Improving the Delivery of Building Performance using Building Information Modelling (BIM)

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Abstract

Purposefully-designed buildings are complex by nature, because they are host to a variety of human activities that require them to perform adequately and be well suited to their intended functions. Building ‘performance’ has been an area of major research interest, so that efficient buildings are constructed that operate effectively to support the functional purposes for which they are being used. It is a complex concept that has been difficult to measure and incorporate into building design. Many methods and approaches have been developed to assess ‘performance’ for the purpose of addressing the gap between predicted – and actual – performance. However, it is acknowledged that these methods/approaches lack accuracy, are time consuming and do not provide a holistic view of the complex procedures and processes involved during the design and physical construction of the building.

Building Information Modelling (BIM) provides a new way of integrating information technology within the construction industry. Its capability as a digital platform has supported managing, sharing and exchanging interdisciplinary information between multi-disciplinary stakeholders. BIM has supported some aspects of assessing building ‘performance’ by emphasising energy consumption, sustainable design and building behaviour. BIM technology excels in situations that have quantitative-based aspects, which often are derived from those involved in the building delivery process. However, the design of successful buildings-in-use, through concepts like building performance, requires incorporating information from multiple perspectives, which requires going beyond the consideration of the characteristics that are quantitative.

This investigation aimed to explore how BIM can enhance the delivery of better construction performance for buildings. A case-study research method was used in this research where data was gathered using semi-structured interviews, documentary analysis, and feedback reports

from the building delivery team, facility management team and building occupants. The research journey was developed through three case studies where one case study influenced the direction of the next case study. Initial findings showed that 'space' as one of the building aspects was used as a reference concept for building performance because it provided a way for situating different meanings of building performance by different stakeholders. Thematic analysis was used to analyse the findings for each case study. The key finding from the case studies showed that there is a gap between data and experience. 'Systems thinking' analysis was used to investigate this gap, as it concerns the complexity, the handling of information modelling and supports addressing 'softer' human aspects. It showed that the reason for the gap between data and experience is that different stakeholders see the parts and the whole differently. Soft systems analysis was then used to explore this gap, as it provides a holistic approach to the situation being investigated. The use of this approach allowed the opportunity to understand the problems and possible conflicts within a particular situation. Wilson's approach of 'soft systems' was also used, as it goes beyond conceptual models to information categories, which can support bridging the gap between data and experience.

An overview of the problem, emphasising its complexity through proposed themes is presented. The delivery of building performance requires richer representation that acknowledges the significance of different parts in a construction project and how they influence stakeholders. Using the information requirements identified through soft systems analysis, a 'space strategy model' was proposed, which suggests that space designs in BIM should, in Zuboff's concept, be informated in order to identify the significance of different parts of a the build and build design, and support richer cognition of emergent characteristics that influence different experiences within a building project.

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Chapter One - Introduction

1.1. Introduction

This chapter introduces the proposal for the research, with background information on the subject area, followed by the rationale, research aims and objectives and finally a summary of the thesis chapters. The research background outlines the complexity of the area of building 'performance', and supporting role the Building Information Modelling (BIM) role offers. The research rationale emphasizes the value and importance of exploring the capabilities of BIM in terms of enhancing building performance of buildings. The research gaps addressed by the present thesis require consideration of the complexity and the importance of incorporating multiple perspectives to enhance the 'performance' of a space.

1.2. Research background

Constructing new buildings is complex art because they could be considered as highly fragmented 'environments'. This is because of the involvement of multi-disciplinary stakeholders, who require intensive data-sharing in order to deliver a well-performing building. Building performance has been an area of major research interest where methods and approaches have been developed to apply the concept of 'performance' in buildings (Gross, 1996). The inherent issue of building performance is based on terms of generalising a definition of it, because various interdisciplinary views are involved, which makes it highly dependent on stakeholders' different perspectives (Davis, 1990). Traditionally, building 'performance' has been evaluated by the perception of measurable factors (e.g. design awards for the architect) while other approaches have required observing the behaviours of the product in use (Duffy, 1990; Douglas, 1996). Holistically, covering various building aspects and approaches such as post-occupancy evaluation (Preiser *et al.*, 1988), building performance evaluation (Preiser, 1989 ; Preiser and Vischer, 2005) and total building performance (Douglas, 1996; Wong and

Jan, 2003; Low *et al*., 2008) have been developed to accommodate the whole building life cycle. The focus of these models can vary, but generally centres on aspects such as energy (thermal performance), spatial performance, and acoustics, depending on what the building is designed for. However, factors such as the quantity of the data produced in a construction project that requires time to process, complexities associated with the involvement of many stakeholders, accuracy issues and additional costs, have resulted in lack of practicality of these approaches. In addition, Persson *et al*. (2009) pointed out that large volumes of information are generated during the building-design process where often time is wasted searching for sharing it, and sometimes recreating it. Conversely, the growing importance of Information Technology (IT) in the construction industry offers potential towards overcoming these issues providing simpler and more-structured ways to solve the problems and manage information allowing different stakeholders to work in real-time environment (Gleick, 2011). One of the more-recent technologies that accelerated the use of information technology in the construction industry in an economic and manageable form (Yan *et al*., 2011) is Building Information Modelling (BIM). According to Aranda-Mena *et al*. (2009), BIM emanates from Computer Aided Design (CAD), but provides more-intelligent and interoperable information. BIM can be defined as a set of interacting policies, processes and technologies, which form a methodology that aims to manage the essential design and project data in a digital format throughout the life cycle of a building (Penttilä, 2006). BIM provides a full design model by integrating all systems (structural, architectural, 'mechanical, electrical and plumbing (MEP)' and 'heat, ventilation and air conditioning (HVAC)') within one single model (Porwal and Hewage, 2012). BIM has improved project coordination, enhanced collaboration among project stakeholders and allowed better visualization of a given project.

Currently, BIM supports some aspects of building performance such as energy efficiency, sustainable sourcing of construction materials, lessening environmental impact by design, and building actualisation. It is important to acknowledge that the use of Computer Aided Design (CAD) methods have been employed to assess building performance. According to Nguyen *et al*. (2010), prior to BIM, mathematical models and CAD methods had been used in the assessment of life-cycle building performance in order to increase the efficiency of building design and construction. However, the functions of these methods cannot satisfy all users' needs when there is a need to share complex information. BIM has extended the application of geometric objects to parametric objects where 'objects' can store semantic information allowing for better consistency and accuracy. Furthermore, BIM captures information from multidisciplinary sources to realise 3D visualisation, rather than fragmented drawings (Meridian Systems, 2008). It is claimed by Motawa and Carter (2013) that BIM can transform the way that the built environment operates by storing, linking and exchanging the project- based technical information for use over the whole project life-cycle and in so doing, benefit all stakeholders. In support of building performance, BIM supports some aspects of building performance such as energy efficiency (Yuan and Yuan, 2011), potential to achieve sustainable design (Barlish and Sullivan, 2012) and building behaviour. BIM capabilities allow for the extension of BIM-based packages, which aim to analyse different building performance aspects.

1.3. Rationale

The literature identifies that the nature of the problem that is the subject of this research lies in the multi-perspective view of evaluating building performance. Therefore, on the one hand, there is a need to model and manage the different perspectives for several elements within building performance in BIM to maximize overall satisfaction of the construction project. On the other hand, what level of accuracy can be expected or desired - as more parameters and fuzzier parameters are considered - has yet to be determined. This research aims to explore how BIM can support the delivery of better building performance for buildings. It also proposes an approach to inform data requirements in BIM in order to overcome complexities of building performance representation in BIM.

1.4. Research gaps

BIM's contribution to building performance focuses on factors that require quantitative geometrical based data. Most research efforts in BIM and building performance, tend to focus on energy performance. However, the design of a good operational building requires not only calculable based *data*, but also indeterminate *judgements* (expert opinion). This means that some characteristics, which influence experience when the building is occupied, need to be considered and incorporated as part of the design and build process. Based on the performance standards defined by the Hartkopf *et al*. (1986), there are six performance mandates: spatial performance, thermal performance, air quality, acoustical performance, visual performance and building integrity. Each of these types of performance form a certain 'comfort zone' and setting their limits of acceptability has arisen from the physiological, psychological, sociological and economic requirements of the occupancy (Rush, 1986). For instance, privacy and psychological comfort are part of the sociological and psychological considerations in performance criteria affecting all human senses. This aligns with Hartkopf *et al*.'s (1986) claim that buildings do not perform, but it is the people who design, build and use them that actually do. Although to some extent, BIM has the capability to provide quantitative analysis of most of the six performances mentioned above (e.g. energy performance), many other characteristics are involved (e.g. privacy) that BIM cannot address neither evaluate. Therefore, for this reason and many others, it is still realised that buildings do not always perform as intended.

Inevitably, the performance of a building becomes more obvious with time (Brand, 1994) especially considering those aspects that are subjected to constant change. This can ultimately be done by measuring satisfaction of the building users in terms of comfort, efficiency or even the interior beauty of the building (Rush, 1986). According to Hartkopf *et al*. (1986), the performance mandate that most significantly affected by interior system design - and is often subjected to change - is the spatial performance. Spatial performance aims to achieve maximum satisfaction through the ergonomic arrangements of the space (Low *et al*., 2008). It involves individual space layout, conveniences and services, amenities and occupancy factors and control (Rush, 1986). Among other performances, it is claimed that spatial performance is the top priority for various building types (Rush, 1986). This is because all design decisions regarding the interior of the building affect the layout of various spaces, which impact ergonomic comfort, accessibility, way-finding and communication for example. Like other performances, there are limits of acceptability (discussed in detail in chapter 2) based on the physiological, psychological, sociological and economical requirements; these limits have been standardised and translated into codes to be incorporated in building design in order to respond to human needs (Rush, 1986). Although it may seem that spatial requirements within buildings have been well-defined over the last three decades ago, satisfying space requirements for different users within the building still remains an obstacle (Dovey, 2010). Forty (2000) pointed out that architects deliver designed space according to representations (abstract space), rather than immersing themselves within that space (lived space). CADD (Computer Aided Design and Drafting) and other 3D modelling systems have represented the space implicitly, which means that its representation is defined by any object (walls, slabs, etc.) that is used to set its boundary (Lee *et al*. 2012). BIM has enhanced the affording of suitable space in a design by integrating interdisciplinary systems into one single model providing better visualisation, accuracy and consistency (Volk *et al*. 2014). Many applications have been proposed using semantic information from BIM such as evaluating design solutions (Jeong and Ban, 2011), improving performance (Kim *et al*., 2012) and many others. Currently, most architectural programs include one that specifies the space requirements where this shows that 'space thinking' has extended beyond its boundaries (Lee *et al*. 2012). The properties of the spaces are defined on the building type (e.g. school, office, or hospital), the intended use of the space (Borrmann and Rank, 2009). The extensive research into ‘space’ using BIM has allowed for the exploration of several problems, which can be related to the type of space, its uniqueness and the fact that different users have different experiences of space (Lee *et al*., 2012). In the BIM environment, ‘space’ is experienced visually and referred to as ‘perception’, where the observer tends to have an internal representation of a surrounding physical space, and then attempts to measure the properties of visual space. This establishes how various properties of physical space are preserved in the mapping to visual space (Loomis *et al*., 1992).

Currently, although BIM as a tool is gaining more momentum worldwide, stakeholders such as building owners and facility managers are only just beginning to integrate the BIM development and implementation process with their work (Becerik-Gerber and Rice, 2010). BIM could and should act as a socio-technical system, where humans can provide essential input to inform the social aspects of construction design, desire and build, where they interact with building forms the technical aspects (Ruppel and Schatz, 2011). However, the current applications of BIM do not support the integration of a wide variety of information (Ding *et al*., 2014). For such a complex concept as ‘optimal space’ requirements, it is essential to highlight that performance of a particular space depends on the intended needs of the users of that space, which means that different types of space must satisfy different needs, thus demand a different way of perceiving them. Therefore, the importance of inquiring into different properties and priorities for different types of spaces from multiple perspectives is required. For the purpose of this research, Freeman’s commonly accepted (Freeman, 1984) definition of ‘stakeholder’ (“any or individual that can affect or is affected by the achievement of a corporation’s purpose”) has been adapted. Therefore in this study, stakeholders refers to those who influence (building delivery team) or are influenced (facility management team and building occupants) by building performance.

1.5. Research aim and objectives

This research aims to explore how Building Information Modelling (BIM) can support the delivery of better building *performance*. The objectives are:

- To review the theory and practice of building performance.
- To determine the perspectives of the building-delivery team, facility-management team and building occupants on performance and different performance aspects.
- To explore the role of BIM in the delivery of different performance aspects from the perspectives of the building delivery team, facility-management team and building occupants.
- To synthesise an approach that informs data requirements in BIM to support the delivery of better performance for buildings.

1.6. Overview of the thesis chapters

This research aims to explore how to enhance the delivery of better performance for buildings through the use of BIM. The first chapter provided an insight into the complex nature of building 'performance', and showed the need to investigate different views on it from different stakeholders. It also showed that BIM in its current form excels in quantitative representations, but they do not support a holistic view of performance. The second chapter reviews different theories and evaluations of building performance, the role of BIM in the delivery of building performance, theories and concepts of space, information modelling and design. The second chapter concludes that as well as the need to inquire into different meanings of performance from different stakeholders, the role of BIM in the delivery of performance needs to be explored, and the value of different stakeholders' involvement to inform the design process need to be evaluated. The third chapter shows that this research follows a critical-realist approach, as it supports inquiring into both the social and technical sides of a problem. The nature of this research is qualitative and uses a case-study approach. Three case studies were used in the evolving research 'journey'. The journey showed that the output of a case study was an input for the next case study. Chapter 3 also elaborated on the role of soft systems methodology in addressing the gap identified by the research journey, as it provides a holistic approach to the problem and seeks to identify information requirements that supports informing data in BIM. The fourth chapter shows the reviewed outputs gathered from the three case studies. The first case study showed that different stakeholders associate different meanings for buildings and building performance, and showed the need to inquire into performance through looking into experiences of space. The second case study showed that inquiring into experiences of space can help encapsulate experiential issues that are faced in a space, and showed the need to further look into the role of representations of space in experiential issues that influence performance of space. The third case study showed that current representations of space lack the capability of representing experiential concerns. Although the main inquiry for each case study was different, each case study has looked into definitions of building performance and the role of BIM in the delivery of performance from the three targeted stakeholders: building delivery team, facility management team and building occupants. The chapter concludes by highlighting the gap between data and experience. The fifth chapter (soft systems analysis) explores the gap between data and experience and showed that this gap is a problem of *the parts* and *the whole* originating from different stakeholders' views of the building. The building delivery team tends to have a reductionist view, where *the parts* drive the whole, whereas users of the building have a holistic view where they describe what influences the whole (experience). Soft systems analysis is then used to help understanding the problem about the parts and the whole by providing a holistic approach for each output identified by each case study. It also helps unravel the significance of different parts and proposed information requirements that can be used to bridge the gap between data and experience. The sixth chapter provides an overview of the problem, which looked at different abstractions of performance, representations of performance, space as a reference for performance, and space as information. The space strategy model proposed suggests that space designs in BIM should be 'informated' in order to identify the significance of different parts and support richer recognition of emergent characteristics that influence different experiences within a building.

Chapter two - Literature review

2.1. Introduction

This chapter overviews the existing literature related to the research investigation area. Primarily, four areas are reviewed: building performance, space, information modelling and finally design. In relation to building performance, the review focuses on concepts and theories, evaluation methods, different aspects of building performance and the space aspect. Followed by, it will be looked at the experiential and inherent aspects of space. This includes reviewing 'space' in relation to building performance and change when buildings are in use. The third area views information modelling where it will be looked into information for BIM, information for simulation, information for design and information management. The final area, design, focuses on aspects such as collaboration, digital design methods, architectural design and experiential design methods.

2.2. Building performance

2.2.1. Concepts and theories

Over the years, the concept of building performance has been undertaken by many researchers (Wong and Jan, 2003). Moreover, performance for buildings is claimed to be an important issue in design, and has a major significance in architectural design (Oxman, 2009). According to Dino and Stouffs (2014), there is a growing interest in the area of building performance to ensure that the intended performance and operation of buildings extends beyond the service-life of buildings. Davis (1990) claimed that it is critical to create a generalized definition of 'building performance' which can address the various interdisciplinary views encountered by contractors, managers, owners, engineers, architects, programmers and policy makers. In addition, Davis' proposed definition of building performance has been divided into two parts: mandates relating to 'building enclosure integrity' and mandates relating to interior building occupancy requirements, including elements of ‘comfort’. ‘Building enclosure integrity’ includes protecting the building’s visual, mechanical and physical properties from environmental degradation such as temperature, air movement, radiation and natural disasters. The other mandates in Davis’ scheme include thermal, acoustic, visual, air quality and spatial comfort in which all are dependent on psychological, physiological, sociological and economic values.

Although the above mentioned mandates have been acknowledged (CIB Report Publication, 1982; Blanchere, 1972), it has been claimed that ‘performance’ is merely a reflection of the building’s designer, builder and user performance (Hartkopf *et al*., 1986). But having a sufficient level of communication is a vital key in shaping the future performance of a building. Thus, and complying with Hartkopf *et al*. (1986), performance can fundamentally be viewed as the measurement of achievement against intention. Wright (1972) claimed that having a performance approach for buildings is similar to systems analysis, where both demand a broad view in terms of problem definition, and a routine for the evaluation of selected solutions. He added that many approaches to ‘performance’ have followed a problem-solving agenda such as the performance requirements for health and safety proposed by the British Building Research Station during the 1930s and France’s performance-based agreement system (Wright, 1972), which was established during 1950s (Wright, 1972). In 1968, the National Bureau of Standards conceptualised performance to comprise three parts: Requirement, Criteria and Test and an optional fourth part called Commentary. Thus, there is a long-established relationship between ‘performance’ and ‘evaluation’, because evaluation acts as the representation of the desired/predicted performance during design. According to Oxman (2009), in the context of design, the term ‘performance’ has many implications and represents various roles. However, as this research focuses on performance during the design stage, the interpretation of it associated with evaluation (Kalay, 2004) is adopted.

One of the major causes of inefficient building operations is inaccurate evaluation of building *performance* at the design stage (O'Donnell *et al.*, 2013). This is because building performance can be interpreted in many different ways such as evaluating it against the identified requirements for the building or how the building is being perceived by users, and thus it is an interdisciplinary concept (Alexander, 2011). According to Duffy (1990), buildings are typically evaluated on the perception of measuring output (e.g. design awards for the architect) where another perception of evaluating performance is observing the behaviour of the product in use (Douglas, 1996). It is argued by Cooper (2001) that performance of the building can only be evaluated after it has been occupied to understand if the building is truly effective.

2.2.2. Evaluation methods

There are many approaches that have been developed to measure/evaluate performance for buildings. In support of this, approaches like Post-occupancy evaluation (POE) have been developed where its aim is to deliver an ideal building that can satisfy occupants (Khan and Kotharkar, 2012). However, although this approach has successfully been implemented, a need for pro-active approaches was necessary like Building Performance Evaluation (BPE) and Total Building Performance (TBP). This section will review these techniques as the most commonly used for evaluating building performance.

Post-Occupancy Evaluation (POE)

Preiser, (1989) claimed that POE was introduced in response to significant problems faced by building performance in 1960s, and emphasised the occupants' perspective as shown in Figure 2.1 (Preiser, 1995). The concept of POE is based on the assumption that buildings are built to enhance and support occupants' goals and activities. Figure 2.1 also demonstrates a traditional process of performance measurement. According to Preiser *et al*. (1988) POE can be defined as:

> "Post-occupancy evaluation is the process of systemically comparing actual building performance i.e., performance measures, with explicitly stated performance criteria. These are typically documented in a facility program, which is a common pre-requisite for the design phase in the building delivery cycle. The comparison constitutes the evaluation of both positive and negative performance aspects".

Moreover, Vischer (2001) stated that POE has supported identifying architectural and social problems that arose in a building through a systematic assessment of the physical environment in terms of how people were using them. It was not until later that POE was seen as a mechanism for collecting useful information for the building industry which could impact on design and construction in the long term (Preiser and Vischer, 2005). Although POE has been part of the Royal Institute of British Architects (RIBA) plan of work since 1965, it does not have a standardised procedure and its use has been patchy (RIBA, 2009). In addition, many other barriers for POE has been acknowledged by Hadjri and Crozier (2009), which suggest reasons for POE not being widely adopted.

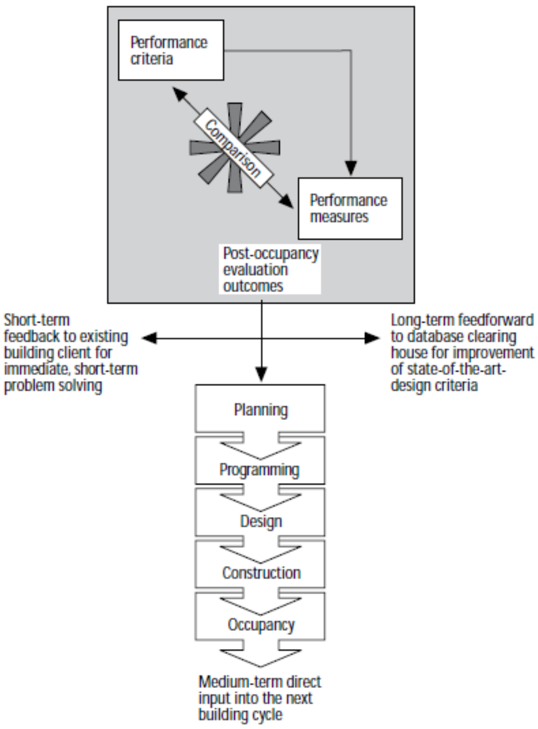

Figure 2.1: Performance concept in the building Delivery Process (Preiser, 1995)

Building Performance Evaluation (BPE)

BPE has evolved from POE (Preiser *et al*., 1988). The basic approaches of BPE were presented by Preiser (1989) in his book *Building Evaluation*. Preiser (1989) believed that there was a need to broaden the range of decision makers and improve quality of decisions in buildings by providing an evaluation which has interfaces with all phases of building delivery (Preiser and Schramm, 1997). BPE is defined as the systematic approach to comparing the actual performance of buildings, places and systems to their expected performance (Preiser and Vischer, 2005). It adopts a process-oriented approach that accommodates relational concepts. This implies that it can be applied to any type of building or environment (Preiser and Vischer, 2005).

The goal of BPE, therefore, is to improve the decision quality at every phase of the building life cycle (see Figure 2.2) from planning to programing, design and construction, to facility management and adaptive reuse. Using an Activation Process Model (Preiser, 1997), BPE presents a holistic, process-oriented approach towards building performance evaluation. Since the 1990s, interest and activity in BPE has diminished as there was insufficient interest in public and private sectors; however POE has continued to expand in industrialized nations such as the USA.

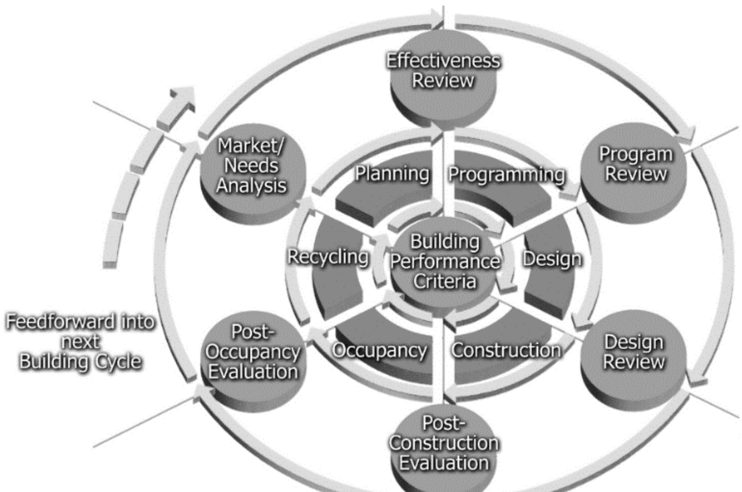

Figure 2.2: Building Performance Evaluation (BPE) process model (Preiser and Vischer, 2005)

Total Building Performance (TBP)

According to Douglas (1996), Total Building Performance (TBP) is the most comprehensive tool for evaluating buildings in use, and considers performances on many different levels. This approach drove an expanded understanding of the importance of the critical balance that is required to fulfil successful building performance (Douglas, 1996). In addition, total building performance addressed a growing need for an effective future prediction of the performance of a building. Figure 2.3 illustrates the inclusion of TBP in comparison to other performances in terms of having more variables.

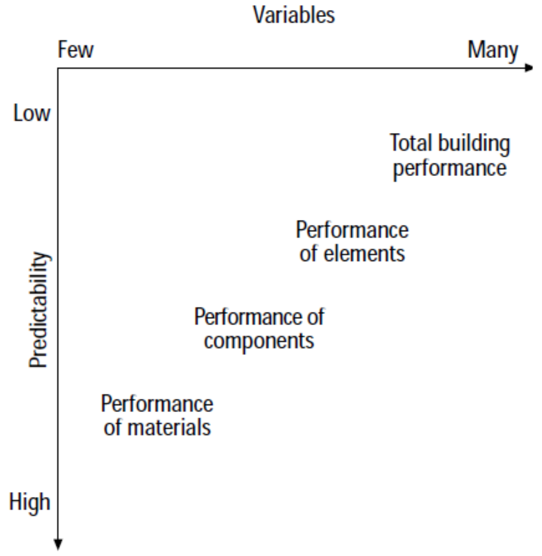

Figure 2.3: Total building performance compared with other performances (Douglas, 1996)

The TBP framework identifies and evaluates all performance areas (Wong and Jan, 2003). It consists of six performance measurements: spatial performance, acoustic performance, thermal performance, indoor air quality, visual performance and building integrity. In addition, each of these types of performance is defined by psychological, sociological, physiological and economic needs for users' satisfaction (Low *et al.*, 2008). TBP provides the needs of the users by considering several building mandates simultaneously, in order to achieve a healthy environment which will facilitate the functioning of the space for the occupants (Low *et al.*, 2012).

