel free to make any additional comments as well.

14. Effective Interface management is more important when using offsite solutions.

Strongly Agree Agree Have no view Disagree Strongly Disagree

Comments:

15. Using offsite solutions improves interface management on this project.

Strongly Agree Agree Have no view Disagree Strongly Disagree

Comments:

Section C - Process factors

16. Procurement : This question relates to the method used to procure a project in the UK, example are:

- Traditional
- Design and Build
- Construction Management
- PFI
- Other forms of the above.

a. The chosen procurement route can significantly affect interface management in bathrooms construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly Disagree.

Comments:

b. The chosen procurement route has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree

Comments: (**is there a route which is better suited to offsite?**)

17. Supply Chain management

a. Effective supply chain management significantly improves interface management in bathrooms.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

b. SCM has more influence on offsite than onsite bathroom construction.

Strongly agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree

Comment:

18. Whole Life Costing

a. Effective interface management will have an impact on the total cost of this project.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

b. Offsite bathrooms have a lower WLC than onsite bathrooms.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree

Comments:

19. Health and Safety

a. Health and Safety is significantly improved thro’ effective interface management.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

b. Good H&S outcomes are more easily achieved in offsite bathroom construction compared to onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

20. Design Management

a. Effective management of the design process significantly improves interface management.

Strongly Agree, Agree, Neither agree nor disagree, disagree or strongly disagree.

Comments:

b. Design Management can significantly affect interface management in bathrooms.

Strongly Agree, Agree, Neither agree nor disagree, disagree or strongly disagree.

Comments:

c. Design Management has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Have no view   Disagree   Strongly Disagree

Comments:

21. Lean Construction

a. Lean Construction significantly improves interface management in bathrooms.

Strongly Agree   Agree   Neither agree nor disagree Disagree Strongly disagree.

Comments:

b. Lean Construction has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   neither agree nor disagree   Disagree   Strongly disagree

Comments:

c. Offsite bathrooms on this project are more ‘Lean’ than onsite bathroom construction.

Strongly agree Agree Neither agree nor disagree Disagree Strongly disagree

Comments:

22. Sustainability

a. Sustainability is relevant to interface management?

Strongly agree Agree Neither agree nor disagree Disagree Strongly disagree

Comments:

b. Offsite bathrooms on this project are more sustainable than onsite bathroom construction.

Strongly agree Agree Neither agree nor disagree Disagree Strongly disagree

Comments:

23. Tolerance

i. Tolerances are significantly improved thro' effective interface management

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

b. Offsite units 'deliver' better tolerances than onsite bathrooms.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

c. Tolerances would be more problematic with offsite bathrooms than onsite

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree

Comments:

24. Quality

a. Quality is significantly improved thro' effective interface management.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

b. Quality on this project is more easily achieved in offsite bathroom construction compared to onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

Section D - People factors

25. Communication

a. Does effective communication improve interface management?

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree

Comments:

b. Effective communication has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

26. Role of the Project Manager

a. An effective project manager will significantly improve interface management in bathrooms.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

b. An effective PM has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree.

Comments:

27. Culture

a. A culture of co-operation significantly improves interface management in bathrooms.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

b. A culture of co-operation has more influence on offsite than onsite bathroom construction.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

28. Client/design team

a. A close client/design team relationship will significantly improve interface management in bathrooms.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

b. A close client/design team relationship has more influence on offsite than onsite bathroom construction.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree

Comments:

29. Perception

a. The perception of construction industry stakeholders is that interface management has little effect on the success of a project

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

b. The perception of stakeholders can significantly affect interface management in bathrooms.

Strongly Agree Agree Neither agree nor disagree Disagree Strongly disagree.

Comments:

c. The perception of stakeholders has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree Strongly disagree.

Comments:

30. Integration

a. Effective integration of personnel improves interface management in bathrooms.

Strongly Agree   Agree   Neither agree nor disagree   Disagree Strongly disagree.

Comments:

b. Effective integration of personnel has more influence on offsite than onsite bathroom construction.

Strongly Agree   Agree   Neither agree nor disagree   Disagree   Strongly disagree

Comments:

Section E – Ranking Questions

31. Of the 15 factors listed above, which 5 would you consider are the most important in relation to '**offsite forms of bathroom construction'** on this project, please **rank** in order of importance, with one being the most important.

Comments:

32. Of the 15 factors listed above, which 5 would you consider are the most important in relation to '**interface management of traditional bathroom construction'**, please **rank** in order of importance, with one being the most important.

    Comments

33. Of the 15 factors listed above, which 5 would you consider are the most important in relation to the '**interface management of offsite forms of bathroom construction' on this project**, please **rank** in order of importance, with one being the most important.

Comments

Section F – Supplementary Question

34. What do you consider is the main interface problem in relation to offsite bathroom construction on this project?

Comment:

Appendix B –Interviewee Coding

The eight projects were each identified from A to H. An interviewee from each project was allocated a number from 1 to 16, with 16 being the maximum number of interviewees from a single project. The third section of the coding related to the discipline code (see below) and finally a role code was applied (see below).

Example: B1/C/PM – Project B/ interviewee number one / client /project manager.

Discipline Codes

Client – C

Main Contractor – MC

Subcontractor – SC

Design team – DT

Manufacturer – M

Role Codes

Project Manager – PM

Operations Manager - OM

Construction Manager – CM

Quantity Surveyor – QS

Director – D

Site Manager – SM

Foreman – F

Architects –A

National Sales Manager – NSM

Consultant Civil Engineer – CCE

Consultant Mechanical Engineer - CME

Contracts Manager – Con M

Senior Project Manager - SPM

Design Manager – DM

Site Engineer – SE

Project Manager Electrical – PME

Project manager Mechanical - PMM

Production Manager – Pro M

Partner – P

Assistant Project Manager – APM

Building Services Manager – BSM

Quality Manager - QM

Appendix C – Sample of Frequency calculations from Minitab

Tally for Discrete Variables: Q14

Q14	Count	Percent
2	8	9.76
3	5	6.10
4	34	41.46
5	35	42.68
N=	82	

Tally for Discrete Variables: Q15

Q15	Count	Percent
1	2	2.44
2	8	9.76
3	8	9.76
4	47	57.32
5	17	20.73
N=	82	

Tally for Discrete Variables: 16A

16A	Count	Percent
2	6	7.32
3	6	7.32
4	44	53.66
5	26	31.71
N=	82	

Tally for Discrete Variables: 16B

16B	Count	Percent
2	14	17.07
3	16	19.51
4	42	51.22
5	10	12.20
N=	82	

Tally for Discrete Variables: 17A

17A	Count	Percent
2	1	1.22
3	5	6.10
4	29	35.37
5	47	57.32
N=	82	

Appendix D – Wilcoxon signed rank test calculations from Minitab

Wilcoxon Signed Rank Test: Q14

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
Q14	82	77	2831.0	0.000	4.500

Wilcoxon Signed Rank Test: Q15

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
Q15	82	74	2421.0	0.000	4.000

Wilcoxon Signed Rank Test: 16A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
16A	82	76	2773.0	0.000	4.000

Wilcoxon Signed Rank Test: 16B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
16B	82	66	1812.0	0.000	3.500

Wilcoxon Signed Rank Test: 17A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
17A	82	77	2987.5	0.000	4.500

Wilcoxon Signed Rank Test: 17B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
17B	82	58	1217.0	0.005	3.500

Wilcoxon Signed Rank Test: 19A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
19A	82	81	3321.0	0.000	4.500

Wilcoxon Signed Rank Test: 19B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
19B	82	73	2599.0	0.000	4.500

Wilcoxon Signed Rank Test: 20A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
20A	82	80	3240.0	0.000	4.500

Wilcoxon Signed Rank Test: 20B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
20B	82	77	3003.0	0.000	4.500

Wilcoxon Signed Rank Test: 20C

Test of median = 3.000 versus median not = 3.000

N for Wilcoxon Estimated

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
20C	82	69	1635.0	0.011	3.500

Wilcoxon Signed Rank Test: 22A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
22A	82	73	2675.0	0.000	4.000

Wilcoxon Signed Rank Test: 22B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
22B	82	65	2019.0	0.000	4.000

Wilcoxon Signed Rank Test: 23A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
23A	82	79	3141.5	0.000	4.500

Wilcoxon Signed Rank Test: 23B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
23B	82	75	2650.0	0.000	4.000