2.2.3. Aspects of building performance

According to the CIB (1982), there are six performance mandates (also known as TBP): spatial performance, thermal performance, air quality, acoustic performance, visual performance and building integrity. With reference to these mandates, this section overviews these performances. It is also important to mention that each of these mandates have their limits of acceptability (Hartkopf *et al*., 1986), which are physiological, psychological, sociological and economic. Moreover, it is often that the building function dictates these limits. It is claimed by Hartkopf *et al*. (1986) that these limits aim to establish what can be described as 'comfort zone' for occupants. Furthermore, often these limits are translated into standards and codes, which should correspond to the intended function of the building.

Thermal Performance

The building's ability to provide thermal comfort to the occupants in the indoor environment is outlined here. There are a number of design factors that can influence the satisfactory performance of thermal comfort, such as air temperature, relative humidity, number of occupants within a space and air movement (Hartkopf *et al*. 1986). Thermal performance has also been described as heat transfer between a building and its surroundings, which is concerned about the heat loss from a building (Communities and Local Government, 2008), and also known as the energy performance. The energy performance-related literature is extensive, as most (if not all) new buildings aim to be energy efficient. Standards such the Energy Performance Certificate (EPC) demand an energy rating for the building.

Visual Performance

As part of the six building mandates, it is an absolute necessity a building is able to provide a comfortable and healthy *visual* environment, which supports the occupants' activities. A healthy visual environment is important to perceive colour, space and different objects within the indoor environment (Hartkopf *et al*. 1986). This performance mandate can be influenced by various factors including quality of lighting and visual contact with the exterior environment and availability of natural daylight (Roetzel, 2008). Currently, this aspect is assessed using simulation applications (Bellia *et al*, 2015), or quantitative analysis (Ochoa and Capeluto, 2006).

Acoustic Performance

According to Paradis (2014), one of the major factors that influence occupants' comfort within buildings is the acoustic considerations. Acoustics can be defined as the physical properties of sound, which affect human being in everyday life. Hartkopf *et al*. (1986) pointed out that acoustics within a building can be influenced by many factors such as materials, structure, mechanical appliances and space division. Furthermore, as being an aspect that influences human health and well-being, acoustic performance is part of BREEAM (Building Research Establishment Environmental Assessment Method) to ensure meeting standards, according to the purpose of the building (BREEAM, 2015).

Air Quality Performance

Inevitably, the quality of indoor air has a direct impact on comfort, health and well-being of building occupants. Within Europe, it is claimed that occupants spend approximately 90% of their time indoors, which make them more exposed to air pollutants (BRE, 2015). According to EPA (1997), it is difficult to have clearly defined factors that affect the air quality, as buildings are different and perceptions on what influence this performance may vary. In general, some of the factors that can affect the air quality include: design, operation and maintenance of building ventilation systems and sources of pollutants (EPA, 1997).

Building Integrity

This performance mandate is mainly concerned with sustaining the material, component, and assembly properties to resist both internal and external forces over time (Rush, 1986). According to Low *et al.* (2008), there are three properties that must be sustained. First, the mechanical properties for the stability of overall geometry where this includes structural strength and stability. Second, the physical properties of water and air tightness, including reflection and absorption of heat, light and sound. Finally, the visible properties including colour, texture and surface finish.

Spatial Performance

According to Robertson and Courtney (2001), spatial performance is concerned with the ergonomic arrangement of the space in order to achieve maximum satisfaction to the occupier. It is claimed this performance mandate is always subject to change and the one that is most significantly influenced by the indoor environment (Hartkopf *et al*. 1986). All design decisions regarding interior components, including their assembly, affect various aspects such as way-finding, comfort, accessibility and communication. More importantly, it has been demonstrated that spatial performance remains a top priority for different buildings (Rush, 1986).

2.2.4. Space aspects

The study of building ‘space’ is complex where form and function of the building plays the main role in determining how space should function, be laid out and utilised. Over the years, many theories and concepts have evolved over the years (Alexander, 1977; Malpas, 1999; Lefevbre, 2000; Massey, 2007) attempting to overcome the complexities associated with space such use of space and user experience within the space. According to Fayard (2012), space is not an empty area to be filled, but instead, it is constantly *constructed*, emerging from relationships and practices of people living, interacting and working within it.

The special use of the term ‘space’ in construction began to emerge in the discipline of architecture at the end of the 19th century with volumetric theories and continued with aesthetic theories (Dovey 2010). In volumetric theories, space is described as ‘enclosure space’ (Hensel et al. 2009) and aesthetic theories describe space as the ‘aesthetic effect of architecture on subjects’ (Holt-Damant 2005). In modern architecture, it is claimed by Forty (2000) that space appears to be a homogeneous concept, partly because architects consider space via representations (abstract space) rather than experiencing space by living it (lived space). Therefore, it can be realised that the concept of ‘space’ is complex and its trans-disciplinary nature increases its complexity.

2.3. Space

2.3.1. Experience and perception

It is important to acknowledge the philosophical transitions of space before becoming a theme that primarily belong to architects (Forty, 2000). Although the philosophical views of space are such that it does not directly feed into the scope of this thesis, they provide rich insights into the meanings of ‘space’, and how this may have influenced the creation of a performance gap for buildings.

Tschumi (1996) argued that by definition, architectural concepts were absent from the experience of space. He added that it is overly complex to question the nature of space and at the same time experience a real space. In an attempt to define what is called ‘the life of space’, Ven (1978) quoted:

> “The human being creates, with his body, what the architect and painter call space. This space is entirely different from the mathematical and epistemological space. The painterly and architectural space is music and rhythm, because it meets our extensions as certain proportions because, in turn, it releases and encloses us … Most people think

> of architecture as the corporeal members, the facades, the columns, the ornaments. But all that is secondary. Essential is not the form, but its reversal, space; the void that expands rhythmically between the walls, and is defined by the walls”

According to Tuan (1977), space is experienced directly as having a room in which to move. In addition, the human mind tends to discern geometric designs and principles of spatial organisation in an environment. Also, human beings embody their feelings, images and thoughts in tangible material, naturally. However, philosophers such as Heidegger and Lefebvre have gone beyond this view of space. Heidegger (1971) claimed that space is neither an external nor an inner experience, but instead, space is defined by the personal location. In fact, Suvanajata (2001) has described experiential aspects of space as being related to passage, junction and place. This approach was reasoned by claiming that often people describe the space according to their movement. According to Lefebvre’s (1991) view, his focus was upon social space, where it is argued that space is not an inert, neutral, and a pre-existing given, but instead, an on-going production of spatial relations. Furthermore, he argued that:

> “Space is a product of something that is produced materially while at the same time “operate[s] … on processes from which is cannot separate itself because it is a product of them” (Lefebvre, 1991: 66).

The view of social space by Lefebvre (1991) has led towards developing his well-known spatial triad, which consists of: lived space (representational space), conceived space (representations of space) and perceived space (spatial practices). However, apart from the fact that Lefebvre’s work is self-evident (Zhang, 2006), it quantifies space, as it potentially tries to settle a certain social situation into one of the three spaces (lived, conceived or perceived). Following on from this, and arguing over Lefebvre’s approach to space, Watkins (2005: 220) quoted:

> "It is necessary for the interactions between the triadic elements to be appropriate and in balance if an [spatial] event was to be persuasive and effect. What he tries to say, it seems to me, is the understanding of an event rather than an event by itself".

It is argued by Hillier (2007) that space, in an important sense is an objective property of buildings. He quoted:

> "Most our common notions of space do not deal with space as an entity in itself but tie it in some way of entities that are not space. For example, even amongst those with an interest in the field, the idea of 'space' will usually be transcribed as the 'use of space', the 'perception of space', the 'production of space' or as 'concepts of space'. In all these common expressions, the idea of space is given significance by linking it directly to human behaviour or intentionality. All these concepts confirm the difficulty of conceptualising space as a thing in itself" (Hillier, 2007: 19).

The root to the above view is, perhaps, the structural view of space, which was introduced by Hillier and Hanson (1984). The phrase 'structure' refers to the methodology used to analyse space that is known as 'Space Syntax'. According to Hillier (2007), in Space Syntax theory, each space is described in relation to its social structure, which in turn makes any spatial configuration of the built environment. It is important to acknowledge that the main foundations of Space Syntax originated in Alexander's work, which concern with social activities and their relation to the structure of space (Alexander, 1977).

In consideration of perception, the 3D environment provides this Euclidean framework for our perception of spatial relations. Loomis et al. (1992) stated that in the study of visual space, it has been assumed that an observer has an internal representation of the surrounding physical space, and then attempts to measure the properties of visual space to establish how well various properties of physical space are preserved in the mapping to visual space. Space perception is only possible in the presence of perceptible objects, and thus, space is the relationship between objects. Space perception can be composed from the properties and relationships of objects in space with respect to direction, size, distance, and orientation. In an environment, object relations can be described in terms of a Euclidean coordinate system (Richards 1975). The complexity of visual space can be looked at using in-depth psychophysical procedures, but this approach does not serve the scope of the research aim defined for the present thesis.

2.3.2. Inherent and representation qualities

Defining and describing 'space' now it is a well-established concept in architecture, allows understanding the problematic nature about this elusive concept. According to Forty (2000), there are different senses of 'space', which have been adopted by architects: space as *enclosure*, space as a *continuum* and space as an *extension* of the body. Space as enclosure is perhaps the most commonly understood sense of space. Space as a continuum suggests that spaces are continuous and infinite. Space as an extension of the body defines perceiving the space in terms of the body's imagined extension within a volume. It is important to consider space planning and its representations, as this provides a richer understanding when discussing the performance gap (see below).

Space planning is considered to be one of the initial steps during the preliminary design process of the building (Duffy et al. 1976; Autodesk 2013). Guidelines have been developed for various building types such as: educational buildings (Stanford University 2009), office buildings (Duffy et al. 1976), hospitals, and so on. There are many elements involved in space planning such as flexibility, efficiency and consistency. For instance, Ching (2007) has identified several factors that affect the design of space: function of architectural spaces at different times, amount of human-oriented (ergonomics) characteristics of the building space, the method of locating the vital and critical areas in the buildings, the independency of the building spaces, and the density of the building spaces. Furthermore, spaces in a building can be identical, unique or defined based on the client's requirements to perform a particular function. Bitrafan et al. (2013) described space based on functionality where spaces are divided into three different types: flexible spaces, adaptive spaces and single functional space. It is important to emphasize that space planning is a major attribute of facilities management within buildings (Best *et al*., 2003). In addition, within facilities management, space planning incorporates both planning and management sides of workspace features in many business operations, which can be as diverse as process engineering, retail, office buildings, and so forth (McGregor and Then, 1999). It is claimed that effective planning of space has a direct impact on how space is managed both efficiently and effectively. The NAO (1996) outlined various factors that affect the management of space: forming a management committee; a model/technique to manage the space; and ensuring that employees understand the operation of space.

In terms of space *representations*, Allen (2009) described representation as an entire intellectual and social construct, which allows the possibility of imagining and constructing new fragments of reality. Some theories regard representations as the mental result of thinking about an activity, which to some extent corresponds to reality (Zhang and Norman, 1994). Others have considered representation as an integral part of an activity itself, based on its communicative role (Lorino *et al*., 2011). Hatfield (2003) pointed out that the visual experience aims to represent a visual space in relation to the physical space. In relation to space experience, Luck (2007) argued that architects recognise the difficulty to predict the experience of space by relying on representations of space. This has led to research to investigate how designers can deliver experience of the space designed for the end users (Dunston *et al*., 2007; Maftei and Harty, 2013). Sanoff (2000) has pointed out the difficulty of delivering this experience is due to the gap between the demands from the users and the design provided by the architects.

2.3.3. Buildings in use: performance gap

The holistic nature of performance implies the importance of considering its significance at an early design stage (Kalay, 2004). Also, it was highlighted that previous evaluations have not been widely adopted, since they are time consuming, costly and are difficult to understand because of the complexity and amount data. As a response to that, the use of information technology in the construction industry has accelerated with the availability of BIM (Building Information Modelling) in an economic and manageable form (Yan *et al*., 2011). BIM can transform the way that the built environment operates by storing, linking and exchanging project-based technical information for use over the whole project life-cycle and in so doing, benefits all stakeholders (Motawa and Carter, 2013). Furthermore, BIM is a collaborative tool where divergent perspectives can be accommodated to achieve better design solutions (Sabol, 2008). In relation to performance, many studies have been conducted (e.g. Cho *et al*., 2010; Yuan and Yuan, 2011; Azhar *et al*, 2011), but most (if not all) of these studies have focused on measurable attributes of performance, and hence, it can be realised why energy performance has received a great attention.

Most approaches to building performance recognise that it requires calculative aspects associated with the building form and fabric in its location and indeterminate aspects associated with the way the people in the building perceive it and experience it in their activities (Mayouf *et al*. 2014). This can be evidenced when recognising that current focus on delivering sustainable and efficient buildings, thus, it can be argued that the concept of performance has become adjacent to energy performance. According to Hunn *et al*. (2012), in many countries such as the United Kingdom, the United States, Canada, common measurements of building performance aim to achieve 'green', 'low energy' and 'high performance' credentials. However, on the one hand, performance can be interpreted in multiple ways, and thus requires holistic considerations. On the other hand, dealing with complex and interdisciplinary information has remained an issue, and thus tools such as POE and BPE (explained in section 2.2.2) are not widely used. More importantly, often performance is based on measurable attributes, which tends to avoid subjective considerations (Ibem *et al*., 2013). Users' satisfaction can be considered as one of the subjective evaluations of performance for users (Hanif *et al*., 2010). It is argued that on the part of both users and community, the crucial aspect is that buildings should meet their expectations and support their daily activities (Davara *et al.*, 2006), which is difficult to outline and be limited by performance indicators, as they are often assigned to measurable attributes (Kim *et al*., 2005).

According to Douglas (1996) the performance of any building declines over time and this is due to many factors such as climate change, technical issues or user misuse (Douglas, 1996). Moreover, the degree of this decline is claimed to be dependent on how well the facilities support the building in order to maintain the performance over a longer period of time (Douglas, 1996; Barret and Baldry, 2003). According to BIFM (2014), facilities management is defined as integrating processes within an organisation in order to maintain the agreed services that support and improve the effectiveness of the primary activities for that organisation. In this context, facility management (FM) includes hard facilities (e.g. building fabrics, Mechanical, Electrical Plumbing 'MEP' systems) and soft facilities (e.g. catering, security, cleaning) in the building. Although it can be argued that BIM can potentially support managing facilities through information integration at an early design stage, the process does not include facility managers in terms of informing design decisions (BIFM, 2012). One of the tools, which is used to manage facilities is the creation of Construction Operation Building Information Exchange (CoBie), which contains structured information related product data sheets, preventive maintenance, and so on (East, 2013). Thus, it is not surprising Wright (1972) stated that "We depended on technological bounty and the implicit satisfaction of user need".

He also added “We are trying to give technology the benefit of judicious application and to encourage the further development of a technology suited to human needs”.

With relation to space, Dovey (2010) pointed out that although it may seem that spatial requirements within buildings have been well-defined, satisfying space requirements for different users within the building still remains an obstacle. Perhaps, one of the reasons for that is employing the digital tools (such as BIM) within the traditional sequential model of performance-evaluated design, which often is pre-determined (Oxman, 2009).

2.3.4. Buildings in use: change

In reasoning why buildings perform poorly, Oxman (2009) pointed out that limited research efforts have focused on understanding users’ changing needs and expectations. Whilst this has not been an issue for other industries where professionals inquire into actual functionality and user-satisfaction to deliver better services and products, professionals in the building industry have concentrated lesson incorporating users’ needs (Meir *et al.*, 2009). It is argued that ‘change within space’ is one of the strategic aspects that should considered when planning the space (McGregor and Then, 1999). According to Brand (1994), space-use changes occur approximately every 3 years. The space change can be in terms of facilities provided per individual, standards of space, the times that the space is used, its functionality and users (McGregor and Then, 1999). The complexity of change within space can vary from one building to another, and thus it has led to the development of many computerised systems to manage and maintain the spaces within buildings (Lai and Yik, 2012). BIFM (2012) claimed that current technologies do not accommodate the necessary information to manage building operations as well as understanding users’ different concerns.

One of the ways to improve the overall performance of buildings is to understand users’ needs and expectations (Kim *et al.*, 2005). Therefore, incorporating the users’ knowledge and preferences in the architectural, engineering and construction (AEC) project is gaining importance (Jensen *et al*., 2011), as this will help to reduce the potential gaps in understanding between what is planned and what is expected. For example, BIFM (2012) claimed that showing a 3D visualisation of the plant room to building maintenance people using BIM could offer the opportunity for better training and avoid maintenance access problems.

2.4. Information modelling

2.4.1. Information in Building Information Modelling (BIM)

According to Eastman *et al*. (2011), BIM is part of the advancements in information technology (IT) that has dramatically changed the way that information is managed, exchanged and transformed in the construction industry, allowing more-efficient ways to collaborate among stakeholders. Moreover, BIM is underpinned by digital technologies which unlock more-efficient methods of designing, creating and maintaining building assets, providing a collaborative way of working among project stakeholders (HM Government, 2012). An asset can be described as any item, thing or entity that has a potential value or actual value to an organisation (IAM, 2013). Assets in buildings involve the physical building, systems (mechanical, electrical and plumbing) and facilities (Fallon and Palmer, 2007). Although BIM provides a collaborative information exchange platform, it is not yet clear how this information can be perceived by other stakeholders who are not directly involved in the design process, such as facility managers and end-users (i.e. the building occupants) who need information about the building and should contribute to the building design process. In relation to information in BIM, it is emphasized that it comprises three types of design information: semantic, topological and geometric (Eastman *et al*., 2011).

2.4.2. Information for simulation

BIM can be seen as an evolution of Computer Aided Design (CAD) systems, but provides more interoperable and intelligent information (Aranda-Mena et al., 2009). According to Oxman (2009), for a CAD model, it is anticipated that simulations in relation to performance and analysis are performed on a geometric model that has already been formulated. Moreover, it is argued that, typically, within an architectural design, performance aspects such as structural stability, acoustic performance and energy performance can be formulated as performance simulations, which can inform decisions related to users, environment and formation (Rahim, 2005). Oxman (2009) emphasized that existing CAD-based performance simulation programs are not programmed to integrate processes of design generation based on the selection of specific performances. More importantly, integrating a certain logic is essential to support a particular simulation for a digital design. With response to that, the reason behind BIM replacing CAD models can be seen, as it allows solving complex problems by integrating information from different disciplines in the architecture, engineering and construction (Eastman *et al*., 2011).

When looking at the space aspect, within the BIM environment, often it is realised that spaces are merely generative features of floors and walls (Aksamija *et al*., 2010). It can, however, be argued that research efforts have tried incorporating different information to represent design concepts within buildings. One of the potential methods is the use of algorithms to represent different solutions. Dzeng *et al*. (2013) developed an algorithm to optimize the function space assignment based on activity simulation. One of the potential methods for representing design concepts is the use of algorithm-based parametric (BIM-based) design tools such as the Rhinoceros' Grasshopper plugin, which can assist architects' geometric possibilities (Lin, 2015). However, it is highlighted that the majority of these algorithms do not form a medium for communication with other stakeholders (Lin, 2015). More importantly, often these algorithms use existing information, which tends to be derived by those involved in the creation and completion of buildings.

2.4.3. Information for design

Conceptually, the term ‘information’ is considered to be ambiguous owing to the variety of ways it can be interpreted or used (Buckland, 1991). In fact, humanity has been living and experiencing various kinds of information since the 4th millennium BCE (also called “the Bronze Age”) when writing emerged as a means of communication (Floridi, 2010). According to (Buckland, 1991), there are two traditional meanings of ‘information’: the process of telling something, and the thing that is being told. In addition, he identified three uses of the word ‘information’: information-as-process, information-as-knowledge and information-as-thing. Buckland emphasized the logic behind considering information-as-thing is that communicating knowledge, beliefs, and opinions are subjective, conceptual and even personal. Therefore, the representation, expression, or description would be ‘information-as –thing’ (Buckland, 1991). Historically, information is considered as a thing (e.g. a drawing) and is communicated between architects, different construction parties and stakeholders (Khatib *et al.*, 2007). Today, building architects, apart from their primary design skills, need to create and communicate information in a way that previous generations never had to (Race, 2012). Architects have to be increasingly cautious in obtaining and filtering the information they require because of the increasing complexity of buildings. In other words, the information that the architects generate is subject to immense scrutiny by all members of the project team. Another reason is that information is changing because of the continual update of processes and software, as the industry’s understanding of BIM evolves (Race, 2012).

In the construction industry, large volumes of information are generated during the building design process, and often time is wasted searching for, sharing and sometimes recreating information (Persson *et al.*, 2009). Therefore, there was a need to establish a common data environment, which includes processes and procedures that enable reliable information exchange between project team members and other stakeholders (CIC and BIM Task Group, 2013). In addition, the way that information is managed, presented and interpreted requires a relatively high level of technical knowledge and experience that also considers the various interdisciplinary stakeholders involved (Kassem *et al.*, 2012). Moreover, providing the required data needed to satisfy the information needs for all stakeholders is a crucial task using traditional methods such as 2D drawings and paper-based documents.

2.4.4. Information management

BIM represents an approach to create and manage information over the whole life cycle of a building (Liu *et al*., 2012). The building life cycle consists of the stages of production, construction, building in use and finally end of building's life (WBCSD, 2007). BIM is described as information-centric software, providing information modelling, unlike CAD, which is a graphic model of a building (Ibrahim and Krawczyk, 2003). BIM does not discriminate between the types of information that can be considered (Race, 2012). It supports the coordination of the following information: construction documentation, visualisation of building design and construction, material and equipment quantities, cost estimates, 4-D construction sequencing and reporting, scheduling and fabricating data and tool paths (Garber, 2014). The operation of BIM is based on digital databases of building information, and by managing and storing these databases, BIM can capture and present data in ways that are appropriate for designers, contractors, client or vendors (Ibrahim and Krawczyk, 2003). Succar (2009) has described the data flows in BIM as critical for BIM stakeholders. The data flows include the transfer of structured/computable data objects (e.g. databases), semi-structured data (e.g. spreadsheets) or non-structured/non-computable data (e.g. images). It is important to mention that data flows do not only include sending/receiving semantically rich data objects (the main components of BIM Models ‘smart objects’ see Figure 1), but also sending and receiving of document-based information (Froese, 2003).

According to Volk *et al.* (2014), BIM can be seen from two perspectives: narrow sense and broader sense. The narrow sense comprises the digital building model itself as a central information management repository (Eastman *et al*., 2011). The broader sense covers a more holistic image looking at functional, informational, technical and organisational aspects. Feasibly, depending on the stakeholders’ needs and project requirements, a BIM model is used to support and perform expert services such as energy or environmental analysis for buildings (AIA, 2008). Potential applications and required functionalities of BIM are needed to suit stakeholders’ and project’s needs (Volk *et al.,* 2014). Thus there are two types of expert software that might interact with BIM. The first type is data input applications providing services of data import, data capture and monitoring, data processing or transformation of captured data into BIM. The second type is data output applications providing technical analysis and reports (Volk *et al*., 2014). Functionalities are based on process maps, which define the logical view of information and activities, also defining stakeholders’ roles with a particular functionality (ISO Standard, 2010). Functionality (which can also be called data output) depends on stakeholder-, building- and project-requirements (e.g. 4-D scheduling). These functionalities are either inherent in BIM or attached to it as independent expert applications.

2.5. Design

2.5.1. Digital design methods

Lawson (2005) claimed that “Architects probably design most frequently with the plan, which is a very poor representation of the experience of moving around in a building”. In Lawson’s book ‘*How Designers Think*’, it was emphasized that the communication between users and clients with the designer is indirect, and a more-holistic approach is required in the design process. This is in order to address the gap between what is demanded by end-users and the design provided by the designer (Sanoff, 2000). Therefore, involving users, their knowledge and preferences started gaining importance in architectural, engineering and construction (Jensen *et al*., 2011).

According to Whyte et al. (2016), delivery of projects is transformed radically using digital technologies, as they support managing complex and large amounts of information. Different applications of digital technologies are widely employed within the construction sector (Whyte, 2003). Virtual reality (VR), as a digital design tool, is considered as one of the forms that provides a natural medium of a building, which can be manipulated and used to explore different stages of the construction process (Whyte, 2000). The use of such technology has provided much potential for collaboration, and with the development of digital technologies, the extent of virtual reality applications has increased (Whyte, 2000). With the increased power and capabilities of information technology, simulation tools have been developed, which can be employed by architects to understand the relationships between users and spaces (Kim *et al*., 2015). Currently, 3D and 4D simulation (e.g. Navisworks) using BIM models have enhanced users' understanding of the design, allowing an objective view to support users in gaining a sense of scale, but this navigation is relatively simplistic (Khemlani 2008). There are some recent research attempts where end-users and facility management teams have been involved. For example, Lee and Ha (2013) have proposed a BIM-based tool for residential buildings to meet different customer needs. The solution proposed a Customer Interactive Building Information Modelling (CIBIM) tool, which would allow customers to be involved in decision-making. It was found that collaboration using the tool helped to meet customer needs for the optimum use of space. Kim et al. (2012) formalized activity-space-performance relationships to improve the accuracy of space-performance analysis. Furthermore, Shen et al. (2012) proposed a user activity simulation and evaluation method (UASEM) that aimed to enhance the user's visual experience of the built environment, but did not explore whether such simulations have an impact on improving design solutions.

2.5.2. Unpacking the architectural design

Following the discussion of digital design methods, it is important to clarify what is meant by 'architectural design'. Markus's (1993) offered convincing accounts of architecture and its meanings. In Markus's work, he introduced terms for architectural analysis, which are form, function and space.