Wilcoxon Signed Rank Test: 23C

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
23C	82	77	1319.0	0.355	3.000

Wilcoxon Signed Rank Test: 24A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
24A	82	82	3403.0	0.000	4.500

Wilcoxon Signed Rank Test: 24B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
24B	82	76	2689.0	0.000	4.500

Wilcoxon Signed Rank Test: 25A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
25A	82	82	3403.0	0.000	5.000

Wilcoxon Signed Rank Test: 25B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
25B	82	57	559.5	0.034	2.500

Wilcoxon Signed Rank Test: 26A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
26A	82	82	3403.0	0.000	4.500

Wilcoxon Signed Rank Test: 26B

Test of median = 3.000 versus median not = 3.000

	N for	Wilcoxon	Estimated

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
26B	82	60	594.0	0.018	2.500

Wilcoxon Signed Rank Test: 28A

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
28A	82	80	3240.0	0.000	4.500

Wilcoxon Signed Rank Test: 28B

Test of median = 3.000 versus median not = 3.000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
28B	82	65	1057.5	0.925	3.0

Appendix E – Sample of qualitative analysis

Question 16A: The chosen procurement route can significantly affect interface management in bathroom construction	**Code**	Design and Built preferred method	Construction mangement not as strong in co-ordination and design	Procurement route based on cost will affect interfaces	Procurement route has no affect on IM	Form of contract will influence IM	Adaquate time to complete design	Early involvement with stakeholders improves IM	Improvred Quality control	Contractor led route preffered	offsite can reduce interfaces on traditional route	More significant Interfaces with tradional route	Nominated supplier

I think the design and build method of contracts works an awful lot better for offsite. Construction management tends to have its own issues, again the design team, and again, it's all about that strong co-ordination and that strong lead in design and development, which tends to be, for some reason, it tends to not be as strong with some construction managers than what it is with design and build contractor, and I think that's because the onous and responsibility for sustainability, for design management, that kind of thing, it's kind of diluted ever so slightly.	A1/C/PM/ 16A												
I think the design and build method of contracts works an awful lot better for offsite.	A1/C/PM/ 16A/S1	1											
Construction management tends to have its own issues, again the design team, and again, it's all about that strong co-ordination and that strong lead in design and development, which tends to be, for some reason, it tends to not be as strong with some construction managers than what it is with design and build contractor,	A1/C/PM/ 16A/S2		1										

I would probably agree, because I think whichever route you go down in terms of the procurement, or the funding of the building, straight away will affect how you look at it in terms of budgeting. So if a pod is more costly short term than a traditional build, so going to your plumb store and buying that pipe work and getting that plan, then you would probably find that budget is taken into account a lot more in terms of how you procure it so I would say that I would agree on that.	A2/C/OM/16A												
I would probably agree, because I think whichever route you go down in terms of the procurement, or the funding of the building, straight away will affect how you look at it in terms of budgeting	A2/C/OM/16A/S1			1									
No Comment	A3/MC/PM/16A												
Direct links between suppliers and managers, construction consultants	A4/MC/QS/16A							1					
If procurement's not in place or it's wrong then the job won't work, end of story, or it'll cost you a lot of money	A5/MC/PM/16A			1									
Because the procurement department, they won't design the bathroom, all they'll do is place the order for £2,400 as a bathroom and then obviously it's the part of the design team to design that pod.	A6/MC/SM/16A				1								

It can depending what contract it is	A7/SC/F/16A					1							
No Comment	A8/DT/A/16A												
The area here with procurement is when an area is sold by Walker Modular our sales guys have to get sign off, crucial. That then creates the bomb, the build of materials, that bomb then goes to our procurement department and that is the buy bomb, that has been signed off by our procurement, because we own our own distribution company. So the distribution, Walker Distribution basically then order that material and they then feed Walker Modular with the ordered goods. So when that projects, whether it be Watkin Jones or Grahams, these would have required a sign off by the main contractors. Once they've signed off, that's it no change, because what we have to get is a design freeze and we have a lead time effectively around 16 weeks on the number of projects we work with.	A9/M/NSM/16A						1						

A bit difficult for me to answer that in the 9 months I've been here. My tendency is to say yes, but probably qualifying that is….I've seen improvement since we have got more involved in the tender process upfront or supply chain, but I wouldn't say it's anything concrete, I think we have fine tuned our own internal processes and it might be our internal processes that have added the most benefit and I'm not quite sure.	A10/M/OM/16A												
A bit difficult for me to answer that in the 9 months I've been here. My tendency is to say yes, but probably qualifying that is….I've seen improvement since we have got more involved in the tender process upfront or supply chain, but I wouldn't say it's anything concrete	A10/M/OM/16A/S1							1					
I think we have fine-tuned our own internal processes and it might be our internal processes that have added the most benefit and I'm not quite sure. The actual bathroom module going into the building design and build I strongly agree that is the best form of doing it. It's a total control of the contactor.	A10/M/OM/16A/S2 B1/C/PM/16A								1				
The actual bathroom module going into the building design and build I strongly agree that is the best form of doing it. It's a total control of the contactor.	B1/C/PM/16A/S1	1											
It's a total control of the contactor.	B1/C/PM/16A/S2									1			

Procurement can have a lot to answer for. If they go down the route of cost only. They all see the product as a speck on a page and not in real life. So procurement, you have to be very canny on your procurement and what you're actually buying. As we all know, unless you have an input to the design, you aren't going to be able to change anything in say pods or whatever else, you get what the manufacturer puts in. We did, or we came across stuff that we felt, we got them to add on additional ball fix valves and all that to make the plumbers' life easy, but that was all because of the interface and I was involved in the procurement and whatever else. If you sit and rely on your procurement then every iota of supply chain for your contract, you'd be as well sitting in the house. You need to be involved in it.	B2/MC/PM /16A												
Procurement can have a lot to answer for. If they go down the route of cost only. They all see the product as a speck on a page and not in real life.	B2/MC/PM /16A/S1			1									
So procurement, you have to be very canny on your procurement and what you're actually buying. As we all know, unless you have an input to the design, you aren't going to be able to change anything in say pods or whatever else, you get what the manufacturer puts in.	B2/MC/PM /16A/S2							1					

We did, or we came across stuff that we felt, we got them to add on additional ball fix valves and all that to make the plumbers' life easy, but that was all because of the interface and I was involved in the procurement and whatever else. If you sit and rely on your procurement then every iota of supply chain for your contract, you'd be as well sitting in the house. You need to be involved in it.	B2/MC/PM/16A/S3									1			
Yes, to varying degrees and to varying people, design and build as Paisley was, I think benefitted the contractor, so it maybe improves, it assists them in that with the bathroom pod all the cost, it's a package, they buy it, they know exactly, there's no hidden surprises. It effects interface management in that respect that there's maybe, for them, less to consider, less to interface, less to deal with because it's a package that they are buying. where as on a traditional project it may well help us the designers, architects because again we're buying a product that we don't have to consider all, and that's bolts and all the baring factors because we're buying into a product and we don't have to then detail out all the different aspects of that.	B3/DT/A/16A												

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Absolutely, strongly agree. We always used to do everything traditional procurement and obviously the interface in traditional procurement between a construction project manager and the client side, the consultancy side which as I am, is obviously much more significant, traditional approach, much more with the design team, much more with the contractor. In the last kind of, probably, 5-8 years now the majority of projects are design and build and while the interface is still very important with the construction project manager, it's probably very different and not quite so involved if it's a traditional contract. So I think the chosen procurement absolutely…	B4/DT/PM /16A												
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I think because different procurement routes have, you know, who's responsible for the specification and traditional contract, the design team, you know, the architects, the engineer, we're all specifying elements for the client directly whereas design and build were working for a contractor and their could be other influences there, sometimes the contractors got a better handle on build-ability and that will help improve the interface management, they'll help us think about tolerance and things like that, whereas on the other hand clearly contractor has to think very much about construction costs etc, so they might look to perhaps reduce the spec to reduce the costs potentially, so that could effect the interface management in some ways. So I think I would agree with that.	B5/DT/CCE /16A												
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I mean, I would agree with that again because as you say, bathrooms is one of the tricky ones because if you can standardise that, then it makes it so much easier at the site stage whereas, and it also helps as well, folk from moving things about because there's a tendency, if you've got a pod, it's in, that's it, it's standard, if you have a traditional, the clients also kind of, I'll move that basin over there and, so.	B6/DT/CME/16A										1		
As long as it's, like the pod arrives and the tails are long enough to go in the service risers, really, it has to be that you know what you are getting before it gets here	B7/SC/ConM/16A												
As long as it's, like the pod arrives and the tails are long enough to go in the service risers,	B7/SC/ConM/16A/S1								1				
Really, it has to be that you know what you are getting before it gets here	B7/SC/ConM/16A/S2							1					

The problem with our pod procurement was they had a relationship with the contractor before we came, the whole institution was very adverse to anything, they were locked in the 1970's and 80's, they don't cope with change, anything new, and they went down the road of Taplans because Taplans do a sectional pod, which means, if they want to replace something or get something into an existing building, and in through an existing doorway to replace it, whereas the times they have to do that, if every 1 in a thousand, you know, so they had this mind set, they went with Taplans, nominated Taplans in some ways through the contract, there was no market research, so anybody…	C1/C/SPM/16A												1
No Comment	C2/C/PM/16A												
I really just can't see how the different methods make any difference	C3/MC/CM/16A				1								
This was procured on a traditional route and so in many regards we would let the client have a high degree of involvement and a design team, particularly the M & E sort of control the interface. In the end that sat too remotely for us to control. If it was a design and build route, we would have been much more hands on with that, it would have been much better managed.	C4/MC/DM/16A												

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No Comment	C5/SC/OM/16A												
No Comment	C6/DT/CME/16A												
No Comment	C7/M/D/16A												
I think the, personally, I still think it requires the same level of communication, same level of design, regardless if the processes on site or offsite, you still have to do your diligence and your quality checks and communicate and tell people what you want. You're still building, just building it offsite, so I don't think it makes any difference.	D1/C/PM/16A				1								

Our hands were pretty much tied just by being nominated as Caledonian have been due to them being within the Tune Group, 5,000 bedrooms over the next couple of years in the UK, but that was forced. We went down and visited the factory, which helped understand the process as well. I didn't go down, Frankie and Kevin went down, but what they did was they video it, dicta-phoned it, took millions of pictures, so it was like going down and you actually seen it going from pallets to full construction at the end.	D2/MC/PM/16A												1
Obviously if you went down the direct build on site it can change what labour and stuff you need.	D3/MC/SE/16A											1	
Yes well it's all very much down to materials and what the spec is. It depends on timescales to get materials, the higher spec the longer it takes to procure.	D4/MC/SM/16A							1					
No Comment	D5/SC/PME/16A												
Well basically procurement of the bathrooms or the pods is predominantly done by the principal contractor, so we just need like a little bit of involvement of how to interface with that with regards to them just buying the pod and what we're actually left with to connect up to. In reality 9 times out of 10 you don't want to even go into the pod because all your services should be on the outside.	D6/SC/PMM/16A												

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No. Because I think Easy Hotel, we were working with a set of brand-standers and they give you, that's the supplier, that's what you're working with and the same was with Tune Hotel. The client decides, even though it was design and build, both projects were design and build, that's what you're working with, so it was more of Thomas Johnson having a good relationship. Yeah, interface as you're calling it. Communication with them to make it work for both parties, because I think, Caledonian as well will see, well if they can do a good job then Tune will use us all the time and insitu bathrooms that they had to build on Tune, there was a few that they had to build insitu, they procured all the materials for that, for example, so all the toilets would match.	D7/DT/A/1 6A												

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Absolutely, strongly agree with that, yes. Because if it's design and build we don't have to get involved, basically it goes over to the contractor, so if you'd chosen the design and build procurement route then, on you go.	D8/DT/QS/ 16A	1											
Obviously because of the programme constraints you've got to be looking at suppliers of materials that are readily available, that the suppliers understand your needs in the cycle of construction. Obviously programme is the main thing.	D9/M/D/1 6A							1					

We do a lot of these, obviously design and build and we'll work with traditional like Tune. I would class Tune as a traditional because they're refurbishing basically a traditional building.	D10/M/ProM/16A	1											
No Comment	E1/C/P/16A												
I think the key thing about the procurement of the offsite bathroom pods if you like has been doing it earlier because there is a long lead time associated with them and when they actually get to site we're keen to get them to site as soon as possible because you're then building them in. Once they're onsite it releases a lot of other works and a lot of other trades, so I think the key elements is irrespective of the sort of type of projects or the type of contract it is, I think the key thing about everybody coming together which is maybe going into the sort of culture of everybody with a common goal, the common goal being get the details agreed, get the spec agreed, check that it works, check that it fits, check that everybody is happy with it and place the order type thing.	E2/MC/ConM/16A												
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The reason for it, the procurement route will dictate as to the budget constraints your under, specification requirements that you are under contract to meet , design and builds generally have a wee bit more give or take in it when pushing the actual design.	E3/MC/QS/16A												
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I would agree with that one. The reason being is some pods are big, how do you get them in the rooms, in a hotel anyway, you know what I'm saying, you can't build, you can't decorate if the pod isn't there. The size of them, see if they could come in a standard door.	E4/MC/SM /16A							1					
Yeah, of course, because the thing is when you do a bathroom pod the good point, the most interesting this is to be in the drawing, if your project is different from their competitors you are around 80% sure to get the project, so it's really, really important to be like, to do, for example, design and build, it's really important, and for management going to change related to the kind of project, like traditional, is I presume like more project, so you have more like a cosier relation with your client to get the project, design and build, you work with the architect and then you work with the main contractors.	E5/M/NSM /16A	1											
No Comment	F1/C/PM/1 6A												
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Well this particular project is a single stage D & B and based on stage, the exemplar drawings RIBA, Stage D exemplar drawings, which were quite detailed however didn't allow, in terms of the time between contact award being Christmas eve 2010, commencement onsite being the 9th of May, a very, very narrow window to design a prefabricated solution and had that been a different type of procurement route for the project you would have had a longer lead in and you would have certainly had an opportunity to have a more coherent and better tested……	F3/MC/PM /16A												
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No Comment	F4/MC/PM /16A												

It's key that procurement happens front end. It has to be…..design and procurement have to be very much front end and focused on the finish. You can't leave anything to chance in terms of it, and it's a good thing in terms of you don't want to be hanging out waiting for…….	F5/MC/APM/16A						1						
I would certainly agree because it may be that we're not able to do offsite manufacturing if you go with a traditional group because of the architect, the design team and the clients. So it might dictate how you construct the building, it certainly influences in it.	F6/MC/QS/16A					1							
No Comment	F7/MC/QS/16A												
Well in this job is design and build, so I suppose I would agree because if we're being told by someone else, if it's a different type of contract and we're being told what we need to supply, but we can't supply it, for example say SPS said they needed their risers to be a certain size but we couldn't make it work with our concrete panels we're tied, whereas because it's design and build here we make the….	F8/MC/CM/16A					1							

I think design and build is always my preferred one to be honest with you but the last few jobs I've been in are design and build. I'm not entirely sure. Neither agree or disagree, if the deign information is on the table from the word go from the traditional method then it's fine but design and build you tend to go with what you know and sometimes it can backfire.	F9/SC/PM/ 16A												
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No Comment	F10/SC/PM /16A												
This project was design and build and I think that the contractor would have been, well he would have been driving this one to go down a pre-fabricated route	F11/DT/A/ 16A	1											

I think that the procurement route will have an impact on interface management, particularly when the design responsibility is split between the clients team, whether it's in-house or a consulting design team and the contractors team, if I take an example of a traditional construction, the interface management and the ownership of that is clearly in one camp there and your architect who leads your design team want half of the clients. On a traditional construction, if we assume that there isn't a large degree of contractor design portions at least, they are in complete control, or they should be in complete control and they should be coordinating the interface management, not only between different design disciplines but indeed between different trades and indeed prefabricated elements off the works as well, if we look at a true design and build form of construction where you have the complete design responsibilities being passed over to the contractor, certainly the interface management, again from a design point of view is clearly allocated to the contractor and he should be well on top of insuring the coordination of different trade packages, forms of construction. Where you have a procurement route which does have a large split of perhaps client designed elements and contractor designed portions, for example, GCT or SPCC forms, if you find that perhaps the contractor design portion of the works interfaces with a client designed interface, you sometimes find there's a bit of friction there between who's	F12/DT/QS /16A										