According to Markus (1993), it is argued that 'form' is the most obvious area of architectural analysis, and it refers to the physical shape and organisation of architectural components such as walls, windows, and so on. Within a building, the form articulates and encompasses the geometry of spaces. 'Function' is used as an expression of a building's use, and is defined not only by form and action, but also by the institutions and it is possible to a subvert building's function by just changing its name. In other words, functional types are forming constantly, which could be as a result of economic or social development. The final analytical tool is the 'space', which represents a more-elusive concept, essentially defined by the configuration of spatial cells and their relationships to other cells through a pattern of connections.

Digitally, Robertson (2011), in his book *The Architecture of Information*, described space in relation to the interaction between user and computer as 'information space'. This is because Robertson claimed that architectural space is more complicated than to be articulated using digital information. In understanding this complexity, Robertson has unfolded this complexity by examining 'information space' as a heterogeneous phenomenon using three separate spaces of information: semantic space, screen space and interaction space. Semantic space is the structure of information held within a computer; screen space is emerges as a result of separating out the visual component of information space; interaction space describes the input actions of a user that change the computer's output. Robertson's view of 'information space' has demonstrated the limitations of current architectural designs using digital technologies and that space is more complex to defined within visible information.

2.5.3. Experiential design methods

It can be argued that Post-Occupancy Evaluation (POE) is the most widely used method to gather feedback on a building by its users (Frontczak *et al.*, 2012). Literature about POE is provided at the beginning of this chapter, along with its benefits and limitations. According to Cherry (1999), various techniques such as observation, questionnaires and interviews in POE. However, it rarely allows users to provide feedback on design requirements, which normally are defined by architects. In contrast, evidence-based design is another method, which evolved to bring research methods to architect's practices to aid the formation of design decisions (Zengul and Connor, 2013). In addition, it uses research methods such as case studies, observations and experiments to capture data about users and their relationships to a building type. Similar to the previous method, this method rarely involves users' feedback on the process. Another method is the workplace planning, which formalises user activities in order to predict the utilisation of spaces (Pennanen, 2004). It simply defines the relationship between users' activities and the space programme of a building. Unlike the previous methods, workplace planning concerns the production for users rather focusing on experience.

According to Sheward (2014), there is a need to capture and formalise design expertise in order to incorporate it in the design process. In addition, it is argued that the knowledge captured on design depends on the area of expertise being documented. For instance, in architecture, an area of expertise can be related to the size of service areas in terms of usable area (square metres). Kimura *et al*. (2004) pointed out that even combining two areas of expertise can form new design knowledge. In BIM, it is desired that the semantic contents for building data can be extended. Moreover, the data structures within BIM allow associations to be made with attribute or parametric information. It is claimed by Sheward (2014) that combining different forms such as the parametric control of geometry, customized parametric objects and hierarchical building databases can provide feedback regarding the performance side of the design at an early stage of development. Motawa & Almarshad (2013) have proposed a KMoBM (Knowledge Management of Building Maintenance) tool, which can represent maintenance information for building objects (such as windows) using data exported from the BIM model. With the consideration of the above and many other experiential design aspects, capturing knowledge in relational space requires incorporating not only the designer's perspective, but also an understanding of the users' perspectives in order to deliver efficient and effective design that can satisfy multiple stakeholders. Kim *et al*. (2015) argued that one of the current challenges in relation to user involvement is virtualising the architect's work in order to support direct user involvement, as this would contribute towards informing design decisions and establishing appropriate methods to communicate these design decisions with different stakeholders.

2.6. Summary of the chapter

This chapter aimed to gain an insight into the following areas: building performance, space, information modelling and design. It emphasizes that 'performance' is a complex aspect, which requires holistic consideration to grasp its rich connotations. Compared to other aspects of building performance, 'space' influences people's experiences, as it combines both quantitative and qualitative aspects. With respect to the mentioned theories and concepts related to space, in a sense, it is influenced by two major streams. The first is the structural view, where the architectural perspective tends to confine experiences faced within a space. The second, and more important, is that even with the philosophical positioning of some theories, space remains aligned with hard/quantifiable measures, which do not acknowledge the view of those involved in experiencing the space. BIM is the current technology that drives the design and plan of the space, particularly in terms of information modelling.

Although BIM has extended the capability of various information integration and modelling techniques, it is clear that user involvement at the design stage is still lacking, and perception is often derived by those involved in the building delivery process. Aspects related to design digital and experiential methods as well as drawing an insight on architectural design were discussed at the end of the Chapter, which concluded with emphasizing the importance of user involvement in order to capture various knowledge aspects, and then embed them in the design proposed by architects.

Chapter Three - Research Methodology

3.1. Introduction

This chapter reports on the methodological approach adopted for the data-collection process during this research. The following sections detail the research design, philosophical positioning, philosophical positioning methodology, and follows by the research method selected for this research. Next, it will be looked at the research process, which documents data collection process, research journey and data analysis. The chapter is concluded with the ethical considerations.

3.2. Research design

According to Yin (2014), research design is defined as a logical sequence that connects the empirical data of a study to the research question of that study. Research design provides a framework for undertaking research and establishes a means for collecting and analysing the data that responds to the defined research questions (Bryman and Bell, 2004). Creswell and Clark (2007) stated that a research design sets out guidelines that connect different elements of methodology adopted for a study. It relates the philosophical positioning (paradigm) to the research strategy, which then links to the methods for collecting the empirical data. Therefore, the above definitions suggest that research design is a vital element to the overall research process.

There are a number of considerations that should be taken when choosing the research design. According to Yin (2013), it is important to ensure that problems, which affect gathering evidence are prevented. This is affected by a number of factors, which can include - but are not limited to - the nature of the research and type of question that research is seeking to address. Elaborating on this, Saunders et al. (2011) argued that research design is determined by research questions and objects, philosophical positioning, extent of existing knowledge, resources and time available. The following section discusses the researcher's philosophical stance.

3.3. Philosophical positioning

Vogt *et al*. (2012) stated, 'like all researchers, we have preferences and are more experienced with some methods than others. But we have attempted to be ecumenical, and our approach is most often intentionally pluralistic'. In other words, researchers can find value in all approaches where any can be effective in a particular research problem (Vogt *et al*., 2012). It is acknowledged by Kelle (2006) that methods in general have their weaknesses as well as strengths, and using both qualitative and quantitative methods can overcome some of these weaknesses since it provides better understanding of the problem and more perspectives on the phenomena being investigated (Easterby-Smith *et al*., 2008; Cresswell, 2003). This follows the *critical realism* paradigm which stands as a 'middle way' between strong positivism and strong constructivism (Meckler and Baillie, 2003). Moreover, investigating different perspectives to clarify the way the stakeholders generate knowledge differently (Mingers, 2008) makes critical realism an appropriate approach for the present research: analysing the different information required for evaluating building performance and whether the data used for evaluation can be assessed using BIM and to what extent. In such matters, critical realism helps answering the questions that cannot be answered by qualitative or quantitative data alone (Cresswell, 2003).

There has been a growing interest in ideas derived from the philosophical tradition of critical realism in a range of disciplines (Ackroyd and Fleetwood, 2000; Fleetwood and Ackroyd, 2004), with some extensive work in the field of information systems (Mingers, 2004; Wynn and Williams, 2012). According to Mingers *et al*. (2013), critical realism offers exciting prospects by shifting the focus away from data and methods of analysis to focusing attention on the real problems as well as their underlying causes. Initially, critical realism was developed by way of arguments against both the empiricist view of science as embodied in positivism

(Bhaskar, 1978), and the idealist view of social science as embodied in constructivism (Bhaskar, 1979). According to Mingers *et al*. (2013), in a critical realist world view, the methodology starts by taking an unexplained phenomenon (which in this case is inquiring into the nature of building performance from multiple perspectives) with proposing hypothetical mechanisms (which in this is case is the use BIM) in order to generate explanation for that phenomenon. Furthermore, this process supports moving from experiences in the empirical domain to possible structures or mechanisms in the real domain.

3.3.1. Exploring how BIM can support the delivery of better building performance for buildings, a critical realist approach

The present research is aligned with the critical realist worldview. From the literature review on building performance, space, information modelling and design, the summary identified that this research requires a critical realist approach to answer the research questions. This is because the nature of this research requires a socio-technical approach, which uses empirical findings to propose a mechanism that can be applied in the real world.

3.4. Critical realist methodology

According to Zachariadis et al. (2010), critical realism allows the flexibility of adopting a variety of research methods, which can be chosen according to the type of research. Perhaps, this is due to the fact that one of the characteristics of critical realism is its strong emphasis on ontology (Bhaskar, 1998), which allows for the combination of both quantitative and qualitative methods. Sayer (2000, p. 19) stated:

> "Compared to positivism and interpretivism, critical realism endorses or is compatible with a relatively wide range of research methods, but it implies that the particular choices should depend on the nature of the object of study and what one wants to learn about it"

According to Zachariadis et al. (2010), it has been pointed out that methodological implications for the use of mixed methods within critical realism have been largely unexplored. In designing mixed methods research within critical realism, they explained that the role of quantitative methods is largely descriptive. This is because correlations between variables cannot by themselves uncover evidence about a certain observation. According to Mingers et al. (2013), qualitative methods have a more profound purpose within critical realism. This is because they are more capable of describing a particular phenomenon, of identifying structured interactions between complex mechanisms as well as constructing propositions. Therefore, this research mainly uses qualitative methods to explore the research question about the role of BIM in supporting the delivery of better building performance for buildings.

3.4.1. Qualitative methods

According to Yin (2013), qualitative research seeks to understand and discover the experiences, thoughts and perspectives of participants by exploring meaning, purpose or reality. It provides a naturalistic approach to the world where the researcher is located in the real world, and includes practices that aim to transform the world into a series of representations, which can be in the form of interviews, conversations, photographs, memos, and recordings for example (Denzin and Lincoln, 2000). The present research requires the researcher to be located in the real world and have close interactions with different stakeholders within the built environment that they deliver and use. This is in order to understand meaningful insights into building performance, and how BIM can enhance the delivery of better building performance.

Qualitative research has many approaches, but there are common characteristics that are central to all these approaches. These characteristics include the natural setting, which acts as a source for data collection for close interaction. Another characteristic is having the researcher as a key instrument for data collection. Also, the use of multiple data sources such as words and images, and inductive, recursive and interactive data analysis. Another important characteristic is the focus on participants' perspectives, meanings and also subjective views (Creswell, 2007). Qualitative research can be conducted using many approaches such as narrative, phenomenology, grounded theory, ethnography and case studies (Yin, 2013). Selecting one or more of these approaches depend on a number of conditions where Yin (2013) stated three main conditions: the type of question posed, the extent of control that the research has over actual behaviour events, and the degree of focus on contemporary - as opposed to entirely historical - events.

3.4.1.1. Case Study research

Creswell and Clark (2007) states that a case-study approach involves the study of an issue through one or more cases within a bounded system. A case-study approach investigates a contemporary phenomenon within a real life context, and employs a variety of data sources (Yin 2013, Baxter and Jack, 2008). The method of case study has been used widely by researchers and many typologies have been defined. According to Levy (2008), there are different types of case study research, which can be ideographic, hypothesis generating, hypothesis testing and plausibility probing. Ideographic case studies aim to describe, explain or interpret a particular case as an end in itself, rather than developing broader theoretical generalisation where this can be inductive or theory guided. Hypothesis-generating case studies aim to generalise beyond the data by examining one (or more) cases in order to develop more-general theoretical propositions that can be tested through other methods. Hypothesis testing case studies aim to test certain types of hypothesis. Plausibility probing case studies are an intermediary step between theory-testing- and theory-generating case studies (Levy, 2008). Apart from Levy's distinction between different types of case studies, Creswell and Clark (2007) identified that case studies can be one of three types: single instrumental, collective or intrinsic. Yin (2013), however, provided a more-simplified categorisation of the case studies, which are single and multiple case-study designs. These two types can be broken down into four types, which are single case (holistic) designs, single case (embedded) designs, multiple case (holistic) designs and multiple case (embedded) designs. The selection between single or multiple case studies is dependent on the type of research, the type of research questions and the resources available to the researcher.

3.4.1.1.1. Types of case-study designs

According to Yin (2013), just as in experiments, a case study approach can be designed as a single case study or multiple case studies. Selecting the appropriate design depends on the problem being studied as well as the period available to the researcher. A single case study is employed when conducting an in-depth investigation into a certain phenomenon or concept in order to provide a rich description (Yin, 2013). Multiple case studies aim to enable theoretical replication where the intention is to allow analysis and comparisons between different case studies (Darke et al. 1998). According to Herriott and Firestone (1983), the evidence gathered from multiple case studies is often considered more compelling and provides more-robust evidence to the overall undertaken study. In both cases (single and multiple case studies), there is another choice of having holistic or embedded units of analysis (see Figure 3.1).

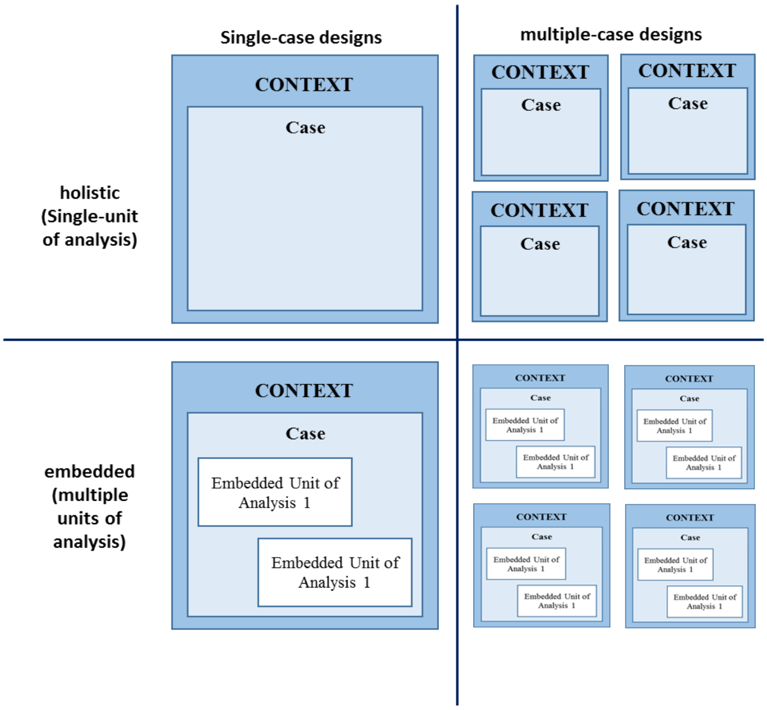

Figure 3.1: Types of case study research designs (Yin, 2014)

3.4.2. Choice of research design

According to Creswell and Clark (2007), there are many characteristics that support the choice between different qualitative approaches. These characteristics are: the type of question to be answered, the discipline background, the unit of analysis, data collection forms, data analysis strategies and type of written report. It is anticipated that these characteristics can support the research in making an appropriate choice of the qualitative method to be employed for the study. Table 3.1 shows the qualitative research methods, the form of question along with two other metrics, which indicate whether a method requires control of behavioural events and whether it focuses on contemporary events.

Table 3.1: Guideline for the choice of qualitative research method (Yin, 2013)

Method	**Form of research question**	**Requires control of behavioural events**	**Focuses on contemporary events**
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival records	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No
Case study	How, why?	No	Yes

Based on the guideline presented in Table 3.1, the research into how BIM can support the delivery of better building performance for buildings aligns with the question of 'how' and 'why'. Thus, by combining the characteristics outlined by Creswell (2007) and the guidelines presented by Yin (2014), a case study approach is chosen to answer the research question for this study. This is because it requires inquiring into the contemporary events where it will be looked at from different stakeholders' experiences and perceptions, and to obtain meaningful responses, a case study approach is useful in order to provide a context for the gathered experiences and perceptions.

3.5. The Case Study Method for exploring how BIM can support the delivery of better building performance

According to Proverbs and Gameson (2008), the use of the case study method is claimed to be highly relevant in the construction industry, because the industry is made up of many types of businesses and organisations. Over the years, the case-study method has received many definitions (Stake, 1995). In that sense, there have been many misconceptions about the case study as a research method where many authors state that it has limitations (Yin, 2013). Miles and Huberman (1994) for example, has linked case study use to the use of a particular evidence or methods. However, Yin (1981) suggested that the case study research method is neither connected to particular evidence (qualitative or quantitative) nor a data collection method (ethnographies or participant observation), but a case study can be exploratory, descriptive or explanatory. Yin (2014) provided a two-part definition that encompasses all aspects of case study research:

1. The case study as an empirical study that investigates a contemporary phenomenon in depth and within its real world context. This is especially useful when boundaries between phenomenon and context may not be clearly evident.

2. The case study as an enquiry that copes with the technically distinctive situation in which there are more variables of interest than data, relies on multiple sources of evidence with the data needing to converge in a triangulating style, which as a result benefits from the prior development of theoretical positions to guide data collection and analysis.

From the above definitions, the strength of a case study method for this research lies in its ability to provide context for the phenomenon being studied. This is because the phenomenon (BIM for building performance) is complex, and requires an in-depth investigation.

3.5.1. Reasons for the case study approach

The traditional approach to the case study often involves gathering evidence from the cases and uses that evidence as a basis to construct a theory (Yin, 2013; Fellows and Liu, 2003). It has been suggested that case study research can be conducted using theories as the main basis (Yin, 2013). Yin (2013) claimed that a good theoretical propositions lays the foundations for generalising the findings from the case study, which can apply to other situations through making 'analytics' instead of 'statistical generalisations'.

In this research, the literature review on building performance, space, information modelling and design leads to the conclusion that building performance is a complex concept and needs to be inquired into from multiple perspectives, and the current BIM applications do not support the integration of a wide variety of information. These two conclusions will form the basis and guidelines for data collection in order to ensure that the research question is answered.

3.5.2. Critical realism and case study research method

Sayer (2000) suggested that there are two broad types of research methods: extensive and intensive. Extensive research uses large-scale surveys, statistical analysis and formal questionnaires, but it is restricted in terms of its ability to generalise, and has limited explanatory power. Intensive research focuses on individual agents in context using interviews, qualitative analysis and ethnography. However, the main distinction between both extensive and intensive research is not identical through the method employed such as ethnography, survey analysis or case study. Instead, extensive methods can be used within a single case study, whereas intensive methods are not restricted to a single case, and can use other methods.

According to Easton (2010), there are many tasks that need to be considered when using a case study approach within critical realism. First is deciding the phenomenon to be studied where studying phenomenon such as organisations or networks of connected organisations is more suited than that for individual behaviour. The boundaries of the phenomena must be identified in order, but these boundaries can change during the course of the research. Second is the nature of the research question. This is because, in critical realism, understanding the social phenomenon is only possible through recording and analysing events that take place as a result of actors acting where this includes both human and non-human. This recording can be live, or by achieved by reflecting on past events. Third is identifying entities or objects that characterise the phenomena being researched. Finally, is the collection of data where it is claimed that case research is extensive with respect to the data that might be collected. Often, data collection commences with qualitative such as semi-structured interviews, as it provides a high level of flexibility. However, other data can also be collected such as experimental data or other types that can respond to the research context identified.

Next, there is the issue of interpreting data where a critical realist accepts that data can be empirical, actual and real, and can be obtained from both people and/or about material things. This makes explanation of the data to be interpretive, which adds another complexity, including understanding of the subjects' (e.g. people or machine) understanding. This may require the researcher to re-visit the research to collect more data until epistemological closure is obtained. Case studies in critical realism may employ deductive or inductive cycles of data. 'Deductive' supports identifying the phenomenon of interest, whereas 'inductive' provides data to be explained, and perhaps test the explanation. Achieving an 'acceptable' explanation" can be through 'judgmental rationality', which implies that claims can be discussed on what the researcher thinks it is (Easton, 2010).

3.6. Research process

The design of this research follows the procedure of multiple case studies, which was presented by Yin (2014) and in Figure 3.1 above. There are three main phases, which are involved when designing the process for research: *theory development and case study selection*, which includes design of the *data collection*. Data collection includes preparing and conducting the case studies (individual case studies) and writing individual reports. The third phase is the *analysis* of individual cases as well as cross case analysis in order to draw cross-case conclusions. This results in developing implications of the results and writing cross-case reports. The process that this research follows is shown in Figure 3.2.

3.6.1. Research design stage

In this research, the design phase can be broken into two main stages: conclusions drawn from the literature and case study design. Conclusions from the literature indicate that building performance is a complex concept and needs investigated from multiple perspectives and current BIM applications do not support the integration of a wide variety of information. Case-study design includes stating data-collection instruments, which will be followed by data analysis. Figure 3.2 gives an overview of the research design employed in this study. It is important to acknowledge the researcher's impact on the study. This approach to research involves the researcher in interacting with the interviewees, interpreting their responses and analysing the collective results. The dangers of this were recognised. Care was taken to support results from more than one source, to have interpretations challenged by supervisors and to make the analyses based on a number of subjects.

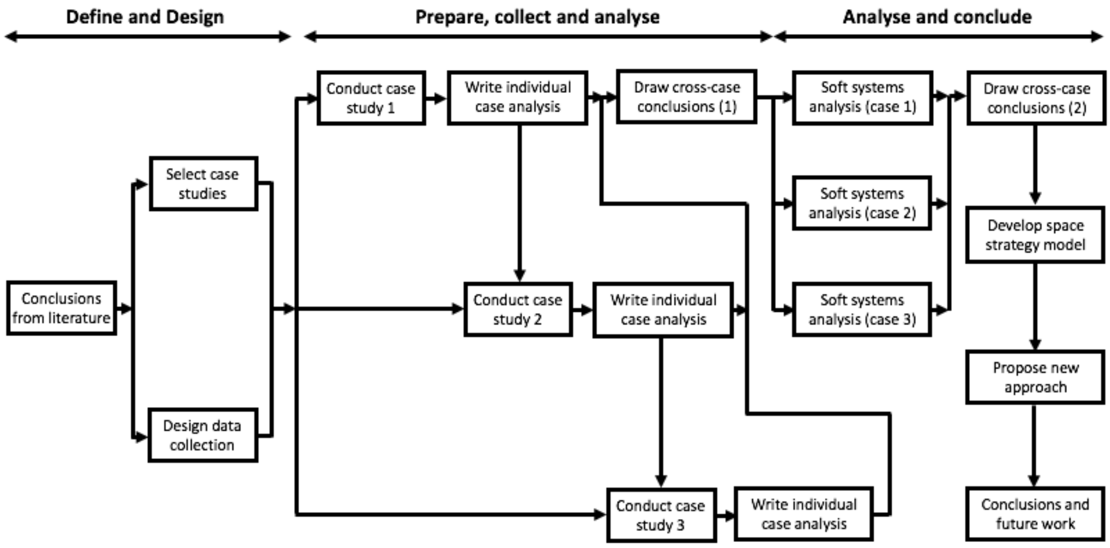

Figure 3.2: Multiple case- study research design.

3.6.1.1. Literature review

The literature identifies that the nature of the problem lies in two main streams. The first is in the multi-perspective view of evaluating building performance. The second is inquiring into the problematic nature of experience within spaces from multiple perspectives. Therefore, there is a need to model and manage the different perspectives for several elements within building performance to maximize overall satisfaction and improve manageability of the whole building life cycle. On the other hand, what level of accuracy can be expected or desired as more parameters and fuzzier parameters are considered has yet to be determined. This research aims to explore how BIM can support the delivery of better building performance for buildings, so that data requirements in BIM can be informed at an early design stage. A framework for information management, which will provide organised data to overcome complexities of representing the performance of space in BIM environment, is proposed.

A socio-technical approach using multiple perspectives is proposed to allow a more-holistic view over the problematic nature of space in buildings. A socio-technical approach is concerned with the relationship between technology and the social context in which technology is used. Simultaneously, BIM requires the integration of multidisciplinary systems in order to reduce conflicts, increase accuracy and satisfy all stakeholders. Therefore, different aspects within the built environment should perform satisfactorily for different stakeholders. However, some aspects are heavily quantitative based such as energy performance, acoustics and air quality when compared with other aspects such as space that requires quantitative and qualitative considerations. This is because the nature of space is not fixed, and often (if not always) designed and delivered by different stakeholders than those who are using it on a daily basis, which has resulted in a performance gap between what is intended and delivered. Therefore, inquiring into the problematic nature of this complex aspect requires a social consideration of the current technologies (BIM and its related applications) used to design and deliver spaces.

3.6.1.2. Case study design

This research uses a holistic multiple case study approach (shown in Figure 3.1), which was outlined by Yin (2014). This approach was chosen to inquire into different perceptions and meanings of building performance by different stakeholders as well as how BIM can support the delivery of building performance. The reason to choose a holistic multiple approach is to allow these two phenomenon within different contexts to be explored. However, due to the complexity of the phenomenon being studied, the case studies have followed a research journey where the output of a first case has influenced the direction of the next case study. A comprehensive review of the research journey will be explained later in this chapter.

3.6.2. Data collection

The data collection in this research took the form of asking and examining. Data collection for the case studies commenced in October 2013 stretched to early 2015. According to Miles and Huberman (1994), it is advised to maintain a concurrent approach, so that data collection and analysis go hand-in-hand. Following a concurrent approach supports identifying new areas of the study where data collection needs to focus in qualitative research or case studies. For the three case studies in this research, a total of 21 interviews were conducted. The number of interviews for each case study was mainly influenced by subject accessibility. Interviewees representing three stakeholder groups were selected (mentioned in section 1.4), which are the building delivery team, facility management team and building occupants. These represent stakeholders who influence (building delivery team) or are influenced (facility management team and building occupants) by building performance. In addition, due to the nature of this research, which seeks to explore the problematic nature of building performance, the number of the interviews could not seek to reach a saturation point. The novelty of the work meant that initially there was a large amount of ambiguity in the research which provided an extremely large scope. Part of the process of the research was to reduce this ambiguity and to better map the area for future more detailed study. This is further acknowledged in the way that one case study influenced the next, which will be explained in section 3.6.4.

3.6.2.1. Interviews

According to Kumar (2005), interviewing is one of the most powerful qualitative methods to gather primary data from targeted people (Kumar, 2005). In addition, interviews provide the researcher with a deep insight into information. In addition, interviews allow attaining highly personalized data and the importance of a good return rate are the main reasons to conduct interviews (Gray, 2004). However, as Jones (1985) stated, it is necessary for the researcher to consider several potentially problematic issues when choosing interviews as one of the methodologies. The structure of the interview is a primary concern, and the time required to gather the information and appropriateness of interviews when compared to other methods is also important. Considering interviews as only a set of questions to be answered is over simplistic. As Easter-Smith *et al*. (2008) claimed, it is important to identify the level of structure before conducting the interview. In this research, it is important to avoid the unstructured interview since it is necessary to capture specific information as the scope of the interview is to provide particular information to satisfy objectives of the research. This research uses semi-structured interviews, as this allows developing an understanding of the respondent so that the researcher can derive meaningful knowledge. The researcher is aware of possible risks associated with data collection such as the level of confidentiality, and others, which are mentioned in the ethical consideration section below. The targeted stakeholders are mentioned accordingly in the next chapter.

3.6.2.2. Document analysis

Document analysis can be defined as a systematic procedure used to review and evaluate documents, which can be printed or electronic (Bowen, 2009). The method of document analysis requires the data to be examined and interpreted to gain understanding and to develop empirical knowledge (Corbin and Strauss, 2008). This method is applicable when using case studies. According to Angers and Machtmes (2005), documents have been analysed as part of their ethnographic case study, which supported exploring different beliefs and context factors with relation to the study they were conducting. In this research, documents such as client's brief and execution plans (e.g. RIBA 'Royal Institute of British Architects) are used to assist the data analysis.

3.6.2.3. Observations

In general, observation is a way of gathering data by watching events, behaviours or noting physical characteristics in a natural setting. According to Marshall and Rossman (1989), observations enable the researcher to describe a situation using the human's five senses. Participant observation is a process that enables the researchers to learn about activities of the people in a natural setting. In this research, and particularly in the third case study (Educational Building 2 Case Study), participants will be required to provide feedback on representations of space, which the researcher is going to display. The task requires the participant to observe the displayed representations (2D plans and 3D visualisations) and provide feedback on forms, which are provided by the researcher. A full description of the task will be provided in the next chapter (see section 4.4.3).

3.6.3. Case Study selection process

There are three case studies that have been selected for this research: Educational Building 1, Office Building and Educational Building 2. Educational Building 1 was selected as the first case study, as at the time the research began, the building has just started operating, which made it ideal to retrieve an early feedback from different parties. One of the main factors that influenced the selection of Educational Building 1 was the available access to different parties (delivery team, facility management team and building occupants). Another factor that influenced the selection of Educational Building 1 is that it has been awarded an ‘A’ BREEAM Excellence rating, which makes it suitable to collect data on, as this research’s main focus was upon building performance. A final reason is that Educational Building 1 was a BIM project, which also suits this research, as it investigates the better delivery of building performance using BIM. The selection of Office Building case study was influenced by additional inquiry resulted from analysis on Educational Building 1, which looked at investigating experiences of using space. One of the main factors that influenced the selection of Office Building was obtaining contacts of those who manage the building, which perhaps played a major role in gaining access to other parties (delivery team and building occupants). Another factor for selecting the Office Building is that it represents a dynamic environment where space can be influenced by many factors such as use, change and maintenance. Another factor, which is similar to that mentioned for Educational Building 1, is that Office Building was rated as ‘A’ BREEAM Excellence. Similar to the Office Building, the selection of Educational Building 2 was influenced by the additional inquiry resulted from analysis on Office Building, which looked at investigating experiences of representations of space. One of the main factors that influenced the selection of Educational Building 2 was, at the time of the research, the building was under construction, which made it ideal for the additional inquiry. Another equally important factor, is that the researcher had access to different parties (future facility management team and future occupants), and more importantly, to the BIM models used for the project at the time. The next section will look into the research journey for the three case studies selected for this research.

3.6.4. Research Journey

The research ‘journey’ commences with the Educational Building 1 case study to inquire into building performance. This is achieved by looking into definitions of building performance and the process of achieving building from the three stakeholders (building delivery team, facility management team and building occupants) mentioned above. BIM is also included in the inquiry since it is part of the process of achieving building performance, in order to determine the value it offers to building performance, and the barriers that need to be addressed. The outputs of this case study show that building performance has multiple meanings and that many factors influence it. The case study also shows that different people have different views of buildings and definitions of building performance. It is anticipated that the range of meanings are perhaps the result of different experiences in buildings. These results suggest that there is a need to select a reference point for building performance and the factors that influence performance. Hence, ‘space’ is chosen to be the reference point for the inquiry into building performance. This is because it provides a medium where different meanings by different stakeholders can be situated. The findings of the first case study (Educational Building 1) are used to shape the second case study - the Office Building.

The second case study aims to inquire into the performance of space as part of building performance by looking into the process of achieving performance of space and the experiences of using space. The data was gathered from three stakeholders, but in this case study the building delivery team, differs from the previous case study, as it is only represented by the client. The reason for this will be explained in the next chapter (Section 4.3). Although the definitions of performance had initially been considered within the first case study, definitions are also explored in the Office Building case study. Exploring the definitions of building performance is considered as an overarching input for all the three case studies in order to demonstrate the problematic nature of building performance and the factors influencing it. BIM is also included as part of the inquiry, but as space was selected to be the focus of inquiry for performance, the role of BIM is considered as part of the process of achieving performance of space. The case study also shows that designers tend to rely on ‘reference representations’ to aid them when producing representations of space. These findings show that it is important to investigate how factors influencing performance are embedded within the representations of space. The third case study (Educational Building 2) considers the experience of space representations to investigate how factors influencing performance are embedded within these representations.

The third case study, which is conducted on the Educational Building 2, aims to inquire into performance of space. Unlike the previous case studies, this case study is conducted on a building during its construction stage. As in the previous case study, the Educational Building 2 case study begins by looking into definitions of building performance, process of achieving performance of space and experiences of using space. The representations of space used in this case study are 2D plans and 3D walkthroughs where participants identify both information and concerns based on the representations that are presented to them. The representations are derived from the BIM model that was designed for the building. Similar to the previous case studies, the data was gathered from three stakeholders, but in this case study the building delivery team differs from the previous case study, as it is only represented by the designer. The outputs of this case study show that representations of space have to be information rich to capture experience of a space.

3.6.5. Data analysis process

According to Corbin and Straus (2008), qualitative data analysis can be claimed as art and science because the process of analysing demands a balance between the two. It is *art* because it relies on creative use of different procedures to solve a problem where it is required to construct a coherent as well as explanatory story from the data, while remaining flexible with the use of procedures. It is also *science* because it systematically supports developing concepts in terms of their properties and dimensions while at the same time validating interpretations by comparing them against the incoming data (Corbin and Straus, 2008). According to Wolcott (1994), qualitative data analysis involves three main processes: descriptive, analysis, and interpretations, where these processes are also described as ‘data transformation’.

The qualitative process begins with descriptive analysis, which draws on field notes and informant’s words to ensure that the researcher stays close to the original data recorded (Wolcott, 1994). The second process is to expand beyond a purely descriptive account with an analysis that commences in systematic, yet careful, ways to identify key findings. The third process can spring from the first or second process with a purpose of making sense of what goes on. In this research, there are two stages for data analysis. The first stage is thematic analysis, which will be done for each of the undertaken case studies, which also can be called within-case analysis. In this stage, the researcher has interpreted the results gathered from the interviews for each of the case studies in order to draw out the first cross-case conclusion. The second analysis commenced based on the conclusions drawn (cross-case conclusion (1) in Figure 3.2) from the thematic analysis of all case studies. A systems thinking approach would be used to make further conclusions from all the case studies. In this stage, soft systems analysis (chapter five) was used for the three case studies where the researcher had formed the rich pictures using the interpretations of the interviews to describe different stakeholders’ worldviews, which is explained in section 3.6.4.1.3.

3.6.5.1. Systems thinking approach

According to Flood and Carson (1993), systems thinking provides a framework of thought that support dealing with complexity in a holistic way. Marsiglia (2008) stated that systems thinking is an approach to understand reality and what interactions occur within it. In simple terms, a system as a *representation* of a situation has many characteristics. The first is that it is the *assembly of elements* related to an *organised whole* where an *element is a representation of some phenomenon* in a social world. Any element must normally be capable of behaviour such that it has some significant attributes that may change. A *relationship or communication between elements* may be flows of interconnections between materials, information, or energy.

In problem solving, there are two approaches, which are *reductionism* and *holism*. A reductionist approach is seen as a traditional way of solving a problem, which also is common across many disciplines (Jackson, 2005). It is stated that reductionism tends to refer to understanding rather than problem solving. As a principle, reductionism breaks down the problem into *parts* and then reconstitutes them into a *whole* to provide systematic understanding. A holistic approach is about understanding the dynamic behaviour of a system, which is an opposite approach to reductionism.

Systems are also representations of a *hierarchal structures and organisations*. Hierarchal structures are representations of systems and sub-systems. It is indicated that, at any study upon system ideas, identifying an appropriate *level of resolution (level of complexity)* is important. This is because identifying this level will support 'problem solving', as it defines the extent of the problem being dealt with (M'Pherson, 1974). The ascending of hierarchal organisations reveals an important phenomenon that is *emergent properties*. Emergent properties indicate that 'the whole is greater than the sum of its parts'.

According to Checkland (1981), there are three types of systems (illustrated in Figure 3.3): natural systems (the climate system), *designed physical systems* and *human activity systems*. *Designed physical systems* can be defined as the systems that are created by people, which are subjected to constraints imposed by physical laws (e.g. the stresses on a structure imposed by wind pressure). Another system type is an abstract system (e.g. mathematical model), which are human inventions. Unlike designed physical systems, this kind of system is not subject to physical laws. This is because software forms the embodiment of an abstract system (see Figure 3.3). Human-activity system (unlike other systems) is seen crucial, as it is highly non-objective, and 'human factors' (e.g. personal preferences) are involved in them.

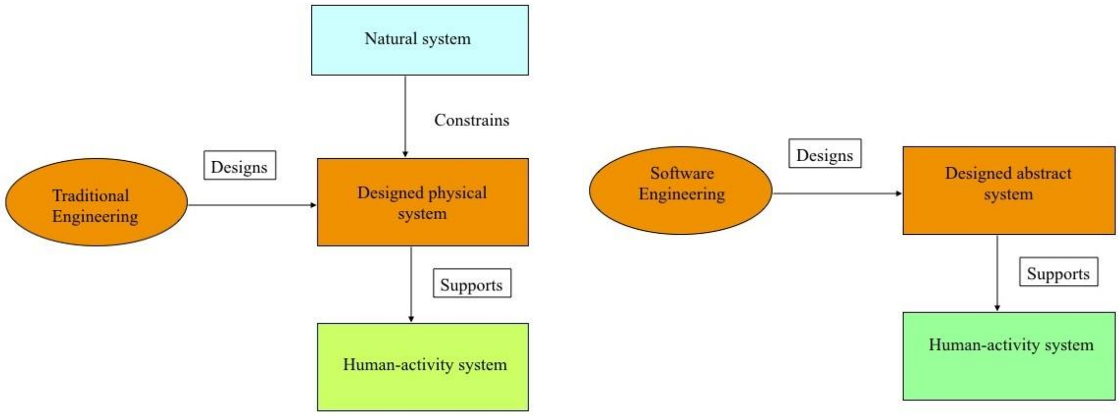

Figure 3.3: Types of systems proposed by Peter Checkland (Checkland, 1981)

According to Checkland (1999), there are two parts of the body of systems, which are hard-systems methodology and soft-systems methodology. Hard systems have their focus upon the physical processes (rather than on human activities) which also can be called as an engineering approach to systems thinking. This is because it follows an organised path, which follows step-by-step. The soft-systems methodology approach appears to have its focus upon human activities, and what they are doing. According to Checkland (1999: 15):

> "In soft problems the designation of objectives is itself problematic. Not surprisingly, hard systems-thinking was not usable in these problems, which were always those of a kind to which the concept, human activity system, was relevant"

Due to the complex nature of this research, soft systems are used to provide a holistic approach into the phenomenon being investigated. In this research, systems thinking is used, as it supports dealing with complexity, handles information modelling as well as handling softer aspects. This will be realised when conducting soft systems analysis later in this research (chapter five).

3.6.5.1.1. Soft systems

According to Mingers (2003), soft systems are considered to be amongst those methodologies that consist of a structured set of methods or techniques, which aim to assist people in understanding their research or intervention. Soft systems methodology has been proposed by Peter Checkland (1981), which later was extended by Brian Wilson (1990) to cover a wide variety of formal and informal activities carried out by the business. It is important to emphasize that Peter Checkland and Brian Wilson have been involved in the development of soft systems methodology (SSM). Checkland has been more involved with the philosophical aspects of SSM whereas Wilson has been more concerned with the practicality and application of the methodology. According to Cox (2014), soft-systems methods have an embedded socio-technical approach where otherwise there are two main approaches to information systems development (hard systems and soft systems). Hard systems are those agreed and defined concepts within a problem where it is based on the philosophy that everyone sees things in the same way. In addition, hard-systems based approaches tend to operate in an objective, systematic and reductionist manner. In contrast, soft systems adopt the stance that people see things differently, where it uses techniques to help exploring the different views of the same situation and expose areas of conflict. Soft systems have been used widely in the information systems field, but more commonly for information management and business analysis work than designing computer systems (Wilson, 1990).

According to Checkland (1981), soft-systems methods provide a means to explore complex situations by facilitating a flexible approach to understand the issues within a particular problematic situation. Cox (2014) quoted that:

> “Soft systems approaches use techniques that help to explore different views of the same situation and expose areas of conflict, which may be the root cause of problems in the organization”.

Soft systems provide a flexible approach to exploring information requirements, providing a constructive method about situation thinking (Liu *et al*., 2012). Soft-systems methods (SSM) recognize that people view the same situation differently and provides tools to explore those different perceptions. According to Wang *et al*. (2012), Wilson has extended SSM to cover role analysis and allow information analysis; this concept is discussed further in the methodology chapter.

3.6.5.1.2. Soft systems methodology in critical realism

Soft systems methodology (SSM) is essentially phenomenological, therefore denying the ontological reality of 'systems' in favour of epistemology, and distinguishing strongly between natural and social science. From a critical realism perspective, SSM explicitly commits the epistemic fallacy of reducing the ontological to epistemological. Also, SSM has been criticized for accepting all viewpoints as equally valid. Critical realism also allows exploration of why particular viewpoints may be held and the social and psychological structures impending or facilitation change. Wilson's soft systems method (1990) is based on the soft systems method proposed by Checkland (1981). Both approaches incorporate the same first four stages (find out about the situation, express the situation, define root definitions and develop conceptual models). Table 3.2 demonstrates the philosophical assumptions embedded within SSM.

Table 3.2: Framework for characterising the philosophical assumption of soft systems methodology adapted from Mingers (2003).

What it says?		To explore different world views, which are relevant to a situation in the real world
Ontology		Real-world problem situation; conceptual human activity systems and worldviews.
Epistemology		Systems concepts; rich pictures; analyses; root definitions; conceptual models; information categories; consensus model
Axiology	Necessary Information	Hard and soft information concerning process, ideology, perspective and relevant worldviews
	Source of Information	Concepts, logic and participation by concerned actors related to the situation
	Users	Analyst, researcher, facilitator, and participants
	Purpose	Learn, inquire and improve a problematic situation by gaining agreement on feasible and desirable changes.

In the present research, the focus is drawn upon understanding the problematic nature of performance and space from multiple perspectives. Wilson's (1990) method is adopted, as it supports exploring different views about the problem to form a consensus model, inquiring into the information needed to support the activities in that consensus model and finally compare it to the existing situation in the real world. SSM is essentially phenomenological, therefore denying the ontological reality of 'systems' in favour of epistemology, and distinguishing strongly between natural and social science. From a critical realism perspective, SSM explicitly commits the epistemic fallacy of reducing the ontological to epistemological. Also, SSM has been criticized for accepting all viewpoints as equally valid. Critical realism also allows exploration of why particular viewpoints may be held, and the social and psychological structures impending or facilitation change.

3.6.5.1.3. Soft Systems Methodology (SSM)

Wilson (1990) seeks to achieve a consensus conceptual model and identify the information categories needed to support the consensus model derived (see Table 3.3 for the stages). In soft systems, there are different tools such as Rich Picture, Root Definition, CATWOE, Conceptual Model, Consensus Model, Information Categories and Maltese cross (Wilson, 2001). These tools can be used to explore the information needs from different perspectives, which then can be used to point out the improvements needed for the current technologies or highlight the necessity for additional tools to deliver an optimum space. Thus, it is realised that SSM is not only used as a method of inquiry, but also as analytical tool to derive useful knowledge.

As part of soft systems methodology (SSM), a rich picture is formed to express the views of these three groups, which can then be used to identify contradictions and points of conflict in the situation (Sutrisna and Barrett, 2007). According to Bell et al. (2015), rich pictures provide an unstructured way of capturing information flows, communication and in essence the human experience of complexity. In addition, they can encapsulate meanings, non-verbal communications, and their primary purpose is to make pre-deliberative analysis assessments, which can offer an insight into different perceptions. More comprehensively, Bell and Morse (2013) stated on describing the rich pictures:

> "Rich Pictures would appear to be a means to almost 'trick' the individual or the group into an examination of cryptic (hidden meaning), arcane (pertaining it the inward or mystical) or occult (hidden secret) aspects of the individual or the group. In total, the picture is an acroamatic device" (Bell and Morse, 2013: 34).

Rich pictures are frequently drawn by individuals, but groups are given the chance to draw together, which can support the identification of worldviews on a problem. However, in this thesis, rich pictures will be drawn by the researcher with the respect to the key findings for each of the case studies without the need to communicate these rich pictures to the research participants. Although this may be claimed to lack consistency, soft systems are employed as an analytical tool to further explore the first drawn conclusion from the case studies. If soft systems were to be applied methodologically, then involvement of the research participants in developing and validating the rich pictures developed becomes vital.

CATWOE, one of the modelling tools in SSM, is used to demonstrate the different space requirements by deriving root definitions based on multiple perspectives of those involved in this research. Vacik *et al*., (2014) suggested that CATWOE has helped to simplify complex situations, which has led to better descriptions of the problem being investigated. In order to analyse the different information needs of each perspective, conceptual models were then developed based on the root definitions derived from CATWOE. A conceptual model was created for each root definition and then a consensus model was formed to encompass a shared view of those involved in the situation. The next step was to define information categories generated from the consensus model in order to determine the information needed to support each view of space in a building. According to Wilson (1990), an information category represents a collection of data that provides a means of classification, which has meaning within the conceptual model being described. There are two approaches to identify information categories using soft systems tools. The first is creating a table that documents the data required as input to and output from each activity in the consensus model (Wilson, 1990). The second is using the words used in CATWOE and root definitions to form the initial list of cognitive categories (Lewis, 1994).

Although it is claimed that combining these two approaches would ensure identifying all information categories, for the purpose of this research, Wilson's approach is used to derive information categories. According to Wilson (1990), an information category is a collection of data that provides classification in which its boundary is defined by specifying the data items that the category contains. In addition, this will be used to identify information requirements, documenting the data required as input to, and output from, each activity in the consensus model. Finally, the Maltese Cross supports two phases of data to process mapping (Wilson, 1990). It separates the systems thinking environment from that of the real world. The Maltese Cross consists of two main parts; the top part of the Maltese Cross considers the information that is needed as input to, and output from, the activities in the consensus conceptual model. The candidate information categories (middle part) is mapped to the activities from the consensus model to form the top part of the Maltese Cross.

Table 3.3: Stages in Wilson's Soft Systems Method (Wilson, 1990).

Real World	**Thinking about the real situation**
1. Investigate and express the situation.	
	2. Formulate Potential Root Definitions.
	3. Develop Conceptual Models.
4. Compare Conceptual Models with Real World and Develop Consensus Model.	
	5. Derive Information Categories.
	6. Map Activity-to-Activity Information Flows.
7. Map Current Information Provision.	
8. Map Organisation Structure.	

3.7. Ethical considerations

This research complies with Birmingham City University's code of ethical practice in research (BCU, 2010). The procedures and methods which were used to collect data were risk assessed. The aim and objectives of the research were made clear for all stakeholders in the project (supervisory team, company, etc.). This was done through incorporating methods and analysis with the supervisory team and providing a brief about the research project and purpose as well, for the ones involved in data collection (interviewees). In addition, as data was collected through interviews, the informed consent of companies and individuals involved was obtained through filling in consent forms. Quotations are not be attributed to any of the respondents by name within the final thesis, or any work that comes from the research. The research is aware of any refused data to be given by any of the stakeholders involved within the research. The direct impact will result in changing the company of the ones involved within it, and thus, choosing another company to commence the research. The interviewees remained anonymous and were informed of the fact. All data collected was kept in a safe place (the University's network and encrypted hard drive which is password protected) and destroyed after the research completion, and the data is no longer needed. The data will be kept for the purposes of any further publication and future practice development.

Chapter Four - Case Studies and Results

4.1. Introduction

This chapter documents the data from the case studies undertaken, which are the Educational Building 1, Office Building and Educational Building 2. As explained in the previous chapter, the purpose of the case studies is to investigate the problematic nature of building performance. The research journey documented in this thesis shows how the output of one case study influenced the direction of the next. Each case study focused on three stakeholders, which included representatives from the delivery team, the facility management team and the building occupants. It is important to note that representatives from the delivery team differed between the three case studies, and will be explained below.

The aim of the Educational Building 1 case study was to inquire into building performance by looking into definitions of building performance and the process of creating the building from the three stakeholders' perspectives mentioned above. BIM is also included in the inquiry as it is part of the process of achieving building performance, in order to determine the value it offers to building performance and the barriers that need to be addressed. The outputs of this case study show that building performance has multiple meanings and that many factors influence it. The case study also shows that different people have different views of buildings and definitions of building performance. It is anticipated that the range of meanings is perhaps the result of different experiences in buildings. These results suggest that there is a need to select a reference point for building performance and the factors that influence performance. Hence, space is chosen to become the reference concept for the inquiry into building performance. This is because space provides a medium where different meanings by different stakeholders can be situated. The findings of the first case study (Educational Building 1) are used to shape the intention of the second case study (Office Building).

The second case study aimed to inquire into the performance of space as part of building performance. This is achieved by looking into the process of achieving performance of space and experiences of using space. The data was gathered from the three stakeholders, but in this case study the building delivery team, differs from the previous case study, as it is only represented by the client. The reason for this will be explained in the Office Building case study in the Section 4.3. Although the definitions of 'performance' had initially been considered within the first case study, definitions are also explored in this case study. Exploring the definitions of building performance is considered as an overarching input for all the three case studies in order to demonstrate the problematic nature of building performance and the factors influencing it. BIM is also included as part of the inquiry, but as 'space' was selected to be the focus of inquiry for performance, the role of BIM is considered as part of the process of achieving performance of space. The outputs of this case study show that inquiring into different experiences of using space has supported better understanding of different aspects that influence building performance. The case study also shows that designers tend to rely on 'reference representations' to aid them when producing representations of space. These findings show that it is important to investigate different characteristics influencing performance are embedded within the representations of space. The third case study (Educational Building 2) has aimed to inquire into performance of space, looking into experience of space representations to investigate how factors influencing performance are embedded within these representations.

The third case study aimed to inquire into performance of space. Unlike the previous case studies, this case study was conducted on a building during its construction stage. As with the previous case study, the Educational Building 2 study begins by looking into definitions of building performance, the process of achieving performance of space and experiences of using space. Additionally, it also explored experiences of space representations in order to investigate how factors influencing performance of space are embedded within space representations. The representations of space used in this case study are 2D plans and 3D walkthroughs where participants identify both information and concerns based on the representations that are presented to them. The representations are derived from the BIM model that was designed for the building. Similar to the previous case studies, the data was gathered from the three stakeholders, but in this case study, the building delivery team, differs from the previous case study, as it is represented only by the designer. The outputs of this case study show that representations of space have to be information rich to capture experience of a space.

4.2. Educational Building 1 Case study

The Educational Building 1 has been operating since September 2013 and is considered to be the first phase of building new campuses for one of the Universities in the UK. It was built to accommodate both the Birmingham Institute of Art and Design and the Faculty of Performance, Media and English. In 2014, the building was awarded the RIBA West Midlands Award, as low-energy consumption targets have been met through the use of renewable energy sources (Associated-architects, 2014).

4.2.1. Rationale for selection

It is claimed that Educational Building 1 is an innovative project that pushed the boundaries of known construction methods through mandating the use of Building Information Modelling (BIM) technology. According to the client team, it was argued that the use of this technology would enable an optimal performance to be achieved for the complete life of the building, and potentially provides a solution to support better management throughout its operational life, post completion and hand-over.

4.2.2. Research participants

In this case study, three parties were involved: the representatives from the building delivery team, the facility management team and the building occupants. The building delivery team was represented by the client team and the designer. It was expected that both the client team and the designer had the same mind set, as they collaborated from an early design stage to completion, thus, are considered as a single party. It is important to highlight that the designer, unlike the rest of the building delivery team participants provided responses through email. These responses are therefore offer more-structured feedback compared to the rest of the team. The facility management team was represented of the facility manager and the building services supervisor. As this case study was a starting point for inquiry, it was desired to involve multiple people representing the facility management team to allow for different views to be explored. The building occupants included three members of university staff. The number of participants from the building occupants' party was not a concern for two reasons. The main reason is that this study aims to understand how different stakeholders view buildings and building performance. Another reason is that the interview questions were designed to allow the exploration of the problematic nature of the research investigated in-depth. This is different to the standard post-occupancy evaluation (POE) method, which is more objective and needs more participants to identify a particular problem.