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No Comment	F13/M/CCE												
Yes it would do, certainly, against traditional, where effectively you've got all the trades coming in and you're having to co-ordinate everything. Design and build you can still do a traditional construction with a design and build project and construction management is far more package related so, yes I would agree with that.	G1/C/PM/16A												
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Because it's often such a small area, you know, such a small room within a building, like here we've got like 76 toilets in this building…***Which, I bet the value is like a project on it's own!*** Well it is almost, yeah, so I mean if you were doing it, you know, as you would on other jobs, if you're sending in your M&E guys and your flooring man and your ceiling man and, you know, it's hard work.	G2/MC/PM/16A											1	
I'd agree with that one. Cost probably being the main one and clients perception.	G3/MC/SM/16A			1									
It all depends on the type of project as well, it has to lend itself to it's repetition work.	G4/MC/QS/16A					1							
No Comment	G5/MC/SM/16A												

I think 5/6 years ago when there was a bit more money in the industry and margins weren't as tight you could afford to package up areas onsite and leave all of the, say for example, all the finishes to one contractor he would co-ordinators his own works but now that we're having to split the procurement up into various packages and manage those interfaces it's certainly more challenging, and again, design and build wise, if you're relying on your architect to be providing you with the information, again fully co-ordinated and detailed that's different to if you're allowing a subcontractor to handle his own coordination, so I would say that's a big factor yeah.	G6/MC/DM/16A												
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Being an advocate of design and build, you've more flexibility in driving a choice	G7/MC/BSM/16A	1											
No Comment	G8/SC/PM/16A												
Well it does. We've changed our procurement strategy on the last few projects we have gone to full supply and fix for a lot of our suppliers and subcontractors. Whether that's different because its pod wall. Yeah we tend to split because the factory supplies it to us like a supplier, so we purchase it from them as a supplier albeit it's the same and there's obviously more scope for discussion. But we do procure projects that have a pod wall underneath I suppose is the difference as well. It's hard to sort of quantify it.	G9/SC/QS/16A					1							

I think especially if it's the offsite and it's the design and build where they can make changes it's a lot easier to make, it difficult when the pods have already been made to change that to suit. Because we had an issue where a ceiling was too low, and we had to call the metal frame in and cut all the panels down to make it fit in, so it was a big hassle doing that. Well the ductwork was to low but had already been fire protected and it would have cost more money than us splitting the pod. Yeah well our jobs were supposed to follow like for ceiling height and stuff it all got approved and Rotary were meant to co-ordinate with our drawings but they never	G10/SC/APM/16A												
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No Comment	G11/SC/D/16A												
No Comment	G12/DT/A/16A												
Yeah, I'd say, for example it's a contractor lead change on this project, so that's an example of, if it had been a traditional job obviously that would have not been the case, ok they could have proposed it I suppose but with the full procurement we've had it was more good luck the mechanism was there to allow the change to be made.	G13/DT/QS/16A									1			
Yes, I suppose if we went, you know, if you're in a traditional job then you're reliant on the clients design team to detail all the interfaces whereas on a design and build, which makes sense to me, it leaves the contractor to deal with the interfaces because they're onsite, they're dealing with it directly and I think you get a better product then.	G14/DT/P/16A	1											
No Comment	H1/C/PM/16A												
No Comment	H2/MC/SPM/16A												

I would strongly agree, and the background behind that would be, it’s all about carrying the risk, I think, carrying the risk, with the likes of here when you’ve got your procure CBS who do the lot, previous projects when we’ve procured bathroom, if you’re looking at bathroom pods specifically. In Media City we used traditional build bathrooms because it was only 24 of them but they were all high spec but different, whereas Athletes Village when we had, had 90 bathroom pods just on my block, 1800 pods on the whole job. In terms of the procurement route It can obviously make a difference to the way the interfaces are managed.	H3/MC/APM/16A												
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The chosen procurement route for it can, because the design and build of it, everybody needs to be working off the same hymn sheet with modular, i.e. your clients, the design, for one and then your module company that's building those modulars, there's certain restraints, so you might not be able to meet what that client wants all the time, so I think I agree that the chosen procurement route is important.	H4/MC/CM/16A	1											
No Comment	H5/MC/CM/16A												
It can, yes, because obviously depending on which of these routes you're going down, if you go down the traditional route it lends itself to having the offsite build with the pod and brought in and dropped in place, but also the market that you're going into dictates the quality and the product that you're actually going to deliver and that's also a key bit to it, isn't it, so whatever is required, so I would say I strongly agree.	H6/MC/BSM/16A												
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Well offsite obviously reduces that, I mean, that’s where your big plus is isn’t it. I suppose the way, I sort of thinking the way the contract’s set up to the prime cost, it’s a repetitive building, in theory there’s four types of accommodation we provide, so it’s a standard layout construction method with have been done over ten years, so you could argue it’s a tried and tested model, so if you’ve got the advantage of having built these modules, you know exactly what you’re going to get on your next job. Obviously part of that is dictated by the time you’ve got to build the things, so obviously apart from the time spent in the factory, the modular route is a lot quicker than the traditional build. I wouldn’t say a lot quicker, it’s quicker. Then obviously interfaces onsite as well, it reduces the need for all those trades to be there and all the problems that come off that.	H7/MC/QS/16A												

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Obviously part of that is dictated by the time you've got to build the things, so obviously apart from the time spent in the factory, the modular route is a lot quicker than the traditional build. I wouldn't say a lot quicker, it's quicker.	H7/MC/QS /16A/S2						1						
Then obviously interfaces onsite as well, it reduces the need for all those trades to be there and all the problems that come off that.												1	
We have come down the road of supply chain, we didn't originally start out with supply chain, we originally started out with wholesalers and who supplied us, we got very cute quickly to the fact that we could deliver a better product, cheaper if we kept the same labour and the same wholesales, they understood what we wanted, we understood the men who did the installations and so we eventually became quicker, better and cheaper.	H8/SC/PM /16A									1			

We've found, we'll say, certain suppliers, say they can do it and they can get the levels of what we require and the quality and we can get it when we need it, and it comes to fruition, the day, and it's not there. You find that you seem to have to go to the tried and tested larger ones that have got that facility.	H9/SC/PME/16A												1
No Comment	H10/SC/PMM/16A												
No Comment	H11/SC/SM/16A												
Yeah, I mean, Debus, it's a design and build with slam so lately they've been tendering stuff out so that does have an impact. Where we've got supply that we've used for a long time, you tend to get that there is a good interface because you've built a relationship with them, but when your company, say it's gone bust, other companies are coming in, you need to build that from scratch again so.	H12/DT/A/16A												1
Slam is probably more design and build and because of that, we're all under the Lend Lease hat, we do coordinate quite well together. He likes to get everybody together and thinking about it which is good, I think you're kind of construction management, I think everybody's left very isolated and I don't think there's the same…	H13/DT/CME/16A												

Slam is probably more design and build and because of that, we're all under the Lend Lease hat, we do coordinate quite well together. He likes to get everybody together and thinking about it which is good,	H13/DT/CME/16A/S1									1			
I think you're kind of construction management, I think everybody's left very isolated and I don't think there's the same	H13/DT/CME/16A/S2		1										
I'd agree with the lead time definitely	H14/M/QM/16A						1						
Yeah again cause if its built as a pod within our factories it has been taken right through to final stage as per as you would in a traditional build but before that leaves our factories we know everything as should be, everything is spot on right there's not going to be any leaks. When we get it to site You haven't just laid your floor and all of a sudden its got to come back up because you've got a pipe burst under the floor or.	H15/M/SM/16A												
Yeah again cause if its built as a pod within our factories it has been taken right through to final stage as per as you would in a traditional build but before that leaves our factories we know everything as should be, everything is spot on right there's not going to be any leaks.	H15/M/SM/16A/S1										1		

When we get it to site You haven't just laid your floor and all of a sudden its got to come back up because you've got a pipe burst under the floor etc.	H15/M/SM /16A/S2											1	
No Comment	H16/M/SM /16A												
	TOTAL	**18**	**2**	**7**	**7**	**8**	**4**	**11**	**4**	**10**	**5**	**9**	**6**