4.2.3. Data collection and scope

The data was collected using semi-structured interviews with the parties mentioned above. It is important to acknowledge that some of the interview questions differed from one party to another. The first reason for this is that the role of each party differed including those who deliver (the building delivery team), the end-users (the building occupants) and finally those who maintain the balance between what is delivered and the end-users (the facility management team). The second reason is the technical knowledge is not the same between the three interviewed parties, and thus a suitable language was used accordingly to obtain sufficient responses. Based on this, some parties may have additional questions, or in some cases different questions to suit their knowledge in order to obtain useful responses.

As mentioned before, the aim of this case study is to inquire into building performance from the view of different stakeholders. To achieve this, the interview questions focused on exploring definitions of building performance and the process of achieving building performance with the targeted stakeholders. As part of the overall research aim, BIM is included as part of the inquiry in this case study to determine the value it offers to building performance and the barriers to be overcome.

4.2.4. Results and findings

The findings are presented in tables where each table represents the parties mentioned above: the building delivery team, the facility management team and building occupants. Each table consists of both the focus of the questions asked and the participants involved with their responses. For the purpose of clarity, the responses are categorised according to Table 4.1:

Table 4.1: The coding used to represent the responses in the tables provided by the interviewed parties of Educational Building 1 case study.

Red 'bold, italic' ***example***	Direct responses to the area (focus)
Black 'bold, italic' ***example***	Factors that influenced the responses to the area (focus)
Black 'bold, underline' **<u>example</u>**	Examples that support the responses to the area (focus)

For this case study (as well as Office Building and partly the Educational Building 2), a reference coding system will be used to simplify referring to some 'quotations' or 'examples' when conducting the analysis. An example of this reference coding can be seen as below:

(Case study, Table #, Question focus #, Participant), so if a quotation is to be referred to the Energy Assessor (EA) mentioned at 'definitions of performance' area in the Educational Building 1 case study, where each question focus is numbered accordingly in each in table, then the reference code will be as:

(PS, 4.2, 1, EA)

4.2.5. Data Analysis

This section draws on analysis from the interviews with the targeted stakeholders. Thematic analysis will be used to categorise the gathered responses from the targeted stakeholders. The themes are definitions of building performance and the process of achieving it. A section on the main findings of this case study based on the results is then be presented.

4.2.5.1. Definitions of building performance

This section reviews the different meanings of building performance derived from the building delivery team, facility management team and building occupants of Educational Building 1. The results are presented in the form of quotations with respect to the question focus highlighted in green from Tables 4.2, 4.3 and 4.4 (attached in the appendixes).

Building Delivery Team

The building delivery team pointed out that performance is primarily associated with energy efficiency, based on the responses received from different participants such as the energy assessor, project director and the BIM Coordinator. In addition, other aspects have been mentioned such as maintenance, operation, and control of the systems within the building where these aspects were mainly driven by the participants' different backgrounds and experiences. For instance, looking at two of the responses received from the Project Director (PD) and the energy assessor respectively:

"My background is actually maintenance, from my perspective, building performance is related to maintenance, energy and operation, and also all the systems within the building, so it's about maintaining all the level of understanding control and maintenance" (PS, 4.2, 2, PD).

"It is whether the building can function adequately to meet the need of the users and do that in a sustainable and low energy manner" (PS, 4.2, 2, EA).

The above quotation show that energy efficiency is the primary driver for building performance, but also that the individual's background played a role in the view of performance too. However, when looking at performance based on the building designer's view, it is realised that a more-structured response was provided with many parameters (in addition to those mentioned by the other team members). Some of these parameters were as follows:

"So many different criteria to assess and achieve a balance between: aesthetics, robustness and durability, thermal comfort, appropriate levels of natural and artificial light …" (PS, 4.2, 2, BD).

The purpose behind this structured response has already been acknowledged, and thus, the other parameters mentioned would be influenced by the background of the respondent and may not necessarily have been incorporated in the delivery of Educational Building 1. With relation to improving performance, there were many parameters mentioned such as ensuring an energy-efficient design, building systems to be working efficiently and maintained correctly. In addition, the team has also mentioned the importance of considering how users operate in the space. As quoted by the energy assessor on the role of users in improving performance for Educational Building 1:

"The users know how to operate the space*, <u>for example, they don't open windows if it's too hot,</u> *the occupants also need to know how to operate complicated systems like lighting" (PS, 4.2, 3, EA).

The above quotation (PS, 4.2, 3, EA) shows that improving performance within the building is related to how users operate the space within the building. In clarifying that, the energy assessor used the 'lighting system' as one of the systems that require understanding of its operation. Also, an example of what users tend to do in a space when the temperature rises was stated to reflect part of the role that users play in influencing performance. Potentially, and using the quotation (PS, 4.2, 3, EA) as evidence, it can be realised that improving performance is about maintaining levels of control with relation to energy efficiency and building systems' maintenance. In aligning with this view, the BIM Coordinator pointed out the value of BIM in improving performance by supporting ease of access to information, which can support maintenance whilst the designer claimed that tight design periods may influence the efficiency of the building. As with relation to achieve performance for users, facilities and clients, the responses were focused on the efficient use of facilities and reactively responding to user needs. Although user needs have been acknowledged, yet this was not clearly described, and may well be interpreted in terms of the level of response when issues are faced by the building users.

Facility Management Team

According to the facility management team, performance is based on two elements, which are 'how the building works' and 'the delivery of customer needs and expectations'. As quoted by the Building Services Supervisor (BSS):

"From my perspective, everything operates within working order and what the customer needs is there for them. I think that a good performing building is having what the customer expects" (PS, 4.3, 2, BSS).

The above quotation demonstrates that performance can perhaps be based on the experience within the building. This is because when looking at attributes such as 'everything within working order' and 'having what the customer expects', they represent a general experience of several elements/factors that may influence them. For example, as quoted by the facility manager when describing some of the duties she is in charge of:

"I am the Facility Manager [FM], I look after the cleaning, some aspects of security. I am the advocate for the building users, I do fault reporting, I make sure maintenance is done on the building, I make sure the building is setup correctly, basically it needs to be fit for purpose" (PS, 4.3, 1, FM).

Following on this quotation, and aligning to what the building services supervisor stated, the Facility Manager has stated on defining performance:

"It needs to function in a way that keeps the occupants comfortable and I suppose It depends what perspective you look at it" (PS, 4.3, 2, FM).

This above quotations show that experience in the building plays an important role in the view of performance. For instance, using (PS, 4.3, 2, FM), both 'function' and 'occupants' comfort' are derived from the nature of a facility manager's role within the building. As with relation to improving performance, the team has highlighted the importance of defining specifications and occupants' needs. As quoted by the building services supervisor on improving performance:

"I really think it comes back to the specification and it comes down to what the customer wants" (PS, 4.3, 3, BSS).

This shows that the specification influence how performance can be improved, as well as addressing the customer needs. However, when considering an attribute such as 'specification', it becomes difficult to clarify what was meant by specifications, as it can be related to several aspects within the building.

Similar to the building delivery team's response, the facility manager mentioned that occupants need to know how to operate within the building. As quoted by the facility manager and reflecting on Educational Building 1:

"**<u>As for Educational Building 1, it is functioning better but because of the energy consumption requirements then certain tolerances have been put into the building</u>*****"*** (PS, 4.3, 3, FM)

The above quotation (PS, 4.3, 3, FM) shows that it is important to take in consideration the role that the occupants play within the building and how it affects performance. This can be reasoned when looking at the facility manager's role (PS, 4.3, 1, FM) where part of the role is fault reporting, which can be as a result of occupants' lack of understanding of how to operate within the building.

When looking at achieving performance, the facility management team has highlighted this mainly relies on understanding how the systems work within the building. For instance, in the case of Educational Building 1, as it was BIM-enabled project, 'soft landings strategy' has been implemented to manage the systems more effectively. 'Soft landing' is a process designed to support the delivery of better buildings. It aims to solve the performance gap between design expectations and operational outcomes (Cabinet Office, 2013). As quoted by the facility manager:

"**<u>With Educational Building 1, I suppose things have been a lot more easier because we have had the soft landings</u>*****"*** (PS, 4.3, 4, FM)

The above quotation (PS, 4.3, 4, FM) shows that although the use of soft landings may have solved part of the issue related to managing facilities and maintenance within the building, yet maintaining the balance between what the building requires and what the customer expects remains one of the main challenges faced by the facility management team.

Building Occupants

In relation to performance, the occupants stated that building performance is related to what the building primarily facilitates in terms of supporting their daily jobs along with other aspects such as atmosphere, feeling, connectivity and providing social environment. For example, as quoted by two of the occupants on describing performance:

"Performance is the way that allows me to deliver my job. I think also that there is aspect of performance, which is the atmosphere that I think it is difficult to be ensured" (PS, 4.4, 2, O2).

"It is how it works for me and whether it is suitable or not for what I want it" (PS, 4.4, 2, O3).

The above quotations show part of the elusiveness associated with performance, as it is described based on experience within the building, which can be realised when referring to the above quotations (PS, 4.4, 2, O2) and (PS, 4.4, 2, O3). In addition, and relating back to the quotations, the nature of the work/job within the building plays an important role in terms of assessing how the building performs.

When looking at improving performance, the occupants suggested some methods such as POE and aspects such as health and safety that can support improving performance. As quoted by one of the occupants on suggesting a method to improve performance:

"Post-occupancy study as it will be really important to learn from people's experiences in the building. I think that there should be space system setup within the building for people to give feedback loop to the project office but that should be proactive" (PS, 4.4, 3, O1).

Also, with relation to improving performance, another occupant stated:

"**Applied performance such as colours like mentioned, but again this is early rectified when compared some health and safety issues**. ***Health and safety in some ways can colour the views of performance for people in a building.*** **In a way, occupants should understand how to use the building*"*** (PS, 4.4, 3, O2).

The above quotations (PS, 4.4, 3, O1) and (PS, 4.4, 3, O2) show that peoples' experiences and the problems they face within the building should be taken in consideration in order to improve to performance. For instance, referring to one of the instances mentioned above, health and safety considerations are essential in any building, and are considered as part of the attributes influencing performance for occupants. Thus, it is realised that experience within the building is a major driver for occupants' view of performance.

Similar to both the building delivery team and the facility management team, and referring back to (PS, 4.4, 3, O2), the occupants stated that improving performance is also associated with the way that occupants use the building. However, unlike the other parties, and using the instance of health and safety mentioned, the intention here is occupants' 'ability to use' the building so that it serves their needs. In addition, and with relation to understanding how to operate within the building, one of the occupants stated:

"**I think there should be better understanding of how we can report issues and problems and get feasible timing for the time needed to fix them*****"*** (PS, 4.4, 3, O3).

The above quotation (PS, 4.4, 3, O3) demonstrates one of the issues that can influence the occupants' experience within the building. As with relation to the importance of facilities for building performance, the occupants have described this aspect by referring to the problems they face within different spaces. For example, on describing some of these problems, two of the occupants quoted:

"**Some facilities are not fit within their spaces, and we don't necessarily have the right furniture*****"*** (PS, 4.4, 4, O1).

"**The positioning of some facilities, for example the projectors, they really need to be thought of carefully*****"*** (PS, 4.4, 4, O3).

The above quotations (PS, 4.4, 4, O1) and (PS, 4.4, 4, O3) show that assessing performance from a facilities point of view is mainly related to the spaces they sit within and how these spaces support the occupants' needs when using that space. This shows the role that space play on performance, and how using space as a context can shape occupants' view of performance within the building.

4.2.5.2. Process of achieving building performance

As mentioned before, the second part of the inquiry was exploring the *process* of achieving performance. To achieve that, the interview questions focused on three performances: energy, space and maintenance to gain an insight into different factors influencing them. This section reviews the different factors influencing energy, space and maintenance from the building delivery team, facility management team and building occupants. The results are presented in the form of quotations with respect to the question focus highlighted in blue from Tables 4.2, 4.3 and 4.4.

Energy

The building delivery team highlighted that energy forms one of the main aspects to be taken in consideration when delivering a building, as it is part of the British Standards. There is a need to comply with the building regulations taking in consideration the legislative requirements. As quoted by the Energy Assessor on the energy standards incorporated in the delivery of Educational Building 1:

"***For the Educational building 1, Educational building 2 and other big projects that we do, we will design them to be BREEAM excellent. My role is to reduce the amount of energy that the university uses so I will attempt to influence designs down the road"*** (PS, 4.2, 5, EA).

Moreover, and on emphasizing the value of BREEAM on the building, the project director stated:

"It wraps the whole issue of energy performance, sustainability, and operational issues" (PS, 4.2, 5, PD).

The above quotations (PS, 4.2, 5, EA) and (PS, 4.2, 5, PD) show that achieving performance for energy is vital and complying with the right standards is one of the main drivers to achieve that performance. As with relation to the role of technology to support achieving energy performance, and using BIM as a reference tool, it was stated that the current capabilities of such technology is limited when it comes to energy. In support of this, and as quoted by the energy assessor:

"BIM is less of an energy tool than it is a facilities management tool, so there is probably sort of scope to increase the energy relevance at BIM" (PS, 4.2, 6, EA).

Furthermore, and in addressing why BIM lacks the ability to support the needs of energy performance of building, the project director stated:

"BIM can potentially contribute towards maintenance, but energy-wise we haven't quite got compatibility between BMS (Building Management System) and the model itself" (PS, 4.2, 6, PD).

Although the above quotations (PS, 4.2, 6, EA) and (PS, 4.2, 6, PD) show that BIM is still limited in terms of supporting energy performance, the building designer highlighted that it can be useful to perform early stage analysis to allow design optimisation. With relation to the current barriers limiting BIM from being an effective energy tool, the designer stated:

"Lack of compatibility between BIM authoring software and analysis packages limit number of iterations of a design to achieve optimal solutions" (PS, 4.2, 7, D).

In addition, it was stated that BIM has the potential to provide structured data to support better accountancy of energy performance. As quoted by the energy assessor on the barriers of BIM:

"**I think that BIM has the potential to provide structured data if it can export reports as in this is how much energy used by a particular space or the maintenance task or the average temperature*****"*** (PS, 4.2, 7, EA).

The above quotations (PS, 4.2, 7, D) and (PS, 4.2, 7, EA) show that BIM in its current form cannot effectively support energy performance, but it is believed that its capabilities would potentially provide solutions to overcome some of the challenges faced by the building delivery team.

The *facility management team* claimed that energy performance relies on both the reliability of building systems and the comfort of building users. According to the building services supervisor:

"Energy, we rely on the users for a certain extent, but also I need the customers to be comfortable; the heating systems has got to be adequate" (PS, 4.3, 5, BSS).

The above quotation (PS, 4.3, 5, BSS) shows that energy performance is related to both the building systems and users' needs. It was stated "we rely on the users for a certain extent", which show that occupants' behaviour influences performance within the building. As when looking at the role of BIM to support achieving energy performance, the facility management team emphasized that their knowledge on BIM is limited, but perhaps mentioned some of the problems that BIM can potentially overcome. As quoted by the facility manager:

"Hopefully it would provide an accurate record, it will be easy to find what you need to find,* because at the moment with O&M (operation and management) manuals we have a huge amount of information which could be smoother and easier to manage through BIM*. I have seen the BIM models, and I know what we were supposed to achieve with BIM, but I don't think we're there yet; it is still a work in progress" (PS, 4.3, 6, FM).

The above quotation (PS, 4.3, 6, FM) shows that information management is one of the benefits, which BIM can potentially support. Therefore, BIM for the facility management team can be seen as a tool for future information retrieval to support their job. The facility management team also claimed that involving them during the design is essential, so they get informed about different things that can support their daily job. For instance, the facility manager stated:

"***I would also like to know about occupancy levels* because you get a lot of complaints with people in a room saying it's too hot in here while the room is designed to only hold three people and you have 20 people in there then of course it is going to be hot in there or whatever because your room hasn't been designed for 20 people but it's been designed for three*"*** (PS, 4.3, 7, FM).

The above quotation (PS, 4.3, 7, FM) can be used as a reflection on some of the current problems that the facility management team face with relation to energy and also other aspects, which shows the need to have their input and provide them the right information that can support their job.

The *building occupants* had no direct responses towards energy performance. As with relation to BIM, it was expected that occupants are not familiar with it, however, responses towards its role were provided, as two of the participants come from an architectural background where one of the occupants stated:

"It's potential a rich information management tool and it can harness complexity and can involve different people to manage different information" (PS, 4.4, 5, O1).

Also in demonstrating how BIM can be useful for building occupants, another occupant stated:

"I don't really know what BIM is, but if it allows better collaboration between occupants and people who design the building, then it should be useful" (PS, 4.4, 5, O3).

Following on the above quotation (PS, 4.4, 5, O3), the occupants have provided suggestions that mainly were based on their current experiences. However, these suggestions were mainly related to space, and will be stated in the next section.

Space

According to the building delivery team, it was stated that, unlike energy, standards for space are mainly driven by the university management team, which normally consists of the client team and selected users from the various management positions. As the BIM Coordinator stated:

"The university has its own space standards, but in terms of space, they are not tight if that makes sense as the British standards" (PS, 4.2, 5, BC).

To support this, the designer stated that typical space information for university buildings includes the client's brief, typical areas for teaching spaces and workplace regulations for office areas. This shows that the delivery of performance for space mainly relies on both available regulations and client's brief. For instance, part of the current regulations is the consideration of how many people can fit within a particular space. In addition, the project director stated:

"Space tends to be fairly static, so you can for instance move walls around, but once you got past the design stage, it's all about the operations and systems within those spaces" (PS, 4.2, 6, PD).

The above quotation (PS, 4.2, 6, PD) shows that both operations and systems can influence performance for space. As with relation to the role of BIM in terms of supporting performance for space, the designer has listed many benefits, which were quoted as:

"The BIM can schedule achieved areas or volumes against a design target set in the brief and display shortfalls graphically …" (PS, 4.2, 6, D).

Although the above quotation (PS, 4.2, 6, D) demonstrates some of the benefits (refer to table 4.2 for further benefits), it was not evident how these benefits have contributed towards the performance of space. Another participant from the building delivery team stated:

"Spatially, it's quite restricted what you can do beyond an appreciation for the space itself, so one thing that BIM in its current iteration lack is that visual connectivity to the building itself so it gives you an understanding of the form and shape but not necessarily how it actually physically looks." (PS, 4.2, 7, PD).

The above (PS, 4.2, 7, PD) shows that in order to understand space, it important to have visual connectivity to the building. However, it was claimed that BIM lacks this visual connectivity, which makes it difficult to understand the form and shape for spaces within the building.

The facility management team stated that generally there are no space standards incorporated within the building. As quoted by the facility managed stated:

"Generally within this building, or throughout the university, often when they construct something new, I don't think we have space standards where we say ok you can't be in that massive office because really you are wasting space" (PS, 4.3, 5, FM).

The above quotation (PS, 4.3, 5, FM) shows that standards related to space from the facility management team is perceived differently than standards from the building delivery team. Standards from the building delivery team are more related to the regulations side whereas from the facility management team are more related to the managerial aspect of it. In the case of the Educational Building 1, the building services supervisor stated that they have faced many problems, as the use of spaces was not as expected:

"When the building was built and before occupancy, people were coming around and say 'yeah look at that space, we could use that area' for so and so, not thinking that in six months-time when the building is occupied, the area is not going to look like that. It's going to be full of tables and workbenches" (PS, 4.3, 5, BSS).

The above quotation (PS, 4.3, 5, BSS) shows that expectations of space differ than its actual use once occupied and used. Following on the use of space, the facility manager has listed a number of issues related to the use of different spaces such as public and private spaces. With relation to these spaces, the facility manager stated:

"I think ownership is the major issue because you have offices next to the public space then you get offices that send letters to complain to me. The only problem I have with the private space is whether the space is being used efficiently or not" (PS, 4.3, 5, FM).

The above quotation (PS, 4.3, 5, FM) shows one of the experiential problems faced by the facility management team with relation to space, which affects performance for the space within the building. As when looking at the role of BIM to improve space performance, no direct response with relation to space was provided, but it was more related to information retrieval to support operations and maintenance, which will be mentioned in the 'maintenance' section. However, they mentioned that having 'information for spaces' is crucial, as often information is lost. As quoted by the facility manager:

"**A lot of information seems to get lost as the room use change or people change the setup of the room so you don't know how the room has originally been designed just by counting how many chairs are in there because it is not static enough*****"*** (PS, 4.3, 7, FM).

This shows that part of the problematic nature with relation to space performance is associated with the level of information available, so that it supports managing different spaces more effectively. This will potentially impact controlling the use of space in terms of its level of flexibility to suit different purposes.

As with relation to building occupants, many of the current problems in relation to space have been mentioned before such as (PS, 4.4, 4, O1) and (PS, 4.4, 4, O3), which shows that occupants use spaces to reflect their experiences (refer to Table 4.4 section 5 for more examples). Thus, with relation to the future input in terms of space, two of the occupants stated:

"As a teacher, the input will be how teaching is going to be. I also think that there should be a consideration of how spaces have been utilised" (PS, 4.4, 6, O2).

"I think that we really need to specify the possibility of multi-purpose spaces*. One of the major concerns I have now, is whether our current spaces provide the right environment to work or lecture within*" (PS, 4.4, 6, O3).

The above quotations (PS, 4.4, 6, O2) and (PS, 4.4, 6, O3) demonstrate some of the concerns that the occupants face with spaces within the building such as the utilisation of spaces and having the right environment for the intended purpose. Therefore, involving their views when designing the space becomes essential to ensure occupants' satisfaction.

Maintenance

The building delivery team stated that maintenance is one of the main considerations to achieve performance for a building. Moreover, and on a broader perspective, the designer stated some maintenance-related elements such as the expected life span and design for robustness, which are normally considered when delivering the building. However, unlike energy, where standards such BREEAM are used as a benchmark to drive energy performance, maintenance was claimed to be an aspect that is driven by a need. In clarifying that, the project director stated:

"Maintenance wise, we tend to try to drive the specification to a need, so what are really controlling over not necessarily legislative side, but more of a specification side, so when you walk into room, and you still feel like a university building. **For Educational Building 1, for example, as we wanted accessibility to services, we went for a raised access floor*"*** (PS, 4.2, 5, PD).

In addition to the quotation above (PS, 4.2, 5, PD), and on responding to standards for maintenance, the energy assessor stated that available budget plays an important part in the future maintenance for a building:

"For maintenance, how well we maintain our estate is determined by how much money we've got, so you've got to prioritize the safety stuff, got to make sure that fire alarm works, the emergency lighting works" (PS, 4.2, 5, EA).

The above quotation (PS, 4.2, 5, EA) shows the correlation between available budget and maintenance within a building, which in this case implied the need to set priorities. When looking at the role of BIM to support maintenance, it was stated that it can potentially contribute towards maintenance where the designer has listed some of the benefits of BIM such as:

"Modelling of required access zones for plant maintenance or replacement allows optimisation of layouts. Incorporation of actual installed components in the as-built FM BIM …" (PS, 4.2, 6, FM).

Although the above quotation (PS, 4.2, 6, FM) shows some of the benefits (refer to Table 4.2 section 6 for more details on potential benefits on BIM for maintenance) of BIM, it was not clarified how BIM contributed towards the maintenance aspect in Educational Building 1. However, the project director suggested that involving the maintenance team can potentially improve the value of BIM in terms of assisting maintenance:

"When you get the maintenance people familiar with the model itself and they're people who are going to look at it daily, and it's about having that streamlined approach to get that information, BIM can be very powerful tool for maintenance people" (PS, 4.2, 7, PD).

This shows that the potential value of BIM for maintenance is dependent on both involving the maintenance people and providing them with the useful information that they need.

According to the facility management team, it was stated that the current maintenance system is reactive, which means that issues get resolved only when they occur. Following on this, the building services supervisor has mentioned that one of the main difficulties associated with reactive maintenance is managing multiple sites. In the case of the Educational Building 1, the facility manager stated that they have overcome this issue:

"For maintenance, Educational Building 1 has been quite good because we have got soft landings, which means that for the next three years to sort out any issues, any problems" (PS, 4.3, 5, FM).

This above quotation (PS, 4.3, 5, FM) shows that providing the soft-landing solution has supported managing maintenance within the Educational Building 1. As with relation to the role of BIM in terms of supporting maintenance, it was mentioned that ease of information retrieval supports managing maintenance more effectively. As the facility manager stated:

"If you can just put in a search into BIM and it will come up and show you with the specification and it can show how things were in the building and how they are now when you changed them, then that would be great" (PS, 4.3, 6, FM).

Furthermore, and following on the above quotation (PS, 4.3, 6, FM), the facility manager stated the importance of their involvement at an early stage:

"I would like to know all about the finishes, all about the over Mechanical and Electrical systems and I would like to know about their layouts" (PS, 4.3, 7, FM).

This shows the importance of involving the facility management team at an early stage, as this would aid better understanding about the building systems and potentially avoid future issues.

According to the building occupants, the majority of the concerns about the role of technology and future input were related or within the context of spaces that they use, and no direct responses were given towards maintenance.

4.2.5.3. Educational Building 1 case study findings

The results of the inquiry showed that building performance has multiple meanings and that many factors influencing building performance. Figure 4.1 summarises the obtained outputs based on meanings of building performance and factors that influence building performance from the targeted stakeholders in the Educational Building 1 case study.

Figure 4.1 shows a summary of the outputs from the investigation on exploring definitions of building performance and process of achieving performance from the targeted stakeholders. As mentioned before, these outputs show that building performance has multiple meanings and there are many factors that influence building performance. For instance, looking into the feedback received from the targeted stakeholders on 'definitions' under definitions of building performance, it was found that performance is related to energy efficiency, building operations and occupants' satisfaction and what the building facilitates to support occupants' activities.

These findings imply that different people have different views of buildings and definitions of building performance.

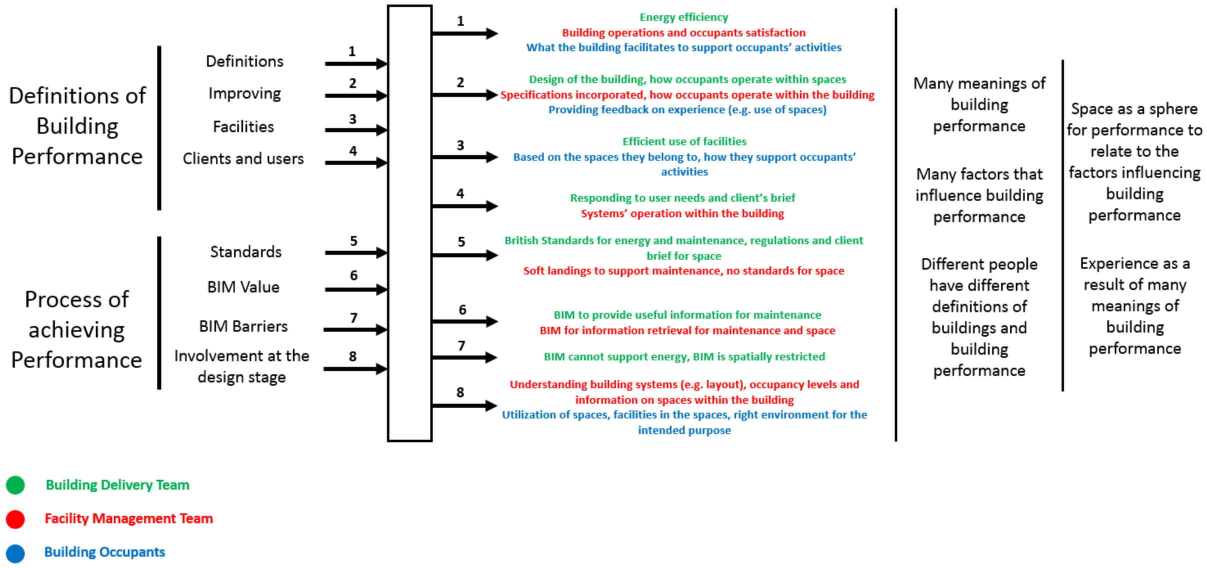

Figure 4.1: Summary of the outputs from the Educational Building 1 Case Study.

The outputs shown in Figure 4.1 represent the divergent views on building performance from the three stakeholders in this case study. This is demonstrated in the feedback received on definitions of building performance and process of achieving building performance where the feedback is categorised into three colours and each colour represents a stakeholder. Therefore, to achieve building performance that satisfy the three stakeholders, it is important to incorporate their divergent views. These divergent views represent the parts that support achieving the whole, which is building performance. Therefore, in the next chapter, how to incorporate these parts, taking in consideration the outputs shown in Figure 4.1, is considered.

In addition to the above, and as part of the findings, it is important to indicate the value of understanding multiple perspectives. 'Multiple perspectives' in this context refers to the views of different stakeholders. Thus, what influenced their views on performance is investigated. As for the building delivery team, their views on performance were influenced by their backgrounds and client's needs. For example, the energy assessor focused on energy, and the project director focused on maintenance, but as their views had to align towards the client's needs, achieving energy performance was the optimum aim. The facility management team's view on performance was influenced by their roles and experiences within the building. For example, the facility manager's focus on the managerial aspects (e.g. security and management of maintenance) within the building, which is derived from her role and her experience, was influenced by both the period that she worked and the issues (e.g. space management) faced within the building. The building occupants' view on performance was also influenced by their roles and experiences within the building. Thus, it is realised how multiple perspectives have resulted in different views of buildings and definitions of building performance. These results suggest a need to select a reference for building performance and the factors that influence performance. Hence, space was chosen to become the reference concept for the inquiry into performance because it can be used to relate to the factors that influence building performance; it helps situate the meanings of performance for different stakeholders.

4.2.6. Conclusion for the Educational Building 1 case study

The primary aim of Educational Building 1 Case Study has aimed to explore the problematic nature of building performance. To investigate that, both the definitions of building performance, and the process of achieving performance, were explored. The findings show that building performance has multiple meanings and that many factors influence building performance. These findings suggest that there is a need to select a reference or container for building performance in order to further explore different meanings of building performance and the factors that influence building performance. Therefore, space was chosen to be the reference concept for the inquiry into performance. Space was chosen because it can be used to relate to the factors that influence building performance; it helps situate the meanings of performance for different stakeholders. It has also been mentioned that different people have different views of buildings and definitions of building performance. It is anticipated that the variety of meanings are perhaps the result of different experiences in the buildings. Consequently, to further understand these differences in meanings, the second case study (the Office Building) will look into experiences of using space as well as the process of achieving performance of space.

4.3. The Office Building Case study

The findings from the previous case study (Educational Building 1) are used to form the inputs for the inquiry for this case study (Office Building). The previous case study showed that, after choosing space as a reference concept for performance, it was decided to look into people's experiences of using space and the process of achieving performance of space. The aim of this case study is therefore to inquire into performance of space.

The Office Building is claimed to be one of the biggest and most-sustainable buildings procured by Birmingham City Council. It was built with BREEAM Excellent with the aim of accommodating up to 3000 employees. The building was designed to overcome some of the challenges faced within office working environment. It is argued by Birmingham City Council that the building has acted as the foundation for the creation of a dynamic community, which had a positive impact on the wellbeing of the staff working in the building.

4.3.1. Rationale for selection

Located at the heart of Birmingham, the Office Building acts as a reference point for Local Government and is based on a common strategic plan outlined within detailed 'Design, Performance and Specification Guidelines', which supported the formation of a core reference for the design of the working environments. In addition to incorporating sustainability within the design of the building, the building provides employees with options for socialising, meetings and performing their jobs (Birmingham City Council, 2012).

4.3.2. Research participants

Similar to Educational Building 1 case study, individuals representing three different parties were involved: the building client (representing the building delivery team), the facility manager (representing the facility management team) and three building occupants. Unlike the Educational Building 1 case study, which had multiple participants representing the building delivery team, the client is chosen as the representative of the building delivery team in this case study. The main reason is due to the nature of the inquiry in this case study, which focused on looking into experiences of using space and process of achieving performance of space. In practice, the client is normally involved in specifying space requirements and is constantly informed about the use of space within the building. Another reason is the data and information confidentiality issues, as the building belongs to the city council, hence access was only gained to the client who represented the building delivery team. In representing the facility management team, the facility manager of the Office Building was selected. Unlike the Educational Building 1 case study, where two participants from the facility management team were selected for further views, this case study involved only the facility manager regarding data accessibility. The building occupants were represented by a number of staff members from different roles, where in this case study three participants were involved. Similar to the reasons stated for the Educational Building 1, the number of participants from the building occupants was not a concern. However, for this case study, data accessibility was the main issue, as the occupants were selected and accompanied by the client during the interview process. Therefore, the data collected from the occupants may be more constrained when compared with the building occupants from the Educational Building 1 case study. Although this may influence the overall understanding of occupants' needs, it was anticipated that the interview questions for building occupants would support gathering meaningful and useful responses that support understanding their views.

4.3.3. Data collection and scope

Similar to the previous case study (Educational Building 1), the data was collected using semi-structured interviews with the parties mentioned in section 4.3.2. It is important to note that both the nature and phrasing of the interview questions have differed between the stakeholder groups so as to obtain more useful and meaningful outputs for the inquiry. Based on the outputs from Educational Building 1 case study, this case study explored the process of achieving performance of space and experiences of using space. Although the definitions of performance had been initially considered within the first case study, it is also explored here within this case study. This is in order to demonstrate the problematic nature of building performance and the complexity of factors influencing it. BIM is also included as of part of the inquiry, but as space is selected to be the scope of the inquiry for performance, the role of BIM in the process of achieving performance of space is explored.

4.3.4. Results and findings

The data was collected using interviews, the same coding system outlined in section 4.5 in the previous chapter is applied.

4.3.5. Data analysis

The primary aim of this case study was to inquire into performance of space from the views of different stakeholders. This section draws on analysis of the interviews with the targeted stakeholders: the building client, facility manager and building occupants. The results from the targeted stakeholders are listed with respect to the input inquiry, which are definitions of building performance, process of achieving performance for space and experiences of using space. The main findings of this case study based on the results are then presented.

4.3.5.1. Definitions of building performance

This section reviews the different meanings of building performance from the building client, facility manager and building occupants. The results are presented in the form of quotations with respect to the question focus highlighted in green from Tables 4.5, 4.6 and 4.7 (attached in the appendixes).

Building client

According to the client, performance was described as delivering a project within the planned budget while ensuring that occupants' needs are met as well as reducing issues such as complaints from the occupants. As quoted by the client on performance:

"***I think it's about saving money, so what we are looking for is a cost effective building, value for money, deliver what we want for the occupants, and try and reduce as many issues as possible***" (WC, 4.5, 2, BC).

The above quotation shows that the budget was a key factor in the delivery of performance for the Office Building. This is evident when looking at the considerations of performance aspects within the building, which mainly focused on energy efficiency. The client pointed out:

"So one of the targets was BREEAM excellent. We developed a CAPS policy and standard guidance, so we were targeting 8 m^2/ workstation overall, 85 ft^2/workstation based on what we were looking for. We also planned to have an energy efficient building, so it would operate within the boundaries that we're setting. In the design of the overall specification, we were looking to deliver as much comfortable building within the budget" (WC, 4.5, 3, BC).

The above quotation (WC, 4.5, 3, BC) suggested that performance was mainly influenced by budget. Hence, using standards such as BREEAM were used to better control over the cost implications by aspects such as energy and CAPS policy was used to ensure occupants' comfort. This relates to the client's claim above the overall specification for the design of the building, which aimed to provide a comfortable building within the available budget. When considering the delivery of performance for users and facilities within the building, the client highlighted that both controlling operation of the building and ensuring comfort were the main key factors where the client stated:

"we invested significantly in sort of BEMS-system, so it operates the building. I mean from our point of view, we tried to make this place as comfortable as possible for people, for longer period of time, that was one of the reasons why we went for the sort of furniture we did, we also invested in the chairs, so all the chairs are ergonomic, they got lumber support and other things" (WC, 4.5, 4, BC).

The above response (WC, 4.5, 4, BC) shows that ensuring an efficient operation and long-term comfort were key factors to achieve performance using BMS (Building Management Systems) to ensure efficient operation of the systems within the building and choosing the right furniture to ensure long-term comfort for the occupants. Following on this, the client pointed out that majority of the responses on the POE conducted with the occupants showed positive feedback, bearing in mind that the areas targeted in the POE were not explained.

Facility manager

The facility manager claimed that performance is about delivering the building to meet the necessary construction standards in order to satisfy the user needs. In responding to definitions on performance, the facility manager stated:

"To elaborate a building can be constructed to meet the most stringent of environmental and construction standards, however, if it fails in supporting the needs of the building user then it has not performed as required" (WC, 4.6, 2, FM).

The above response shows that although incorporating construction standards is important, making sure that it serves the occupants' needs is the primary factor of performance. This means that performance is not necessarily bounded within the standards incorporated and may require further consideration to meet the occupants' needs within the building. This can perhaps be clarified when looking at the facility manager's view on improving performance, and hence stating the importance of engaging the facility manager at an early design stage:

"The FM operator needs to have been engaged right from initial design if they are to maintain the building efficiently without disruption to the function or excessive ongoing revenue costs associated with impractical maintenance plans. **However, there are many examples of generic buildings constructed which have to be adapted to client needs prior to occupation. These reverse engineered buildings very often do not fully meet the client's true needs and as such the building will never fully perform*"*** (WC, 4.6, 3, FM).

The above response (WC, 4.6, 3, FM) demonstrates the importance of involving the facility management staff at an early stage, as this will reduce costs associated with poorly planned maintenance for the building. Moreover, the facility manager argued that satisfying the client needs only when constructing building often result in some short falls, and thus becomes difficult to maintain or improve performance for the building when it is in operation. In addition to being involved at an early stage, the facility manager stated the importance of considering internal environmental conditions, and thus, employing systems such as BMS to maximise occupants' satisfaction. However, and through experience, the facility manager recognised that such systems cannot totally ensure the overall occupants' satisfaction within a building. In total, it can be claimed that the facility manager's view on performance was driven by the issues faced with relation to both the building itself and building occupants.

Building occupants

According to the building occupants, their views on performance were influenced by their role in the building. For instance, two of the occupants claimed:

"Me personally, because I haven't got technical background into building management, is very much about a building to have maximum utilisation. And I suppose running an efficient building, so cost wise, maximizing saving potentials I suppose" (WC, 4.7, 2, O1).

"It means how the building itself performs from a cost perspective in terms of you know the overheads, the resources required to run it, but I think the performance also means what the building can actually deliver" (WC, 4.7, 2, O2).

The above quotations show that the role of the individual in the building can influence their view of performance. For instance, when considering the quotation (WC, 4.7, 2, O1), their role as a logistics manager has perhaps directed the view on performance towards cost-related aspects such as maximum utilisation, and need for the building to be running efficiently. Despite the other occupant's role (a business change manager), and referring back to (WC, 4.7, 2, O2), other cost-related aspects were highlighted such as looking at resources required and considering the building as a solution provider. Thus, it can be asserted that such views align with the client's view of performance, as the primary focus was upon cost-related aspects. This can be reasoned by their roles, which impacted their view on performance as being part of ensuring it rather than reflecting how they are influenced by it. However, another occupant stated that performance for them is related to the environment the building provides in terms of lighting, temperature, lighting, and so on, which shows more of what typically an occupant can experience when they are in a building.

As for improving performance, both O1 and O2 provided suggestions such as constant monitoring and providing effective solutions for the occupants in the building. For instance, on improving performance, both O1 and O2 stated:

"Through constant monitoring, so I don't think ever you should sit still, you have to work to understand your customers and the people who use the building and what their needs are, which is constantly changing in our case" (WC, 4.7, 3, O1).

"I think there is no common point when you can only get the energy bill down to a certain level, I think that's a finite performance to measure, but in terms how well the building can be used by its occupants, and by the mix of its occupants, I think we can simply review that, analyse and adjust that to make more effective solutions for the building" (WC, 4.7, 3, O2).

The above responses show that their views have been influenced by their roles in the building. This means that they see themselves as part of not only driving performance, but also contribute towards improving it. This can be identified when compared to the third occupant's (O3) response on improving performance, which reflects more of an experiential view highlighting that noise is one of the current issues in the building. As when looking at the importance of facilities, the first two occupants (O1 and O2) stated that their roles imply working closely with the facilities management staff where one of these occupants stated:

"We need to work very closely hand in hand with facilities management, so if we are the strategic part of how the building should be used, and facility management should be seen as the day to day enforces how the building should best be used" (WC, 4.7, 4, O2).

This above quotation (WC, 4.7, 4, O2) demonstrates the influence of an occupant role within the building, hence providing a third person response rather than a reflecting on personal experience. This is realised when looking at the third occupant's (O3) response who provided a more-subjective view looking at the current available facilities (e.g. kitchen) and mentioning their pros and cons based on their personal experience. To conclude, it can be highlighted the role of the occupant plays is vital in terms of shaping their views and perhaps took over their personal concerns in the building to look after other occupants' concerns within the building.

4.3.5.2. The process of achieving performance of space

This section reviews responses on the process of achieving performance of space from the view of the building client, facility manager and building occupants. Similar to the previous section, the results are presented in the form of quotations with respect to the question focus highlighted in blue from Tables 4.5, 4.6 and 4.7 (attached in the appendixes).

Building Client

The client stated that the space at the Office Building has primarily been planned using 2D plans, engaging with conceptual workspace designers. In addition, the client stated that 3D models were not as necessary to plan the space, and he reasoned that by saying:

"We already determined the sort of layout of desking that we were planning to use. We gone through a process to choose the furniture that we were planning to use, so we were looking to utilise the space to try and make it non-demarcated, could simply be used and moved around by anybody. We didn't do a lot of 3D modelling, I mean there was some of that done initially, but it was very high-level stuff really" (WC, 4.5, 5, BC).

This above response shows that the space was planned based on selected aspects, which mainly concerned selecting the appropriate furniture along with the layout to ensure maximum utilisation and ease of movement, hence 3D models were not required. Also, as part of the space planning process, the client stated that AUDIT commission guidelines were adopted to ensure an adequate personal space area for the occupants with respect to their organisation. The client also stated that as part of reducing complaints by the occupants, which often is result when their indoor environment is changed, it was important to make the spaces as uniform as possible so they can adapt to the new space easily.

According to the client, it was stated that the use of BIM would potentially be useful in considering the maintenance regimes. In clarifying this, the client stated:

"I think the benefits coming from BIM approach would be around how its going to be maintained in the future, most architects don't have this as one of the top things in their list, they more look at the design, just how things will operate" (WC, 4.5, 7, BC).

The above response shows that maintenance is perhaps one of the current challenges faced within the Office Building. The client also suggested that the architects do not take such a vital aspect into consideration when they design buildings, and hence, stating that BIM can potentially provide solutions to overcome complexities associated with future maintenance. With regards to the barriers that prevents BIM to deliver building performance, the client emphasized that apart from the funding required to use BIM, it is not clear yet how the BIM approach provides cost effective solutions. Moreover, expanding on the previous point, the client stated:

"I suppose the other concern is that the influence of BIM doesn't push the cost, so it becomes unaffordable to sustain, if you like for the building in, things you know to be in future maintenance, it does in effect/prevent the initial capital investment, because you just don't have funding to do it. I mean theories are great things really, but seeing that savings and efficiencies come through are not always proven to be honest, and that's case really" (WC, 4.5, 8, BC).

The above response (WC, 4.5, 8, BC) shows that there is a gap between what BIM can do in theory compared to its capabilities in practice. This aligns with the client's view of performance, which mainly focuses on cost-related aspects, hence mentioning that BIM's primary value would be about maintenance of the building in the future.

Facility manager

According to the facility manager, it was emphasized that BIM can support managing the space, and potentially break down barriers so different stakeholders can appreciate the importance of each of others role. In addition, the facility manager highlighted that his primary focus was upon the operational issues, and he expanded on the importance of such issues as below:

"I would tend to focus on operational issues**, **the client would tend to focus on operational issues of a different sort, they would look at the people issues, the soft FM, I would look at the hard FM issues, because that's my specialism, that's why I am coming here for" (WC, 4.6, 8, FM).

The above quotation shows the importance of incorporating the facility manager's input where he demonstrated the importance of this by reflecting on his experience within the building and highlighted the operational issues as an important aspect to be considered. In relation to BIM, the facility manager stated:

"I would be looking at BIM model, with my hard FM hat on; I will be looking at space, looking at service clashes and all the stuff that goes behind the scene, but that tends to be the design stage, I think BIM is not just a 3D model and that's where many people think its only 3D and I think this is where it falls down, I think that BIM is a building information management system" (WC, 4.6, 8, FM).

The above response (WC, 4.6, 8, FM) shows that the value of BIM is not limited to the representations produced, but more importantly the information that can be obtained from it. The facility manager has reasoned this by stating that BIM Models should act as a reference when problems occur and lessons learnt for future buildings. To sum up, it is realised that the facility manager's view of digital technology is related to its capability to show and provide information on different aspects within the building. He added that a technology with BIM capabilities should remain as an information reference point where it can be accessed when required.

With relation to the involvement of the facility manager in the design of space, the facility manager claimed that his involvement would be vital many current issues faced within the Office Building. In demonstrating some of the current issues, the facility manager stated:

"*With this particular space, there are simple things that I could have done, far too many to mention, that wouldn't affect the overall aesthetics, but would have made the on-going revenue costs for this building a lot less*" (WC, 4.6, 7, FM).

The above quotation reflects the purpose why the involvement of the facility manager at early design stage is vital, which can benefit the cost-side of the building on the long term. The facility manger also pointed out that some of the current maintenance procedures within the building not only have implications of cost, but also health and safety too. In total, it can be concluded that the facility manager's view on space is perhaps driven by the experience with both management of the space and issues faced within the building.

Building occupants

Unlike both the building client and the facility manager, the building occupants were not asked about BIM, but instead were questioned about the value of 3D models in representing the space before occupying the building. With relation to that, the occupants provided different opinions such as:

"Probably if I have seen the model, I might have thought that it would look boring*, *but actually being in the space, what you can't get from looking at the model is the amount of natural light you receive within the building" (WC, 4.7, 7, O1).

***"Well, that would be dependent on the way that I was asked*, **like asking for my feedback, I think it would help perhaps things like movement of people within the space like the moving between the staff members**"** (WC, 4.7, 7, O3).

The above responses show that occupants have different opinions over the usefulness of space representations. Taking (WC, 4.7, 7, O1) as an example, the occupant recognised that the space representations (e.g. 3D models) would not provide an indication of the amount of natural light coming into the building and perhaps how it looks in reality. However, and referring to (WC, 4.7, 7, O3), it was mentioned that the space representations would be useful to provide feedback to overcome different problems such as movement of people. Thus, it is realised that the value of digital technology for the building occupants is perceived differently, and hence, defining the purpose of the utilised technology is important to ensure value for the occupants.

4.3.5.3. Experiences of using space

This section reviews responses on experiences of using space from the building client, facility manager and building occupants. Similar to the previous section, the results are presented in the form of quotations with respect to the question focus highlighted in orange from Tables 4.5, 4.6 and 4.7.

Building client

As part of investigating space performance, the client was asked about whether some spaces have changed. In response to that, and aligning with the initial plan of the space, the client stated:

"The floor layout has changed a little. **If we move stuff around, then it's relatively easy, so people just pick up their belonging to move, so it's not like the old days** " (WC, 4.5, 6, BC).

The above response (WC, 4.5, 6, BC) shows that although few changes have occurred to the layout, this has not caused any problems, as ease of movement was one the aspects when the space was planned. However, the client has mentioned a problem that was encountered when the building was occupied with relation to the impact of the Sun on the building:

"we also discovered when we occupied the building that that we should have done some modelling on the Sun in terms of the way it comes around, and the relatively deep plan of the street would actually mean the Sun wouldn't penetrate the building and create light issue, because on this front elevation we don't have any blinds or anything, so we had to retrofit internally and you can see up there the blinds are hanging, so that was something we had to introduce" (WC, 4.5, 6, BC).

The above instance shows one of the issues, which showed an additional requirement to overcome the problem imposed by the sunlight. In total, it can be claimed that space based on the client's view is determined by the parameters incorporated to design the space.

Facility manager

According to the facility manager, space performance is mainly determined by operational efficiency, which itself is influenced by several factors:

"So for me, the space needs to be well-defined, well-met, well-serviced and not break down, so to me that's the space performance, it's versatile so that people can adapt whatever task they want to do within that space within reason" (WC, 4.6, 4, FM).

The above response (WC, 4.6, 4, FM) demonstrates some of the required aspects for the space to make it operationally efficient. Furthermore, some of the attributes mentioned above such as 'well-defined', 'well-met' and 'well-serviced' are difficult to measure and assess, but perhaps are derived from the facility manager's experience within the building. Although it was mentioned that versatility is an important aspect of the space, the facility manager emphasized that this should be done in a cost-effective way, as this influences both managing and maintaining the space.

It was important to gather the facility manager's feedback on different types of spaces within the Office Building in order to further understand his views of performance of space. With regards to the public space, the entrance area at the Office Building, the facility manager stated that it is a space where people want to be. As with regards to the community space, more elaboration on the attributes were given such as:

*"**So the community space is multi-faceted, it can be for anything. It needs to be flexible, so nothing is fixed, nothing rigid***, **if you need to think about lighting and power, lighting needs to be generic, it needs to be good overall even, so that you can adapt the space, power needs to be softly installed in locations where it is not intensive but its available, like floor sockets, setting to the raised floor, the carpet is over the top, it's not affecting or causing an inconvenience**, ***so to make it versatile*"** (WC, 4.6, 5, FM).

The above response (WC, 4.6, 5, FM) shows some of the characteristics required for the community space, which is primarily making it flexible (versatile). In addition, the facility manager has elaborated some of the factors influencing the flexibility characteristic such as lighting and power sockets. Furthermore, the facility manager provided information about some of the issues faced within the community space, and reflecting on some of these issues, the facility manager argued:

"I can't repair the lights easily because the designers never thought about access arrangements, so when I do have to repair the lights, I either have to do it out of hours,

which costs me more, or take the area out of public use, which has a business impact. ***So it's all about versatility, maintainability, from an FM operational point of view it will be about serviceability***, **is it easy to clean? Are the surfaces a brush clean, or do I need to clean them by the end of every day?**" (WC, 4.6, 5, FM).

The above response, shows other important aspects for the community space in addition to versatility, which are maintainability and serviceability. With relation to maintainability, the facility manager mentioned some of the current issues such as repairing lights and how cleaning affects the serviceability for the space. Thus, it is realised that using community space as an example space to reflect on has helped to identify some of the characteristics influencing space using reflective examples. With regards to the private space, the facility manager stated that private space in the Office Building is the individual's working (personal) space, as the building is a communal open plan office. In emphasizing some of the necessities for such a space:

"You obviously need a little bit of space where you got sufficient room to move, sufficient room to put your cup of tea down, your IT and the stuff that you immediately needing without the person next to you elbowing you or someone behind you when they move their chair they are knocking you, it is that space ratio, but your private space in the building is not totally private space, it's your working space" (WC, 4.6, 5, FM).

The above quotation (WC, 4.6, 5, FM) demonstrates some of the requirements of individuals within their personal space. However, it is acknowledged that these requirements can differ and the facility manager has demonstrated some of these common requirements such as 'sufficient room to move' and information technology. With regards to the problems relating to space, the facility manager stated:

"One of the main issues in the office accommodation is that an insufficient design time is given at the design stage for ease of maintenance that's all. The building users on the other

hand are different set of issues, they have issues about the environment, **<u>some of the building users find it's too noisy in the atria, some of the building users find that for some reason every time somebody comes to the revolving doors, a draft goes through there, blows around the land course, and that door is in use all the time</u>*"*** (WC, 4.6, 6, FM).