Appendix F – Problems and Solutions Tables

Table No 1 – Design Problems

Statement Number (Refer to Appendix A)	Description of Sub-theme	Numb-er of respo-nses
14	Clearly define interfaces	20
14	Design team problems	13
15	Important to get design correct early	11
16A	Adequate time to complete design	4
16B	Project type can influence use of offsite methods	10
16B	Insufficient time allowed to develop design	2
17B	Project type can influence form of SCM	5
17B	Design can influence the form of SCM	4
19A	Design has an influence on H&S and IM	2
19B	Design can influence H&S	5
20A	Poor design can be expensive in time and money	1
20A	Coordination of incomplete design is crucial	17
20A	By others-incomplete design	1
20A	Clients input at design meetings	3
20B	Lack of design management will hinder successful outcome	3
20B	Bad design costs money	5
20C	DM more relevant to offsite	24
20C	Design of onsite connections critical for offsite units	14
20C	Tolerances more critical in the design of offsite	10
23A	Design required to incorporate offsite and onsite tolerances	13
23C	Design complete for manufacture	13
24B	Design impacts on quality	4
25B	Drawings form of communication	4
28A	Client/design team influence on offsite methods	3
28A	Main contractor relationship with client/design team	10
28B	Client/design team have little opportunity to make alterations to offsite	8

Table No 2 - Procurement Problems

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
15	Dependant on procurement method	4
16A	Procurement route based on costs will affect interfaces	7
16A	Procurement route has no effect on IM	7
16A	Construction management not as strong in co-ordination and design	2
16B	Procurement route established before methods of construction detailed	2
16B	Choices of procurement route, cost and time the main deciding factors	9
17A	Influenced by procurement method	6
17B	Influenced by cost	5
26B	PM influence dependant on procurement route	2

Table No 3 – Manufacture Problems

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
15	Buildability problems	6
15	Offsite solutions made IM worse	5
15	Requires good planning and organising of the total process	9
16B	Offsite method does not lend to alterations onsite	2
16B	Buildability and logistics can influence the use of offsite methods	10
16B	Offsite methods more problematic on traditional route	5
16B	Tolerances must be identified	2
16B	Offsite constrains contractor in profit margins	1
16B	Risk factors mainly with contractor and manufacturer	3
17B	Problems with supply chain can have a greater impact on offsite	8
17B	Offsite quality control issues	4
19A	H&S rules not applied in a factory as on site	1
20C	Volume of offsite units demands greater level of	8

	DM	
20C	Site architect little involvement with design of offsite	4
20C	Offsite less flexible to design changes	10
23A	Offsite units demand a focus on onsite tolerances	18
23B	Offsite units require more pre-planning to achieve required tolerances	1
23B	No flexibility in tolerance levels of offsite units	10
24B	Offsite environment does not produce better quality	3
24B	Tolerances of offsite materials can affect quality of offsite	5
26B	Offsite demands earlier involvement and planning by the PM	8

Table No 4 - Client/Project Manager Problems

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
17B	Client influence on SCM	3
19A	Poor relationships will affect H&S and IM	1
20A	Co-ordination of client requirements important	8
20B	Client relationship with manufacturer	2
25A	English not first language	2
26A	Project managers vary in the form they take	8
26A	Project managers relationship with client	6
26B	PM influence will depend on input by client and design team	4

Table No 5 - Communication Problem

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
25A	Lack of Communication can create problems	11
25A	Key: Communication impacts on all aspects of process	24
25A	Can good communication be taught	1

Table No 6 - On Site Problems

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
16A	More significant Interfaces with traditional route	9
16B	The more interfaces the more problem areas	5
17A	Relationships with supplier	20
17A	S.C.M. more relevant to traditional bathroom construction	1
17B	On site requires more co-ordination	12
19A	Craning of units into position on site	1
19A	Manual handling reduced through IM	5
19B	On site more hazards	12
19B	Craning units on site more hazardous than traditional build	9
20C	On site involves many more different organisations	2
23A	Onsite bathrooms require greater tolerances	2
23A	Quality can be affected by tolerances issues	2
23B	On site preparation and installation works crucial to offsite bathrooms	21
23B	On site tolerances more variance than offsite	12
23C	Onsite environment makes control of tolerance more difficult	8
23C	Tolerances more problematic with onsite than offsite	5
23C	Tolerance issues with offsite units more difficult to resolve onsite	16
24A	The amount of snagging can affect quality	3

24A	The lack of IM will adversely affect quality	6
24B	On site environment can result in poor quality	25
25B	On site bathroom construction requires a greater level of communication	16
25B	Late decision making more acceptable in onsite forms	8

Table No 7 – Design Solutions

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
14	Most important to co-ordinate design early	28
17A	Co-ordinated flow of information approach	11
17A	Standardisation approach	4
20A	Important to allocate sufficient time for design	7
20A	Design manager important to co-ordinate design	5
20A	Contractor led design	2
20A	Make the basic design simple	2
20A	Good communication important to the effective management of design	15
20A	Review design prior to construction	12
20A	Influence of BIM on design	2
20A	Important to consider buildability	12
20B	Early involvement of all parties aids design management of interfaces	5
20B	Client input important to design	4
20B	Good design promotes less interface problems	15
20B	Good design management can promote good sequencing	3
20B	Proto-types aid design management of interfaces	2
20C	Offsite requires earlier participation in design	5
23B	Design important to achieving installation of offsite bathrooms within tolerance	4
24A	Co-ordination of design fundamental to IM of quality	3
28A	Positive and early client/design team involvement	49

Table No 8 – Manufacture Solutions

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
14	Benefit of manufacturers expertise	12
15	Manufacturers expertise	12
15	Offsite a faster production process	5
15	Offsite methods improves IM	8
15	Less interfaces improves IM	7
15	Aids programme and time of delivery	4
15	Less snagging works	3
16A	Improved quality control	4
16B	Benefit from manufacturers experience	16
16B	Manufacturers influence on supply chain	3
16B	Offsite a faster and cheaper process	7
17A	Build mock-up	2
17B	Single modular company advantageous to SCM	20
19A	Reduced site work improves H&S	13
19B	Offsite promotes greater level of pre-planning	2
19B	Less interfaces promotes less risks	4
19B	Less labour on site, less risk	10
19B	Factory more controlled environment less hazards	38
19B	Safety record in factory	6
19B	Offsite promotes less manual handling	4
20A	Build mock-up aids design interfaces	2
20A	Important to consider maintenance	1
20A	Quality of manufacturer design critical to success of units	4
20C	Clients requirement better achieved with offsite	4
23A	Offsite units manufactured to a more controlled tolerance	18
23B	Offsite units manufactured to a high level of tolerance and quality	29
23C	Tolerance easier controlled in factory	24
23C	Better quality and less snagging achieved with offsite tolerances	3
24A	Inspection process	5
24A	Offsite manufacture aids quality	5
24A	Samples and mock-ups aids quality	1
24B	Offsite environment produces better quality	51
25B	Offsite environment makes for simpler forms of communication	12
28B	Early involvement by Client/design team required for offsite bathrooms	32

Table No 9 – Management Solutions

Statement Number (Refer to Appendix A)	Description of Sub-theme	Number of responses
14	Early involvement and procurement	9
14	Teamwork and good communication	14
15	Good communication and teamwork	11
16A	Form of contract will influence IM	8
16A	Design and built preferred method	18
16A	Contractor led route preferred	10
16A	Early involvement with stakeholders improves IM	11
16B	Form of Contract more of an influence than procurement route	2
16B	Construction management preferred route	4
16B	Communication important regardless of procurement route	1
17A	Partnerships	10
17A	Influenced by good communication	4
17A	Requires good management and planning	12
17B	Management of the supply chain important to its influence	15
19A	Good communication and relationships have a positive effect on H&S and IM	19
19A	Effective management important to good H&S	12
23A	Procurement route can influence the IM of tolerances	2
23A	Co-operation and communication by supply chain required to IM tolerances	10
23A	Interfaces management is about understanding tolerances	4
23A	Main contractor pivotal in IM of tolerances	5
23C	Effective co-ordination and communication important in resolving tolerance issues	7
24A	Client input aids quality	1
24A	A team work co-ordinated IM approach aids quality	13
24A	Communication important to aid quality	6
24A	Good management aids quality	7
24B	Clients input can influence quality	3
24B	People influence quality	2
24B	Offsite bathrooms more sustainable quality	1
25A	Clear, concise and continuous communication	31
25A	Verbal communication	20
25A	Inter-relationships between teams	9
25B	Early communication most important with	15

	offsite form	
26A	Team work rather than the single influence of the PM	11
26A	Project managers leadership can improve IM	24
26A	An effective PM requires good communication skills	24
26B	PM influence will be influenced by communication	9
26B	PM involved in logistics and onsite co-ordination of offsite	6
28A	Communication between client/design team and main contractor important	17
28A	Experience of client can have an impact	23
28B	Main contactor relationship with client/design team	7