The above quotation (WC, 4.6, 6, FM) shows that both ease of maintenance and ensuring occupants' satisfaction are the main difficulties faced with relation to space. Thus, the facility manager emphasized the importance of considering the design of the space not relying only on standards, but also considering further operational requirements, and suggested that computer modelling can potentially be a solution to overcome issues associated with such requirements.

Building occupants

Building occupants were asked to reflect on different spaces within the building in order to understand space performance from the building occupants. For the public space, more characteristics were provided when compared with the facility manager's view. Some of the responses were as:

"Public space should be welcoming, light, airy, comfortable, easy to recognise how they can access whatever that they need to access within the building, very friendly, customer service and part of that welcoming is having a good front facing staff" (WC, 4.7, 5, O1).

"A public space like the reception point of view, well, I always think that natural light is an important thing, but generally I would say, seating areas, friendly reception and welcoming staff, clean and open environment" (WC, 4.7, 5, O3).

The above responses show that public space is influenced by different aspects such as ease of access, lighting, furniture, and so on. Thus, it is realised that the public space is related to the use of that space by occupants, hence providing details that may influence the use of such space. However, it was acknowledged that the Office Building itself is not a public facing building, and thus, use of the public space in it is expectedly limited. With regards to the community space, some of the responses were as following:

"So I think its good to have a combination of different types of furniture, different types of space for people to be in for different purposes, and for it to be easily accessible for everyone, and welcoming I guess" (WC, 4.7, 5, O1).

"For a community/social space, I think lights, airy, welcoming and multi use really and also adapt the space into variety of uses really. so I think it's about adapting that space into variety of uses" (WC, 4.7, 5, O2).

The above responses (WC, 4.7, 5, O1) and (WC, 4.7, 5, O2) show similarities with the public space where different aspects such as furniture type, lighting, and characteristics such as multi-use influence the community space. Similar to the public space, the emphasis on the community space related to the use of the space by occupants. With regards to the private and personal spaces, both O1 and O2 have focused mainly on the importance of depersonalising that space where their managerial roles (mentioned in Section 4.3.5.1) is perhaps the main driver for the focus. Furthermore, emphasising on depersonalising the space, one of the occupants stated:

"I think its important to depersonalise that space, I think attached to that is how we treat things such as storage and making that a consistent approach across the building" (WC, 4.7, 5, O2).

The above response shows the intention behind moving towards depersonalising the space, is to enable the space to be used by multiple users. In relation to the factors that can influence the use of personal space itself, one of the occupants stated:

"For private space, I think it's important to have a designated team area" (WC, 4.7, 5, O1).

The above response (WC, 4.7, 5, O1) shows the personal space requirements such as arranging individuals within their appropriate teams for communication purposes are important for the personal space. Also, one of the occupants stated that one of the current issues for personal space is the movement between spaces, which may cause not only disruption, but also possible accidents (e.g. run somebody's foot with the chair). Thus, it is realised that personal space is more about establishing a working space while maintaining social values within that space.

The occupants were asked to provide details about major issues they face with relation to space at their building. Both O1 and O2 stated that both desk ownership and increase of occupancy were issues. Perhaps, both issues are influenced by their roles where the solution to the first one (desk ownership) will be overcome by depersonalising the space. As for the second issue, O2 stated:

"The start to increase occupancy of the building*, *is about storage, there is going to come a point when the storage provision within the building can only really cater for certain amount of occupants" (WC, 4.7, 6, O2).

The above response (WC, 4.7, 6, O2) shows that increasing occupancy raises issues such as storage requirements by the occupants. This issue has also been mentioned by another occupant who stated that their current personal space does not provide enough storage for their personal belongings. In summary, building occupants' view of space is not only more subjective, but also issue-driven to suit their needs and requirements within different spaces in the building.

4.3.5.4. Office Building case study findings

The outputs from the inquiry into the Office Building show that inquiring into different experiences of using space exposes characteristics influencing building performance. It is also found that designers tend to rely on 'reference representations' to aid them when producing representations of the space for a new building. This is apparent in the Office Building, as the designer used an exact replica of an existing office interior from an existing building to show the building to the client and the future occupants how their proposed space would look. For further clarity, Figure 4.2 summarises the obtained outputs based on meanings of building performance, process of achieving performance of space and experiences of using space.

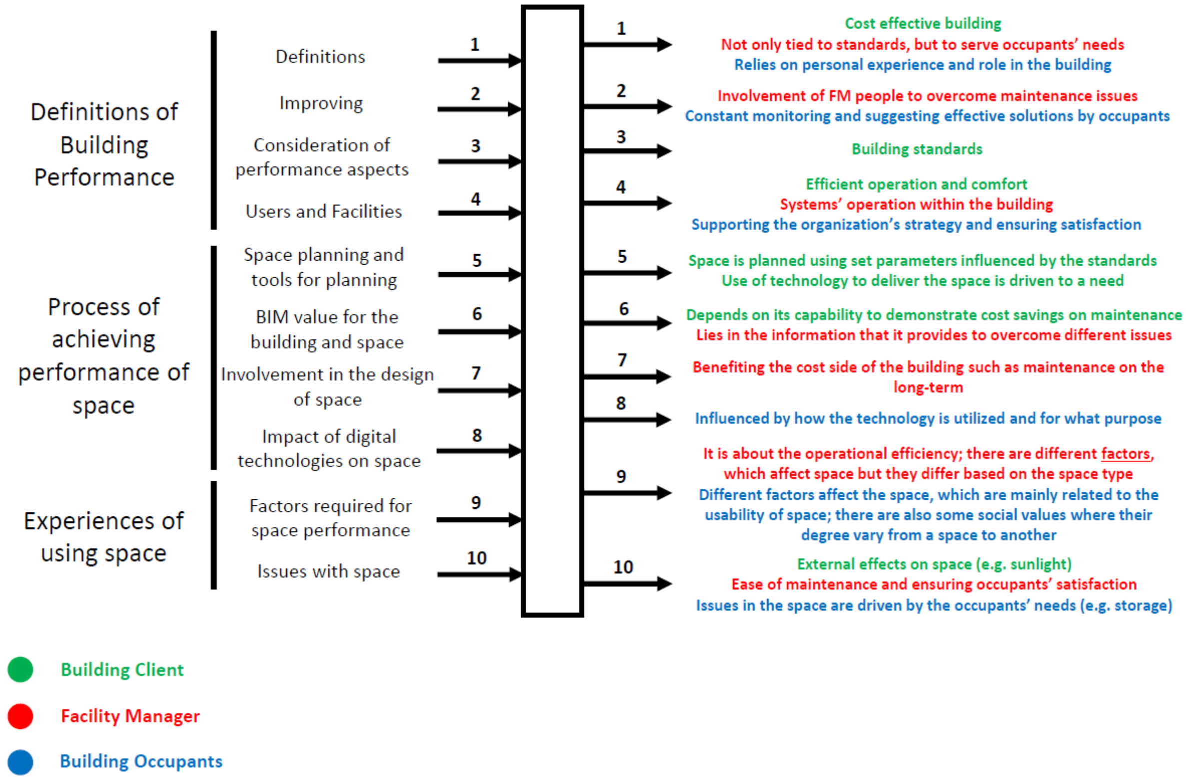

Figure 4.2: Summary of the outputs from Office Building Case Study

Figure 4.2 shows a summary of the outputs from the investigation on exploring definitions of building performance, the process of achieving performance of space and experiences of using space from the targeted stakeholders. For instance, looking at the feedback received under experiences of using space, it is shown that in order to capture experience of space, it is important to encapsulate aspects that influence the space. Some of these factors were captured when the facility manager and building occupants reflected on different spaces (public, social and private). These findings show that inquiring into different experiences of using space has supported surfacing characteristics that influence building performance. Also, inquiring into the process of achieving performance of space showed that further investigation is needed into how factors influencing performance are embedded within the representations of space.

The outputs shown in Figure 4.2 reflect the divergent views on performance of space from the three stakeholders in this case study. This is demonstrated in the feedback received on definitions of building performance, process of achieving performance of space and experiences of using space where the feedback is categorised into three colours and each colour represents a stakeholder. Therefore, to achieve performance of space that satisfy the three stakeholders, it is important to incorporate their divergent views. In the next chapter, and similar to the previous case study, how to incorporate these divergent views, which in this case is related to the different experiences of space, taking in consideration the outputs shown in Figure 4.2, will be considered.

Similar to the previous case study, and as part of the findings, it is important to indicate the value of understanding multiple perspectives for the Office Building case study. As for the client, it can be claimed that performance of space is influenced by the budget available, ensuring the delivery of energy efficient building and predetermining the use of space. Hence, incorporating BREEAM excellence for energy performance and CAPS policy to plan the space. As for the facility manager, performance of space is about the operational efficiency of the space, which is influenced by other aspects that differ depending on the type of the space and its intended use. For instance, reflecting on experience by demonstrating issues with relation to public, social and private spaces. The building occupants' view on performance of space is influenced by their roles in the building and usability of the spaces. As for the roles, it is realised that the role that an occupant holds can influence their view, which for example can be identified from their responses 'major problems with relation to space'.

4.3.6. Conclusion for the Office Building case study

The primary aim of the Office Building case study was to inquire into performance for space. To investigate this aim, both the process of achieving performance of space and experiences of using space were explored. The findings show that inquiring into experiences of using space has supported many characteristics that influence building performance. However, when inquiring into the process of achieving performance of space, it is found that further inquiry into representations of space is needed. This is in order to investigate how factors influencing performance are embedded within the representations of space. Therefore, the third case study (the Educational Building 2) aims to inquire into experience of space representations in order to determine how factors influencing performance are embedded within these representations.

4.4. The Educational Building 2 Case Study

The findings from the Office Building case study will be used to form the inputs for the inquiry for this case study. The previous case study showed that further inquiry into the representations of space is needed in order to investigate how factors influencing performance are embedded within the representations of space. Therefore, it was decided to look into experiences of space representations as an additional inquiry into performance of space.

Educational Building 2 is considered as part of a large campus extension for one of the universities in the UK, which at the time of the study was projected to start operating by September 2015. The building will consist of five storeys, providing accommodation for the faculty of Education, Law and Social Sciences, Business School and the University Directorate, along with many facilities. Similar to the Educational Building 1, the building was projected to achieve low-energy consumption targets to achieve BREEAM Excellent rating and Energy Performance Rating of A.

4.4.1. Rationale for selection

Unlike the previous case studies (Educational Building 1 and Office Building), the Educational Building 2 case study was undertaken during the design and development stages of the building. BIM process was been applied to aid the delivery of Educational Building 2. There were a number of reasons for selecting this building development as a case study. The first was that it provides a different angle on understanding the problematic nature of space and building performance using the available digital BIM models. Another reason was that, unlike the previous case studies where the evidence is gathered based on occupied buildings, the evidence in this case study will be based on a building that was under construction. The final reason was the availability of the BIM model of the Educational Building 2, so that feedback could be provided over the representations within it by those who often are not involved in the delivery process, which are the facility management team and building occupants.

4.4.2. Research participants

In this case study, there are three parties that are involved: the building designer, facility management team and building occupants. As this case study seeks to understand the problematic nature of space performance, and as the project was during its design development stages, it was anticipated to involve the view of the building designer. This is not only to gain their view on performance for space, but also how the designer embeds different characteristics that influence performance of space in their digital designs. The facility management team consisted of the facility manager and the building services supervisor. It is important to acknowledge that the facility management team involved in this case study was the same one involved in the Educational Building 1 case study. For the same purpose as the Educational Building 1 case study, the aim was to involve multiple people representing the facility management team to understand different perspectives. Also, as the nature of their role differs, it was anticipated to gain understanding how that influences their views about the digital models of a building that they have not occupied yet. Similar to the Educational Building 1, the building occupants were represented by four university staff members who would be occupying the building after completion. The number of participants from the building occupants' party was not a concern, however, as it was expected that the technical expertise in understanding the digital models of a building would vary, so an introductory session about the use the representation of space that was part of the inquiry in this case study was provided to the occupants, so they provide both meaningful and useful feedback.

4.4.3. Data collection and scope

The data was collected using both semi-structured interviews with the building designer, the facility management team and building occupants. With the facility management team and building occupants, the data was gathered through interviews about both past experiences as well as digital representations. The digital representations were based on the BIM model developed to aid the delivery of the Educational Building 2. The digital representations used were 2D plans and 3D navigation where participants provided comment, which consisted of captured information and concerns. Information and concerns were captured by asking both the facility management team and building occupants about what information they could gather from the 2D and 3D representations.

4.4.4. Results and findings

The data gathered from the building designer, facility management team and building occupants are respectively presented in Tables 4.8, 4.9 and 4.10 (attached in the appendixes). With relation to the data collected by interview (Table 4.8), the same coding system applied in the previous case studies has been applied. The captured information from the 2D and 3D representations, is referenced to the yellow shaded sections within Tables 4.9 and 4.10.

4.4.5. Data analysis

The primary aim of this case study was to inquire into performance for space from different stakeholders. This section draws analysis based on the data gathered from different targeted stakeholders: the building designer, facility management team and building occupants. The results from the targeted stakeholders is listed with respect to the input inquiry, which are definitions of building performance, the process of achieving performance for space, experiences of using space and experiences of space representations. The main findings of this case study are then presented.

4.4.5.1. Definitions of building performance

This section reviews the meanings of building performance based on the building designer's view. The results are presented in the form of quotations with respect to the question focus highlighted in green in Table 4.8.

Building designer

According to the building designer, building performance is based on how the building answers different questions/queries. Some of these questions were as:

"Did it performance a capital construction project, so did you bring it on budget, time, does it perform as a financial asset, so if you are talking about a commercial buildings, does it give good yields …" (CB, 4.8, 2, BD).

The above response shows that performance is influenced by many factors, which perhaps are driven by experience. Although such a response provides awareness of different views of performance, and demonstrates different levels of complexities depending on different questions, the designer argued that performance is primarily associated with metrics related to energy performance. In describing some of the metrics that influence energy performance, the designer stated:

"So how much heat does it lose, how much heat is gained in the spaces, how much energy spend on cooling, how much spend on lighting, those sort of metrics" (CB, 4.8, 2, BD).

The above (CB, 4.8, 2, BD) demonstrates the questions which act as a metric used when achieving performance for the building. This perhaps reflects the metrics that were deployed in the delivery of performance for the Educational Building 2. With regards to improving performance, the designer stated that it is oriented towards energy and sustainability. In describing what affects improving performance, the designer claimed:

"Number of angles on that I suppose, so there is user behaviour, but there is sort of design optimisation is the one that we probably more interested in. So design optimisation is understanding how energy is being used in different areas in the building, different systems, all those sort of things and then make it better" (CB, 4.8, 3, BD).

The above response (CB, 4.8, 3, BD) shows that both user behaviour and design optimisation mainly influence the improvement of performance. The designer has also elaborated on what should be considered to optimise the design, so that the building is energy efficient. Furthermore, he emphasized the value of BIM in terms of providing flexibility to optimise a design of a building in order to perform better. In terms of users' behaviour, the designer pointed out the importance of users' understanding of how to operate within the building. Reflecting on some of the user's behaviours that influence improving performance, the designer provided an instance:

"The operation stage is incredibly important, so that goes to things like user training, so they know how the building is designed to be operated so they can operate it in that way. **Obviously sitting in a hot room and then thinking how bad the design of this building is because he/she fundamentally didn't know how to use the building, so that works at the end-user level*****"*** (CB, 4.8, 3, BD).

The example mentioned within the response (CB, 4.8, 3, BD) above shows how users' behaviour can influence improving performance, which can have implications over both energy performance and users' satisfaction. In addition to both design optimisation and users' behaviour, it was stated that aspects such as maintenance play a role in improving performance once the building is occupied, as this influences the sufficiency of facilities within the building. This links to the building designer's statement on achieving performance for users where he mentioned:

"As people understand how they work and they manage, it's important for lots of reasons I suppose, they need to do what they suppose to do, because otherwise productivity might be affected" (CB, 4.8, 4, BD).

The above statement (CB, 4.8, 4, BD) reasserts the importance of people (building users) understanding how to operate in their built environment, as this can for example influence their productivity within the building for example. This shows that people (users) and performance within the building are interconnected and influence each other.

4.4.5.2. Process of achieving performance of space

This section reviews the process of achieving performance of space based on the building designer's view. The results are presented in the form of quotations with respect to the question focus highlighted in blue from Table 4.8.

Building designer

According to the building designer, it was claimed that the delivery of space relies on defining a metric that acts as a reference. Furthermore, the designer added that this metric depends on the client's brief while bearing in mind that the brief does not necessarily include specific requirements for space. In describing how this metric is often driven, the building designer stated:

***"So Building Regulations is minimum statutory requirement that we need to achieve*, there are British standards, which define lots of things, for different types of buildings there are different guided piece of guidance, CIBSE guides define a lot of sort of energy, M & E systems, services design criteria, and then any specific user briefing requirements"** (CB, 4.8, 5, BD).

The above response shows that building regulations are one of the primary drivers for different metrics when delivering performance for space. In demonstrating what these standards often include, the designer stated that a standard like CIBSE (Chartered Institution of Building Services Engineers) defines different requirements related to both the building itself as well as users. In addition to the foregoing, the designer also stated the importance of considering intangible aspects, and in clarifying what was meant by intangibles, the designer demonstrated an example as below:

"I am always drawn to things that are intangible as well, **so these are sort of metrics that you can measure, you get thermometer you can measure the temperature, you get a microphone you can test the acoustics**, ***but there is a lot of immeasurable things that are equally important like well-being"*** (CB, 4.8, 5, BD).

The above response (CB, 4.8, 5, BD) shows that in addition to the standards and regulations incorporated when designing the space, the value of intangibles is as equally important. The designer elaborated an example of how intangibles are considered through providing an example of British council for offices award criteria (BCO, 2012), as it includes a category ('lifting the spirits') that discuss the sort of intangibles involved in a building. That category considers intangibles through answering questions related to how good the place is for working, atmosphere, colour scheme, and many others. Thus, it was concluded by the designer that considering intangibles is important in the delivery of performance for space.

To gain further insights on space and performance, the designer was asked to reflect his view on considerations for different types of spaces. As mentioned before, the spaces considered are public, community, private and personal spaces. To begin with, the designer provided some of the considerations for public space such as:

"For a public space, it's sort of accessibility, are there barriers that prevent you to enter that space, so when you see these spaces from outside, you can move into them, when you are in them, it is easy to move around them, is it clear, is there a clarity of signage if you need signage, eligibility I suppose for the space, so if it's a long space can you see the end of the space, can you see the exit, all that sort of things" (CB, 4.8, 6, BD).

The above description (CB, 4.8, 6, BD) shows some of the questions that the designer considers answering when designing a public space. The designer has clarified this view by providing some of the elements incorporated when designing the public space for Educational Building 2. Some of these elements included visual communication, security, quality of materials, and many others that were claimed to be essential when designing a public space. As when looking at community (social) space, the designer stated that such spaces often involve more subjective metrics. Some of the essential aspects mentioned with relation to community space include looking open, inviting, comfort, flexibility and ownership. In demonstrating what considerations have been taken when designing the community spaces in the Educational Building 2, the designer stated:

"It depends where it is and what you are trying to do with it really. **So social learning covers a lot of ground really, so it could be learning spaces, it could be seats outside the classroom corridor really all the way to the big central spaces, you know lots of things to activate those spaces and make people use them*"*** (CB, 4.8, 6, BD).

The above instance (CB, 4.8, 6, BD) shows that elements considered for a space such as the community space are driven to a need, so that they can be used efficiently by occupants of the building. As for the private and personal spaces, the designer stated that creating benchmarks for such spaces was important, as they can be used in different ways. The designer demonstrated some of the benchmarks as below:

"To do with personal space, every member of staff gets a fixed agreed size of desk, fixed type of chair, fixed amount of shelving, a personal storage, so personal spaces is how you do that or how you configure a space to make that as good as you can" (CB, 4.8, 6, BD).

The above response (CB, 4.8, 6, BD) demonstrates some of the parts that were considered as requirements when designing the personal space. Following on this, the designer also stated additional considerations such as privacy, which is important for personal spaces.

4.4.5.3. Experiences of using space

This section reviews the experiences of using space based on the views of the facility management team and building occupants. The results are presented in the form of key elements with respect to the question focus highlighted in orange from Tables 4.9 and 4.10.

Facility management team

To gain an insight into the facility management's experience, representatives were asked to state the problems they generally face within spaces in a building. In responding to that, the issues stated were related to operations, maintenance and management. For instance, the facility manager stated that some of the operational issues faced are cleaning and movement within the building. In order to get more details about performance-related issues, the team was asked to describe issues with respect to six aspects, which are temperature, ventilation, space comfort, noise, facilities and maintenance. These aspects were proposed so that different characteristics that influence experiences in the building can be gathered. These aspects were proposed based on the results gathered from both the Educational Building 1 and Office Building case studies.

With respect to the selected six aspects, the issues mentioned were related to their responsibilities (operations, maintenance and management) within the building and the problems faced/caused by occupants within the building. For instance, when looking at one of the problems under temperature aspect, which is the inability to open windows, such problems can have operational implications (e.g. energy efficiency), and also influence occupants' comfort. Similarly, looking at some other issues such as those mentioned with respect to facilities, it is realised that issues are related to both occupants' satisfaction (e.g. facilities satisfying occupants' needs) and others that fall under operation (e.g. heating and cooling) and maintenance (e.g. roof leaks) problems. With relation to space, which also is the primary focus in this case study, the responses were more generic, and perhaps may reflect problems that apply to certain spaces, hence mentioning that space issues depends on the type of work within the building. For instance, stating that 'inefficiency of the space usage' may apply to certain spaces within the building.

The facility management team gave feedback on different spaces concerning both important considerations and concerns in relation to the four spaces (access space, social learning space, teaching space, office space) mentioned previously. For the access space, and similar to the building designer, the facility management team stated that such space should include some essential aspects such as being open, airy, welcoming and well signposted. When looking at a space such as the social learning space, the view has been extended from only looking at aspects to include other considerations, which can be claimed to be driven by their role and experience with such spaces. For instance, aspects such as having versatile correct furniture and connectivity were mentioned to be essential for such social learning space. However, when looking at the concerns about social learning space, other considerations such as usability, maintenance, ownership and cleaning access were mentioned, as they perhaps tend to become a source of different issues when the space is actively used.

Similar to the social learning space, responses on what is important for a teaching space included essential aspects to be considered such as facilities required (e.g. projectors and white boards), lighting and occupancy level. Also, some other aspects that need to be considered for the teaching space were mentioned such as functionality and flexibility where both can be influenced by different aspects such as size and facilities. In terms of concerns about the teaching space, the stated concerns were related to aspects such as usability (e.g. adequacy of facilities, complicated AV systems and moving facilities) and operation (e.g. everything being in working order). Finally, the importance for academic office space was considered where the feedback showed that elements such as storage and number of facilities are necessary while considering aspects that influence that space such as housekeeping. In relation to the concerns with relation to the academic office space, some were related to those caused by the users of that space where some of these problems include change of configuration, additional furniture, other concerns included those faced by users such as understanding how to operate the space (e.g. lighting systems and floor boxes).

Building occupants

Similar to the facility management team, the building occupants were asked to state problems they face within spaces in a building. The responses provided were related to those influencing their usability of the building. For instance, usability issues mentioned were related to facilities (e.g. location), temperature, lighting and accessibility. However, it is expected that the issues mentioned were personal and driven by both their present and past experiences. To get more detailed information, the occupants were asked about the issues they face with relation to the six aspects mentioned previously.

As with respect to the selected six aspects (temperature, ventilation, space comfort, noise, facilities and maintenance), the issues mentioned have reflected both personal and usability-related problems within the building, where both were mainly derived by their day-to-day job/role within the building. For instance, looking at issues related to temperature, responses were either personal such as ‘too hot/cold’ or usability-related such as controlling the temperature. Another aspect such as ventilation had more usability-related responses stating that ‘opening windows’ is a major issue influencing this aspect. It is important to acknowledge that some responses have relied on level of knowledge/understanding and thus been perceived differently. For instance, looking at the responses towards ‘problems with maintenance’, the responses were related to the problems they faced or the period taken to fix the problem. As when looking at the responses to the space, it can be realised that general feedback was provided, and it can be claimed that this is due to not specifying a particular space where occupants can reflect on where this can be based their working space or use of other spaces for different purposes.

Similar to the facility management team, the building occupants were asked to provide what they think is important and their concerns with respect to the same spaces undertaken by the facility management team. To begin with, when it was looked at what is important for the access space, the feedback showed aspects that should be considered for that space such as accessible entrance, welcome point, signage, light, information and many others. When looking at the social learning space, aspects such as required facilities (e.g. computers, charging points, nearby café), enough space and other personal preferences (e.g. inspiring quotes) were mentioned. With relation to the social learning space, the main concerns stated were noise levels and social characteristics (e.g. confidentiality).

When looking at teaching spaces, the occupants identified some of the important aspects such as required facilities (e.g. computer and projector), lighting, acoustics and space layout.

However, when looking at the concerns related to teaching space, it can be realised that the mentioned concerns were not only limited to those within the space, but also external concerns influencing the space. Internal concerns included aspects such as temperature and ventilation, while external effects included distraction and glare from windows. Finally, with relation to the academic offices, the important parts identified mainly related to the usability of the space such as storage space, appropriate space, and ventilation, required facilities (e.g. PC, phone and printer) where this also included some of the characteristics such as privacy. The concerns for office space were related to some social characteristics such privacy and confidentiality, aspects such as noise and usability such as inadequacy of facilities.