Appendix G – Analysis of all Findings

No		Procurement	Supply Chain Management	Health and Safety	Design Management	Tolerance	Quality	Communication	Role of the Project Manager	Client/ Design Team
1	The main finding from the sub theme 'early design coordination' is that the procurement route must allow input at the design stage from the contractors and manufacturers associated with the offsite bathroom, to minimise interface problems.	1			1					
2	The main findings associated with sub-factor 'Clearly defined interfaces' are that consultants need to co-ordinate and communicate interfaces early in the design process before the procurement process, otherwise the benefits of offsite will be lost. Furthermore, the tender documents should allow for a mock-up of the bathroom to be constructed, to clearly identify potential interface problems.	1			1			1		1
3	The main findings associated with 'Manufacturers expertise' suggest that designers should look to incorporate as much offsite processes into a project as is possible, this should equally apply to refurbishment projects. However, regardless of the manufacturer's expertise, the main contractor should maintain close co-ordination and supervision of the manufacturing process and not adopt an 'out of sight out of mind approach'.								1	1

4	The main findings attributed to sub-factor ‘important to get design correct early’ suggest that the procurement route must allow for the client, main contractor and manufacturer to liaise during the design stage, to ensure the client has been informed of the offsite bathroom design options available to the project.	1			1			1		1
5	The main findings regarding ‘good communication and teamwork’ highlight the importance of early and effective communication between the client, design team, contractors and manufacturer when using offsite bathroom construction. This level of communication should be maintained throughout all the stages of the project, also the development of a teamwork approach is vital not only in the factory but between the manufacturer and the contractor to ensure the successful installation and operation of the offsite bathroom onsite.							1		1
6	The main findings regarding ‘Design and build the preferred method’, confirmed that the total control acquired by the main contractor from the design and build procurement route, reduced the level of interface problems on the project, furthermore, it was considered important that the main contractor and manufacturer develop and maintain good relationships with clients, to inform clients of the merits of offsite bathroom construction.	1							1	1
7	The main findings associated with ‘Early involvement with stakeholders improves IM’ suggest that the main contractor and all subcontractors with an input to the offsite bathroom construction should be involved at the design stage. Furthermore, the lead in time for design and installation of offsite bathrooms is critical to the programme, due to the configuration of the built.				1				1	
8	The main findings regarding ‘Contractor led route preferred’ suggests that with the main contractor in total control of the design and build, this allows for greater levels of innovation and adaptability to be introduced into the project. Also the lines of communication and co-ordination were more direct, which aided the management of interfaces.							1	1	
9	The main findings regarding sub-factor ‘The procurement route makes no difference to offsite or onsite construction’ would suggest that the direct cost of the project is considered more important than the form of procurement. Furthermore, the inference from the interviewees would suggest that the procurement route was no influence on the specification, design, quality and interfaces. However,	1						1		

	the importance of good relationships was offered, which can be influenced by the procurement route chosen.									
10	The main findings regarding sub-factor 'Design and Build preferred route for offsite' would suggest that by integrating design and construction under the control of the main contractor, the 'single point of responsibility' will have the benefits of reducing the level of interfaces, allow for better control of the programme of works and lead to safer methods of construction.			1	1				1	
11	The main findings regarding 'relationship with suppliers', highlight the importance of 'soft' issues such as communication and co-ordination, it was also suggested that small well informed supply chains were preferred by main contractors to large supply chains as good relationships with suppliers can often lead to repeat business some times in the form of partnering arrangements. Furthermore, while good relationships between the main contractor and manufacturer were viewed as beneficial to offsite bathroom, it was also important to manage problems head on with a level of open communication and transparency, endeavouring to maintain a good working relationship.		1					1		
12	The findings regarding 'requires good management and planning', suggests that efficient management and planning are interrelated with effective communication, in particular when important milestones require to be met and non-English speaking suppliers are part of the supply chain. Conversely, ineffective communication between members of the supply chain will result in poor levels of management and planning. Consideration must be given to managing in-house subcontractors, which can be problematic and the strategy for integrating changes in personnel during the project.		1					1	1	
13	The main findings regarding 'Co-ordinated flow of information approach' suggests that poor management of the flow of information is a primary cause of interface problems and that the management of an integrated supply chain that communicates effectively is paramount to ensure that the correct information and sequencing of operations is timeously available to the correct members of the supply chain, with the objective of efficiently managing potential interfaces problems.		1					1		
14	The main findings from the sub theme 'Partnerships' would suggest that members of the supply chain that are engaged in projects where integration is encouraged will tend to form unofficial partnerships, which can prove to be as effective as contractual partnerships. Training and education on all aspects of		1						1	

	offsite bathroom construction should be disseminated to all members of the supply chain. Main contractors should be encouraged to reduce the size of their supply chain data bases, to a level that would give subcontractors a more sustainable opportunity to work in a more trusted and integrated environment with the main contractor.									
15	The main finding regarding 'the same influence for both' suggests that the same level of management of the supply chain is required regardless of whether the subcontractor is located on site or working offsite, to ensure effective management of the interfaces in bathroom construction.		1							
16	The main findings regarding 'single modular company advantageous to SCM' suggest that having a single point of contact with the modular company benefited the relationships, the quality of the product and considerably reduced material wastage within the process. The offsite process was considered to be better organised, compared to the frantic process onsite, which continually appeared to re-invent the wheel, leading to an inferior quality bathroom. Furthermore, a number of main contractors consider that the only contact they require to have with their manufacture is providing delivery dates, this practise could be interpreted as ineffective management.		1				1			
17	The main finding regarding 'Good communication and relationships have a positive effect on H&S and IM' is that effective communication is the main catalyst for building strong relationships between stakeholders, this will have a positive effect on the interfaces within the project, which in turn will promote a health and safety culture, whereby all parties are pulling in the same direction for the success of the project.			1				1		
18	The main findings regarding 'reduced site works improves H&S' are that every effort should be made to minimize the works that are required to be executed on site. Offsite construction can be better co-ordinated, controlled and sequenced, thus promoting a safer working environment compared to onsite. The correlation of less work on site, requiring less labour resulting in a reduction of accidents, provides a strong moral argument for adopting offsite practises where possible within a project and in particular with bathroom construction.			1						
19	The main findings regarding 'effective management important to good H&S' are that less bureaucracy and more pragmatic management of the works will be more effective in the management of H&S.			1					1	

	When meeting with subcontractors, H&S should be a specific item on the agenda and managed proactively by encouraging subcontractors/manufacturers to contribute on an equal footing in the areas of H&S and interface management, rather than being reactive and continuing with the blame culture, which is more the norm in the main contractor/subcontractor relationship. Finally, efficient management of the sequence of the works, normally equates to a safer method of working, which could be construed as a positive argument of offsite working.									
20	The main factors regarding ‘ Factory more controlled environment, less hazards’ is that by minimizing work carried out on site, this will have the positive effect of reducing accidents overall. Moreover, the work force in the factor is more consistent and familiar with the environment, whereas onsite the workforce is more transient and the environment is continually changing, implying that onsite is a more hazardous environment. Furthermore, offsite bathrooms demand a high level of pre-planning to eliminate interface problems in comparison to the normal onsite process, which in turn will reduce H&S risks.			1						
21	The main findings regarding ‘They both have safety risks’ is that offsite and onsite environments have different safety risks. Safety risk assessments should be applied to both environments and a pragmatic approach applied to enforce the appropriate safety standards to each environment. Furthermore, assertions should not be made that the offsite environment will be a safe environment, rather random safety checks should apply to both offsite and onsite.			1						
22	The main findings related to ‘Onsite more hazards’ suggests that with the number of trades working within a small bathroom area on site, accidents are more prevalent. While the majority of injuries relate to minor accidents such as cut fingers and dust in eyes, there is also a greater occurrence of falls from heights due to onsite working practices when compared to offsite bathroom construction.			1						
23	The main findings regarding ‘coordination of incomplete design is crucial’, is that incomplete design will always result in problems occurring, which in the main will manifest as interface problems, due to the strong link between design and interface management . Stakeholders with an input to the design must be encouraged and allowed to participate early in the design process. Particular attention needs to be given to the coordination and integration of the M&E element of the design.				1					

24	The main findings regarding ‘good communication important to the effective management of design’ is dominated with the importance of early communication with the supply chain, not only electronically but also face to face and to encourage the art of free hand drawing, which is being lost due to the dominance of electronic formats such as CAD. All with the intension of resolving design problems and enhancing relationships among the relevant parties.		1		1			1		
25	The main findings’ regarding ‘Important to consider buildability’ suggests that the complexity of construction should considered buildability during the design stage and not ignore it until the construction stage. Moreover, most buildability issues result in interface problems.				1					
26	The main findings regarding ‘Review design prior to construction’ suggest that the additional time spent by the design team effectively reviewing the design before issuing for construction will reduce potential interface problems. Manufacturers must be allowed to input early into the design process, preferably communicating periodically on a face to face basis and the main contractor should liaise with the manufacturer during the design process to ensure the offsite/onsite connectivity is understood.				1			1	1	
27	The main findings regarding ‘Good design promotes less interface problems’ is that bad and incomplete designs have the potential to cause interface problems. With bathrooms being highly serviced areas the mechanical and electrical connections were considered of high importance to avoid costly and time consuming abortive works. The design team should promote the integration of all designers, in particular the M&E consultants when designing bathroom.									
28	The main finding regarding ‘Design management not any more important to bathrooms’. Is that the process it is of equal importance to all areas of the project and therefore the management of the bathroom design is not given any preferential focus in comparison to other areas of the project.									
29	The main findings regarding ‘design management same importance for both’ is that the parts of the design, regardless of whether constructed offsite or onsite are all interrelated, confirming that design management is not considered more important to offsite in comparison to onsite bathrooms. This finding concurs with the finding in 5.12.2.2, which suggested that the management of the design is of equal importance to all areas of the project.				1					

30	The key findings regarding ‘design management more relevant to offsite’, suggests that while design management is relevant to the whole of the project, when volumetric bathroom are part of the design, it is most important to give priority to the management of their design as early agreement and design freeze are critical to allow manufacture to proceed in accordance with the programme. Furthermore, last minute changes to volumetric bathrooms would prove to be costly and time consuming.				1					
31	The main findings regarding ‘design of onsite connections critical for offsite units’, while M&E and drainage connections are the dominant problem areas, other trades such as joiner work must also be considered, when installing offsite bathrooms on site. Furthermore, the onsite connection problem is likely to be compounded by the number of units installed.				1					
32	The main findings from sub-factor ‘Offsite units manufactured to a more controlled tolerance’ suggest that the factory environment is more conducive to implementing the control measures necessary to achieving the tolerances required of the offsite units. Furthermore, the units should all be manufactured to the same consistent standard.					1				
33	The main findings from sub-factor ‘Offsite units demand a focus on onsite tolerance’ suggest that in the main tolerance and interface issues generally result from inaccurate onsite works, which further indicates that onsite tolerances are less stringently controlled than offsite tolerances and that the onsite work force have a different mind-set to tolerances than the offsite workforce. This would suggest that manufacturers should be involved in onsite inspections as they will be more knowledgeable about the installation of their product than the main contractor.					1				
34	The main finding from sub-factor ‘Design required to incorporate offsite and onsite tolerance’ suggests that consideration must be given not only to the tolerances of the manufactured bathroom but equally to the entire room incorporating the bathroom, otherwise problems will rebound. Furthermore, the incorporation of manufactured offsite bathroom on site will require a different mind-set from the actors involved due to working to more stringent tolerances.					1				
35	The main findings from sub-factor ‘Offsite units manufactured to a high level of tolerance and quality’ suggest that the environment, which lends itself to an industrialised mass production process, where by less human activity is incorporated into the process than is demanded of the onsite process, results					1	1			

	in the production of a quality bathroom within the tolerance allowed. Also of significance is the consistency of labour involved in the offsite process, compared to the transient labour involved in the onsite equivalent. However, the differentiation of the tolerance levels of the onsite floor to the matching manufactured bathroom floor may result in remedial works.									
36	The main findings from sub-factor 'Onsite preparation and installation works crucial to offsite bathrooms' suggest that the installation of volumetric units such as pods should be installed by skilled labour, trained in the installation process and that consideration should be give during the design process to incorporated engineered propriety systems to the adjoining surfaces of the pods, which can be constructed to tolerances compatible with manufactured pods.				1	1				
37	The main findings from sub-factor 'Tolerance easier controlled in a factory' suggest that the factory environment of a production line will produce offsite bathrooms within the required tolerance. However, not all offsite production is carried out within a production line process and therefore a greater level of monitoring may be required by the main contractor than they had envisaged by using offsite production.					1			1	
38	The main findings from sub-factor 'Tolerance issues with offsite units more difficult to resolve onsite' suggest that out of tolerance units do not lend themselves to an onsite solution, other than possible replacement. Furthermore, incomplete bathroom pods create difficulties when completion is carried out on site due to the differential of tolerance allowance between offsite and onsite works.					1	1			
39	The main findings from sub-factor 'Tolerance issues with onsite bathrooms easier to resolve and accepted' suggest that tolerance issues onsite can be more easily resolved 'more forgiving' in comparison to offsite manufactured bathrooms, sometimes at the expense of the resulting quality of the bathroom. Provided the out of tolerance components of the onsite bathroom appear visually correct, the client will generally accept the onsite bathroom.					1	1			1
40	The main findings from sub theme 'Design Complete for manufacture' suggest that all stakeholders must be aware of the importance of design management in identifying tolerance/ interface issues when incorporating offsite bathrooms. The design team must be made aware of the strategic importance of early design completion for both offsite and onsite elements that relate to the offsite				1	1		1		

	bathroom design, to avoid costly variations to the project.									
41	The main findings from sub-factor ‘A teamwork co-ordinated interface management approach aids quality’ are that coordination and accountability of the members of the team will aid the management of interfaces between trades and contribute to a quality product. At the heart of a team work approach is organisational interface, whereby all members of the team communicate openly within a transparent environment.						1	1		
42	The main findings from sub-factor ‘Good management aids quality’ are that effective and efficient management of interface issues will positively contribute to the quality of the final product. Moreover, proactive management is required throughout the project to maintain the specified level of quality with the added benefit of reducing the level of snagging.						1		1	
43	The main finding from sub-factor ‘Offsite environment produces better quality’ is that if the working environment is compatible to the standards of a modern manufacturing factory and quality procedures are followed and checked a quality product should consistently result. A strong link exists between identifying and resolving interface problems during the design stage before manufacture and producing a quality bathroom				1		1			
44	The main findings from sub-factor ‘Onsite environment can result in poor quality’ are that inclement weather and site conditions are generally not conducive to building a quality bathroom. A total reliance on human endeavours, with trades working over each other in congested areas all contribute to a greater level of snagging, resulting in bathroom constructed to a poorer quality compared to the offsite equivalent. Notwithstanding the effects of the environment on the quality of onsite bathrooms, a significant effect will be the level of ‘quality control’ exerted on site, which is professed by interviewees not to be as stringent as performed in a factory.						1		1	
45	The main findings from sub-factor ‘Quality achieved onsite is equal to offsite standards’ are that a competent contractor with effective site management that engage with pre-planning and quality control should be able to construct a quality bathroom. Furthermore, some offsite facilities are no more than a construction site within a ‘tin shed’ and therefore require efficient management not only from the manufacturer but also the main contractor to achieve the required quality.						1		1	

46	The main findings from sub-factor ‘Clear, concise and continuous communication’ are that it is important that client’s clearly communicate the what, when and how to the design team. It is the project manager that is required to promote a culture of direct and concise communication with all stakeholders. The contract programme and method of recording progress on the project should be disseminated to all parties. While email is now the dominant method of written communication, it should not be allowed to discourage verbal communication and human contact, which is central in building good relationships between actors on a project.							1	1	1
47	The main findings from sub-factor ‘Impacts on all aspects of the process’ are that effective and efficient communication is extremely important and central to the success of a project. There is a danger that the art of verbal communication is being lost to email, as many stakeholders prefer to avoid face to face contact to resolve disputes. While the industry has become very contractual, often unofficial means of communication are very effective in resolving interface problems that could potentially impact on the project.							1		
48	The main findings from sub-factor ‘Verbal communication’ are that informal communications has a part to play in building and maintaining good relationships within the project. Face to face communication can more readily resolve interface problems. However, consideration should be given to the interpretation of verbal communication, as stakeholders do not always identify with the same conclusions. Furthermore, stakeholders must realise that verbal communication does not just mean ‘talking’ that ‘listening’ is equally important.							1		
49	The main findings from sub-factor ‘Makes no difference’ are that communication is of equal importance to both offsite and onsite bathroom construction. Regardless of whether the bathroom is constructed onsite or offsite, the correct information/instruction must be made timeously to suit the method of construction. Furthermore, good communication promotes better relationships, which can have a positive influence on the management of interfaces.							1		
50	The main findings from sub-factor ‘On site bathroom construction requires a greater level of communication’ are that onsite bathroom construction requires a greater number of subcontractors onsite compared to offsite and therefore there will be more lines of communication to manage the							1		

	process. However, the level of communication needed for offsite bathrooms is of equal importance.									
51	The main findings from sub-factor ‘Early communication most important with offsite forms’ are that design management and communication are inextricably linked to facilitate early design of offsite forms of bathroom construction. Furthermore, the relationship of design management and communication should also be encouraged for onsite bathroom construction, to minimise incomplete design.				1			1		
52	The main findings from sub-factor ‘The project manager’s leadership can improve interface management’ are that the attribute of leadership is fundamental to the role of the project manager. Unfortunately the project manager problem solving experience is not always utilised at the pre-construction stage, which would help to identify potential interface problems. Also the leadership trait should also be common to the manufacturers and subcontractors project managers.	1							1	
53	The main findings from sub-factor ‘An effective project manager requires good communication skills’ are that there is a strong link between an efficient project manager and having effective communication skills to co-ordinate and lead a successful project. The project manager should apply his/her communication skill to all levels of stakeholders connected to the project. Conversely, a project manager lacking in good communication skills will have a detrimental effect on the co-ordination and management of interfaces. Furthermore, project managers should be aware of the tone and manner by which they communicate.							1	1	
54	The main findings from sub-factor ‘PM influence the same for offsite and onsite’ are that regardless of whether the process is offsite or onsite the effectiveness of the PM is paramount to the success of the project. However, where the bathrooms are constructed offsite, the PM will require to adapt his/her skill-set to a manufacturer environment to maintain his/her effectiveness and not abdicate his role to the manufacturer.								1	
55	The main findings from sub-factor ‘PM will have more influence in the onsite bathroom construction’ suggests that PM’s from a trade background are more comfortable with the onsite bathroom process, which has a greater level of flexibility compared to offsite bathrooms. And when faced with managing the offsite process PM’s from a trade background tend to negate the responsibility for the								1	

	manufacturing process entirely to the manufacturer, whereas PM’s from a university education will be more likely to engage with the manufacturer during the process.									
56	The main findings from sub-factor ‘PM will have less influence in the offsite bathroom construction’ provided a mixed response, from PM’s happy to relinquish direct involvement of that part of the project to the manufacturer as they consider that they have no control over the offsite process, to the PM’s that considers its important to maintain a level of control by closely monitoring the manufacturing process and delegating a member of the main contractors team to interact with the manufacturer. The latter is the method that modern PM should adopt to ensure the quality and timeous delivery of the offsite units.						1		1	
57	The main findings from sub-factor ‘Positive and early client/design team involvement’ are that early integration of the client with the design team can foster good communication and co-operation between the parties, such that the design complies with what the client wants. The client’s involvement in the project team should be positively encouraged rather than discouraged by the design team, which would create an inclusive project team, whereby lines of communication are open to all.							1		1
58	The main findings from sub-factor ‘Experience of client can have an impact’ are that it is very important for the design team to forge good relationships with the client, which in turn will benefit the decision making process. Also important is harnessing the client’s knowledge of the end users, which can have an effect on the design and a positive influence in resolving interface issues, this approach should also be applied to inexperienced clients.									1
59	The main findings from sub-factor ‘Communication between client/design team and main contractor important’ are that ease of communication between the three parties promotes an open forum for face to face and other forms of verbal communication. Transparent communication between the parties contributes to building good relationships that make interface problems easier to resolve. The phrase ‘By Others’ should be avoided on drawings, as it is not considered a positive form of communication, rather it denotes incomplete design.							1	1	1
60	The main findings from sub-factor ‘No difference/teamwork’ is that a good working relationship is						1			1

	important between the client and design team, which should fosters a team spirit with the outcome of a quality product regardless of whether the bathroom is constructed onsite or offsite.									
61	The main findings from sub-factor ‘Early involvement by client/design team required for offsite bathrooms’ is that early involvement of the client in the decision making process should be encouraged to progress the design early, which is very important when incorporating offsite bathrooms in the design. Of equal importance is encouraging the client/design team to visit the offsite premises, which should also help them to visualise the product that will be installed and make any subsequent decisions to allow the design to be finalised.				1			1		1
62	The main problems identified relating to design, suggest that the procurement route can affect the time allowed to complete design, which will have an effect on designing out interface problems. Furthermore, the type of project can influence the chosen procurement route, which may in turn influence the relationships between the actors involved, to the detriment of not considering the use of offsite bathrooms.	1			1					
63	In summary, the main problems associated with the procurement route suggest that as it is established before the design, this will affect the form the supply chain will take, which may restrict the PM’s influence on the choice of offsite bathrooms. Design and Build was considered the only current procurement route aligned to allowing the PM to influence incorporating offsite bathrooms in the design.	1	1		1				1	
64	The main problems relating to the manufacturing process identify with the architects lack of involvement in the manufacturing process, suggesting it can have an effect on the offsite/onsite coordination. With the strict tolerances on manufactured units, this can aggravate the resulting interface problems on site. If the PM does not manage the manufacturing process as diligently as the onsite works, problems such as health and safety can result.			1		1			1	1
65	The main problems identified in the client/PM connection, can result when the client takes a silent role and does not engage as a member of the team. Moreover, poor relationships between the parties will have a negative effect on the adoption of offsite bathrooms.								1	1
66	In summary, the main problem identified in relation to communication, is that while communication is							1		

	a ‘key’ component of all factors, the level of meaningful communication can considerably vary among actors on a project such that many consider communication to be solely verbal/written, whereas the ability to listen is of equal importance and often ignored.									
67	The main problems with the onsite works associated with offsite bathrooms, suggest that onsite tolerances are required to be compatible with offsite tolerances, however, the onsite environment makes this difficult to achieve. Furthermore, the early decision making required for offsite bathrooms is required of the corresponding onsite works. With a greater number of interfaces between supply chain members onsite, the importance of good relationships cannot be underestimated.		1		1	1				
68	In summary, the main solutions offered with regard to design, suggest that the client should be incorporated early as a member of the project team, such that adequate time can be allowed for the design of the project. While the architect may be the design leader, the design should be managed independently by a design manager, with the mandate of focusing on interfaces. The strong connection between procurement and design should promote design and build when using offsite bathrooms.	1			1					1
69	In summary, the main solutions identified in relation to the manufacturer, suggest that the main contractor should inspect the manufacturer’s premises before contracting the manufacturer to satisfy that a manufacturing process will be used. With the client being part of the project team he/she should engage with the manufacturer during the early stages of design. The use of offsite manufactured bathrooms should allow the concurrent progress of the onsite works, promote better H&S and less snagging with the manufactured product.			1	1				1	1
70	In summary, the main findings relating to management solutions would suggest that the promotion of a good relationship between the main stakeholders can influence the ease of resolving interface problems. The management of the client is important, as is the communications between the client and the other members of the project team. While the procurement route can influence the early involvement of the main contractor and contractor led design, consideration should be given to the form of contract to ensure the same compliance. The strong leadership and influence of the main contractor’s PM is considered pivotal to resolving interface issues connected to offsite bathrooms. The	1						1	1	1

	PM should instigate a culture of co-operation and teamwork to benefit the management of the offsite bathrooms and the project as a whole.									
	Total of frequency	**10**	**9**	**9**	**22**	**11**	**11**	**25**	**25**	**17**

Appendix H – Questions for Validation of Conceptual Model

1. Name

2. Position in company

3. Do you have any experience of offsite bathroom construction?

    a. Expand how many years' experience in, bathroom pods, pods, modules, offsite, general construction

4. Explain the format of the model (This can be done just before the start of the interview or at this point).

5. How relevant are the factors to the interface management of offsite bathroom construction?
    a. Would you agree with the use of process and people factors?

6. How relevant are the sub-factors to the main factors?

7. How relevant are the people factors to the process factors?

8. What factor/factors would you deem most significant of the nine factors?

9. Would you consider any of the factors irrelevant or do you consider that I've missed any?

10. How valid would you say this model is to the understanding of interface management of offsite bathroom construction?

11. The main disciplines identified in the research, comprised of clients, main contractors, sub-contractors, design team and manufacturers. Which of these would you say the model would be most useful too? Or would you say it would be beneficial to all?

12. Any other comments you would like to make.