4.4.5.4. Experiences of space representations

This section reviews the experiences of space representations based on the views of the facility management team and building occupants. The results are presented in the form of key elements with respect to the question focus highlighted in yellow from Tables 4.9 and 4.10.

Facility management team

As an initial inquiry, and prior to providing them with both 2D and 3D representations of the four specified spaces in this case study, the facility management team were asked about their experience of looking at building designs and the familiarity with the building plans. In terms of looking at building designs, the response relied on their previous experience where the facility manager mentioned that she was involved as a requirements manager, which mainly looked at critiquing different aspects such as cleaning contracts after the design happened. As for familiarity with the building plans, the facility management claimed that they are familiar with plans, as they are used to aid maintaining and managing different services within the building. The facility management team were presented with both 2D and 3D representations for the access space, social learning space, teaching space and academic office space of the building being developed.

The facility management team stated that the 2D plans provided information on different elements such as areas, layout, access routes, reception and access for disabled. However, and perhaps influenced by experience and role, the facility manager argued that the information presented was not sufficient. The 3D navigation for the access space helped capturing some of the missing parts such as seats, signage and information about the building. The 3D navigation also triggered some concerns in relation to some parts such as reception and lighting. In relation to the concerns generated from both the 2D and 3D representations, characteristics such as accessibility, usability and maintenance along with other concerns such as availability of information for the customer and cleaning problems were raised an concerns when the space is used.

For the social learning space, the 2D plans provided information on different elements such as seats, tables, layout, but also triggered some concerns such as the limitation of use for that space. In 3D navigation, additional elements were identified such as electric boxes, book shelves and other facilities. However, 3D navigation also triggered a number of concerns such as location of the lights, acoustic considerations and whether the furniture is fixed or not. Based on both the 2D and 3D representations, the facility management team was asked to state their concerns with relation to temperature, ventilation and facilities needed. The concerns highlighted for both temperature and ventilation were derived from the expected users' concerns such as complaining whether the temperature is too hot/cold and whether there is access to fresh air. As for facilities, it was stated additional facilities may be required by the users such as printers and a nearby café.

For the teaching space, the 2D plans provided information on parts such as seats, tables, access points, and layout. However, the 2D plans also triggered some concerns relating to the flexibility of the space, whether the walls are foldable, whether the walls were solid or glass and whether the floor is hard or soft. In 3D navigation, more concerns related to that space have been triggered such as location of the projector, type of the lighting system and whether the chairs are stackable. Similar to the other spaces, based on both the 2D and 3D representations, the facility management team were asked to state their concerns with relation to temperature, ventilation and facilities needed. The concerns about temperature were related to occupancy rate and comfort while those highlighted for ventilation were the availability of floor vents and access to fresh air. As for the additional facilities needed, the responses included both those that expectedly required by the user such as tables and bins, and those that are related to the management of the space such as a storage cupboard for furniture, or the location of a nearby logistics room.

Finally, for the academic office space, 2D plans provided information about different parts such as natural light access, layout and furniture. However, the 2D plans have also triggered a number of questions/concerns such as accessibility type, tightness of the space and additional facilities required. Based on the 3D navigation, additional elements were identified such as shelves, but additional concerns were also triggered such as clarity of some objects, maximum occupancy and the concern that the space may not look spacious for the users. Similar to the other spaces, based on both the 2D plans and 3D navigation, the facility management team were asked to state their concerns with relation to temperature, ventilation and facilities needed. The concerns highlighted with relation to temperature included the type of control (central or manual), while those highlighted for the ventilation were blocking the floor vents and manual control of the floor vents. Finally, for the facilities needed, additional user requirements were provided such as copy machine, white boards and coffee machine.

Building occupants

Similar to the facility management team, prior to providing the building occupants with both 2D and 3D representations of the four specified spaces in this case study, the building occupants were asked about both their experience of looking at building designs and familiarity with the building plans. In terms of looking at building designs, most of the participants stated that they have been part of the briefing for the Educational Building 2 where they were shown the design of the building. As for familiarity with the building plans, as expected, the majority of the participants were not familiar with them, but some had seen some of the plans for the building during the briefing session. The building occupants were presented with both 2D and 3D representations accordingly of the access space, social learning space, teaching space and academic office space. However, as most of the participants were not familiar with the digital representations, an introductory session was conducted to ensure gathering useful and meaningful feedback.

For the access space, based on the 2D plans, the participants claimed that it provided them with an overview of the layout, but it did not include much information. The participants also stated that parts such as size and scale of the space were difficult to be appreciated using the 2D plans. The participants stated 3D navigation provided better visualisation of the space, but had concerns about, for example, the actual colours within that space. Based on both the 2D rand 3D representations, the participants listed some concerns such as understanding some of the objects, and others related to the space itself such as considerations of disabled access along with other personal preferences regarding the doors used for accessing that space.

For the social learning space, the participants stated that 2D plans helped to capture the layout of the space, but provided limited perspective. Perspective in this context refers to the appearance of viewed objects. As for the 3D navigation, the participants raised concerns in relation to some parts of the space such as maximum occupancy, actual colours, types of furniture and characteristics such as access for both disabled and workers. Also, one of the participants highlighted a possible issue that could arise from the limited number of tables within the space. Based on both the 2D and 3D representations, the participants raised some concerns in relation to the temperature, ventilation and facilities needed. In relation to temperature, the participants referred to the number of windows. As for ventilation, they stated that both access to fresh air and ability to open windows can influence it. Finally, additional facilities included having more seats, disabled access and facilities for the disabled.

For the teaching space, the participants were able to capture the layout of the space from the 2D plans, but stated some concerns such as maximum occupancy and lighting. They also claimed that it was difficult to understand the scale using the 2D plan. In 3D navigation, more parts were captured such as desks, chairs and projector. However, concerns were also triggered from the 3D navigation such as missing facilities and the actual colours within the space. Similar to the previous spaces, and based on both the 2D and 3D representations, the participants listed some concerns with relation to the temperature, ventilation and facilities needed. In relation to temperature, the concerns were related to different elements such as windows and movable walls. In relation to ventilation, both access to fresh air and windows were claimed to be influencing it. Finally, with relation to the facilities needed, they provided some personal preferences such as coffee makers or extra shelves.

For the academic office space, the participants were able to identify some parts such as number of desks and furniture layout from the 2D plans. However, some concerns were triggered about ventilation and lighting. Based on the 3D navigation, a number of elements were identified such as number of desks. However, a number of concerns were highlighted such as accessibility related issues (e.g. number of doors and access type) and size of desks. Furthermore, it was highlighted that the 3D representations lacked sufficient details. Based on both the 2D and 3D representations, the participants listed some concerns with relation to the temperature, ventilation and facilities needed. In relation to temperature, few elements were identified to be influencing it such as too much furniture and ability to control the temperature. Finally, with relation to the facilities needed, the participants claimed that personal space is desirable.

4.4.5.5. Educational Building 2 case study findings

The outputs from the inquiry on the Educational Building 2 show that representations of space have to be information rich to capture experience of a space. More importantly, the experience of space representations has supported recognising the gap between experience and data. For instance, the data used to form a particular space representation did not provide sufficient information to reflect the experience within that space by the participants in this case study. For further clarity, Figure 4.3 summarises the obtained outputs based on meanings of building performance, process of achieving performance of space, experiences of using space and experiences of space representations.

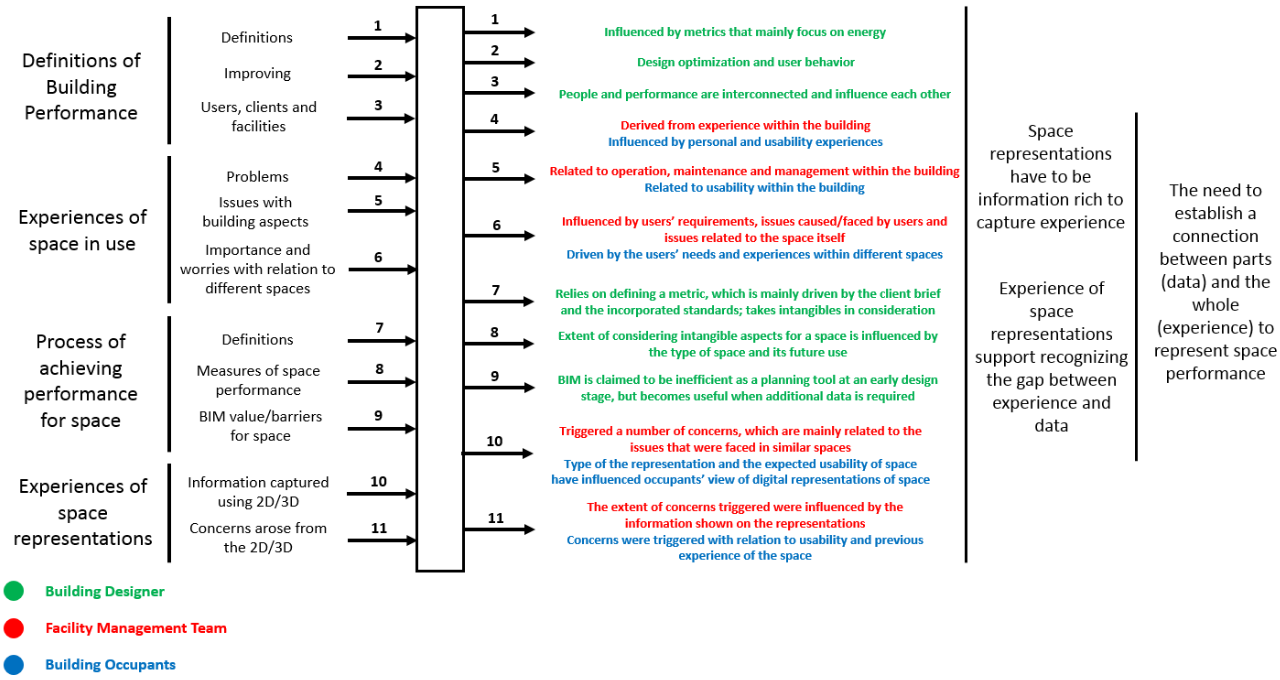

Figure 4.3: Summary of the outputs from the Educational Building 2 case study.

Figure 4.3 shows a summary of the outputs from the investigation on exploring definitions of building performance, process of achieving performance of space, experiences of using space and experience of space representations from the targeted stakeholders. For instance, looking at the feedback received 'information captured using 2D/3D' under experiences of space representations, it is shown that the representations' impact was different for the facility management team and building occupants. As for the facility management team the information captured raised concerns related to the space whereas for the building occupants, the type of representation influenced the information captured, and questions were triggered in relation to the expected usability of space. These findings show that it is important for the space representations to be information rich in order to capture experience of space. The outputs thus show the need to establish a connection between the data presented and different experiences to represent information that enables people to interpret how space performs.

The outputs shown in Figure 4.3 represent the divergent views on performance of space from the three types of stakeholders in this case study. This is demonstrated in the feedback received on definitions of building performance, process of achieving performance of space, experiences of using space and experiences of space representations. As shown in Figure 4.3, the feedback received is categorised into three colours and each colour represents a stakeholder. Therefore, to achieve performance of space that satisfies the three stakeholders, it is important to incorporate their divergent views. In the next chapter, consideration is given of how to incorporate these divergent views, which in this case is related to the representations of space.

Similar to the previous case studies, and as part of the findings, it is important to indicate the value of understanding multiple perspectives for the Educational Building 2 case study. As for the designer, it can be claimed that performance of space is determined by the criteria set, which is influenced by the client's brief, incorporated standards and the designer's personal experience. The personal experience includes the consideration of intangibles, which the designer referred to when responding to the considerations taken to deliver performance of space. The facility management team, reflecting on their experience with the digital representations of space, claimed that performance of space is influenced by the issues faced with similar spaces in the past and the clarity of information that the representation of space provides. For instance, highlighting issues such as flexibility and maintainability based on issues faced by a similar space or potential user needs, which are based on their experience. The building occupants, reflecting on their experience with the digital representations of space, argued that performance of space is influenced by their familiarity with the representation of space provided, available information and experience of using similar spaces. For example, familiarity with the representation of space is determined by the perspective provided by the representation, where in this instance 'perspective' refers to the viewpoint whereas having been in similar space in the past have triggered issues and concerns with relation to the use of space.

4.4.6. Conclusions of the Educational Building 2 case study

The findings show that inquiring into experiences of using space representations supports recognising that representations of space have to be information rich to capture experience of a space, which also showed that there is a gap between experience and data. Therefore, further investigation is required to establish a connection between the data presented and different experiences to represent information that enables people to interpret what influences performance of space. However, establishing the connection between data and experience is complex, and difficult to be achieved even when using latest construction technologies such as BIM.

4.5. Conclusion

This chapter documents the data and findings from each of the case studies undertaken in this research. The research journey showed how the output of one case study has influenced the direction of the next. For each case study, there were three targeted stakeholders, which were the building delivery team, facility management team and building occupants. It was also shown that the intention of the case studies (Office Building and Educational Building 2) influenced the targeted stakeholder representing the building delivery team.

The output of the first (Educational Building 1) case study showed that there are multiple meanings for building performance and many factors influencing it, which led to select space as a reference concept for performance. In addition, it was also shown that different people have different views of buildings and building performance, which implied the need to look into different experiences of using space as well as the process of achieving performance of space in the second (Office Building) case study. The outputs of the second case study showed that looking into different experiences of using space supports encapsulating different factors influencing performance. Also, by looking into the process of achieving performance of space, it was found that there is a need to investigate how the factors influencing performance are embedded within the representations of space. This implied the need to look into different experiences of space representations to investigate how factors influencing performance are embedded within these representations in the third case study (Educational Building 2). The outputs of the third case study showed that representations of space need to be information rich to capture different experiences of a space. Also, the experience of space representations support recognising the gap between experience and data. This implied the need to establish a connection between the data presented in space representations and different experiences to represent information that enables people to interpret how space performs.

The findings from each of the case studies reveal divergent views of performance of space. The first (Educational Building 1) case study showed that different people have different views of buildings and building performance. The second (Office Building) case study showed that inquiring into different experiences of using space supported encapsulating different factors influencing performance. The third (Educational Building 2) case study showed that representations of space need to be information rich to capture different experiences of a space. Therefore, for the next chapter, soft systems will be applied as an analytical tool to explore the divergent views for each of the case studies. Each of the Figures 4.1, 4.2 and 4.3 presented at the end of each case study show a list of the outputs from each case study. Therefore, using soft systems, each of these figures will be used to represent the divergent views. It is anticipated that the use of soft systems will help to explore how to bridge the gap between data and experience in order to enhance the delivery of better performance for space.

Chapter Five - Soft Systems Analysis

5.1. Introduction

This thesis explores the problem of how to design better buildings in terms of building *performance*. The findings reveal that there are two fundamental domains that constitute this problem. These domains concern the different ways that people perceive and act in the world. First, there is the experiential domain. This is rich with human perception and leads to the difficulties of expressing these perceptions in language, so that views can be taken into account when incorporating them into design. Second, there is the data domain, where information exists which is reproducible, defendable and independent. Thus, data is computable, adheres to set rules and can be used as a measure of improvement. These domains currently exist independent of each other, although there are many approaches to establishing their connections. This fundamental problem is not new to the Information Technology (IT) world, but often is neglected, since new applications and models are promoted to give a new meaning and facility to act in the world. This chapter takes the empirical findings and uses them to explore the research goal. First, a framework for discussion that involves the divide of data and experience, but addresses this as a problem of parts and wholes, is set out. Then Soft Systems Analysis (SSA) as a tool to understand and bridge the divide is presented (see Figure 5.1). SSA has been used in other IT situations for similar tasks, but mainly for system specification. In the present work it is its ability to make the divide between data and experience understandable that is used, in order to point to ways that the gap can be bridged. Figure 5.1 is used as a framework to illustrate the complex nature of the gap between data and experience, which is explored in this chapter through soft systems analysis.

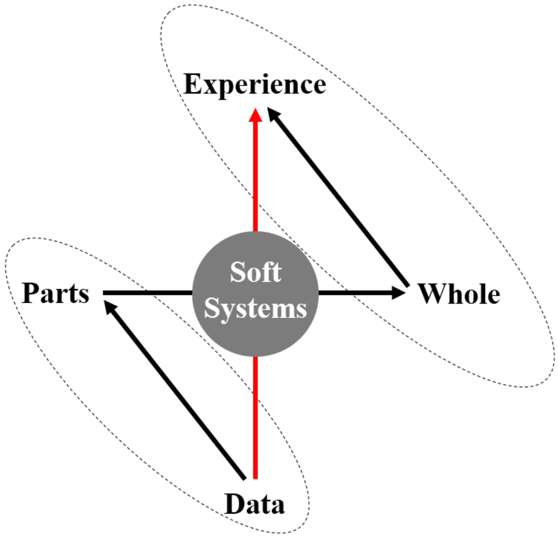

Figure 5.1: The framework that demonstrates the attempt of soft systems to bridge the gap between data and experience, the parts and the whole.

Performance: parts and whole, data and experience

The initial findings (the Educational Building 1 case study) show that building performance is seen differently by different stakeholders. Thus, space was selected as a reference in the present study for assessing performance as it supports situating different meanings for buildings and building performance. The later findings (the Office Building case study) show that different experiences of space have influenced the views on space, which highlighted some of the aspects that influence the performance of space. The final findings (the Educational Building 2 case study) showed that different experiences of representations of space recognise that the current representations' lack the capability of demonstrating aspects that influence the performance of space. Thus, there is a gap between data and experience. To understand this gap, the building is here considered from a systems point of view (explained in Section 3.6.4.1). According to systems thinking, a building is a '*designed physical system*' (see Section 3.6.4.1) because it consists of physical parts such as building systems, materials, and so on that are assembled in a certain way. Assembly of the physical parts define the emergent characteristics that determine experiences in a building. In this context, emergent characteristics are the results of interaction between different building parts which is a key concept in systems thinking (as explained in

Section 3.6.4.1). The view of a building as a designed physical system arises from a reductionist view of the building as a system where the whole (experience) is merely the sum of the parts. A building, as a whole, is also a '*human activity system*' (see Section 3.6.4.1) because it is where experiences are created within it. Experience within a building is influenced by the emergent characteristics of the building in addition to other personal factors. Other factors include individual those such as mood, health, psychology or other organisational factors that are hard to predict through studying the parts. The view of a building as a human activity system demonstrates a holistic view where the focus is on what influences the whole (experience) and what emerges from the interaction of the parts, including the human actors. Thus, like any other system, buildings have various levels of complexity, which can be viewed using both the reductionist and holistic views (see Figure 5.2) to understand different aspects. In the previous chapter both '*parts*' and '*emergent characteristics*' were referred to as '*aspects*' (e.g. temperature, accessibility and usability). In this chapter, and as the analysis use 'systems thinking', different '*aspects*' will be situated within the terms '*parts*' and '*emergent characteristics*'. This will support a holistic understanding of the problem being investigated and emphasize the complexities associated with understanding experiences within a building.

Bridging the gap between data and experience using either a reductionist or a holistic view is difficult. This is because there are many levels of complexity (see Figure 5.2), which are difficult to consider on a building level. Therefore, space is used as a reference to situate meanings about the reductionist and holistic views. From Figure 5.2, it is realised that space itself is an emergent characteristic, but it can act as a 'reference' for different building parts and emergent characteristics experienced by building users.

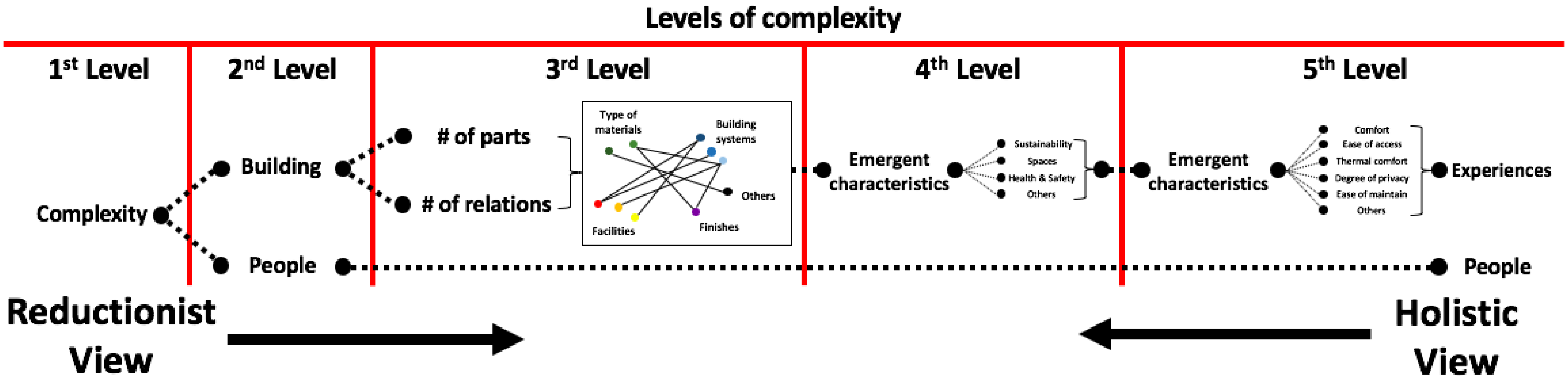

Figure 5.2: Levels of complexity when viewing building as a system.

The aim of this thesis is to investigate whether the modelling world can bridge the gap between data and experience. This is simply because a model is a representation of the parts, whereas visualisation of a model is an attempt to get a feeling of the whole (experience). Models present visual structures of the parts of a building, which are the results of data provided by the building delivery team. This means that the modelling approach is reductionist in nature because it uses data to represent parts, which then are used to represent the 'expected experience'. The expected experience emerges from reviewing models of a building within the context of its predicted use and past experience of using similar buildings. In other words, people visualise building models as representations of the whole, even though it is just an assemblage of parts. This models represent the building as both a physical designed system, and an expected human activity system. However, since the nature of the modelling approach is reductionist, the expected experience is never fully realised. In the BIM world, data is contextualised in a way to represent parts. This contextualisation of data is driven by the building delivery team whose view is reductionist when creating the building. Thus, representation of the experience in a model is limited to the expected emergent characteristics from the represented parts in a model. This perhaps shows that a BIM model lacks the ability to represent experience because it is limited to the data provided. Representing experience in a building is a complex phenomenon and requires richer approaches than current modelling approaches offer. Thus, the gap between data and experience requires a technique that supports the recognition of the whole, hence the use of soft systems proposed.

Why Soft systems?

The limitations of modelling in considering the significance of the whole, which in return influence experiences of different people in a building were discussed in the previous section. Understanding the greater understanding of parts requires a view of the whole in order to understand different complexities in a situation. ‘Soft systems’ is an approach that seeks to represent a more holistic and collective view in complex situations taking in consideration the divergent views. Systems thinking is embedded within soft systems, which means acknowledging not only the whole of a situation, but also the parts that are included in constructing it. Soft systems often (if not mostly) is applied methodologically to explore the conflicts in a situation, and notify a way to handle these conflicts in order to enhance the situation. Findings from the previous chapter showed that there are divergent views of performance. The nature of each case study and the people involved revealed some of the complexities related to performance, but did not imply a way of handling these complexities. Therefore, in this chapter, an approach based on soft systems will be applied analytically in order to investigate a way of handling the complexity that bridges the gap between data and experience. Soft systems are applied to each of the case studies, to support unravelling the significance of the whole.

Wilson’s soft systems approach will be used, as it seeks to identify information categories, which is proposed as a way of handling the data-experience gap. This is because it was demonstrated that the current use of technology (e.g. BIM models) does not acknowledge the limitations of data (parts) in terms of presenting experience. Therefore, as soft systems support providing a holistic view of a situation, the significance of parts that influence the whole is demonstrated more explicitly. This is because Wilson’s approach in soft systems supports transcends conceptual models, which are used to enhance a situation further to identify information categories, which can be used to demonstrate the significance of the parts. This involves using his Maltese Cross tool. Although the use of Wilson’s approach in identifying information categories may imply a certain determinism, it supports dealing with soft information that manifests people’s needs. More importantly, identifying information categories supports the data required in BIM, which serves the main objective of this thesis.

Soft systems analysis begins with a ‘rich picture’, which represents a holistic view of the current situation, highlighting those involved in that situation. Based on the rich picture, CATWOE analysis will be used to show the different worldviews of the parties involved in this study, which then support deriving root definitions. These root definitions allow the real world to be represented in a systems modelling world. Conceptual models are then formed to represent the activities required to satisfy different worldviews. Information categories are then be derived from the consensus model, and are mapped onto the Maltese Cross in order to show the information required. These steps will be applied to each of the case studies in turn. Modelling is generally about ‘parts’ and the way that these work together; however, in this study, the limits of what this can show and what it cannot are recognised. Thus the conceptual models and Maltese cross have limitations but in recognising this there is the opportunity to use them for the greater purpose of bridging the gap between data and experience.

5.2. Educational Building 1 soft systems analysis

5.2.1. Introduction

The aim of this case study was to inquire into building performance from three targeted stakeholders and demonstrated that different people have different views of buildings and building performance. Therefore, a soft systems analysis of the Educational Building 1 case study aims to address different information requirements that are needed to overcome the divergent views on buildings and building performance. Figure 4.1 (see section 4.2.5.3 in chapter four) is used to construct the rich pictures for the three stakeholders involved.

5.2.2. Rich pictures

The initial step in soft systems analysis is to form the 'rich picture' to express the views of different stakeholders; often one rich picture is produced that represents the different views. However, in this case, three rich pictures (one for each stakeholder) were produced with each rich picture referring to a particular view. This is because although the pictures address the same subject, they have different connotations. For instance, the occupants' comfort can be seen differently by the three targeted stakeholders. Therefore, the rich pictures, initially identify an interaction (building performance), but the difficulty is that different stakeholders perceive it differently, hence, the rich pictures need to be separated out. The rich pictures of the targeted stakeholders are represented in Figures 5.3, 5.4 and 5.5.

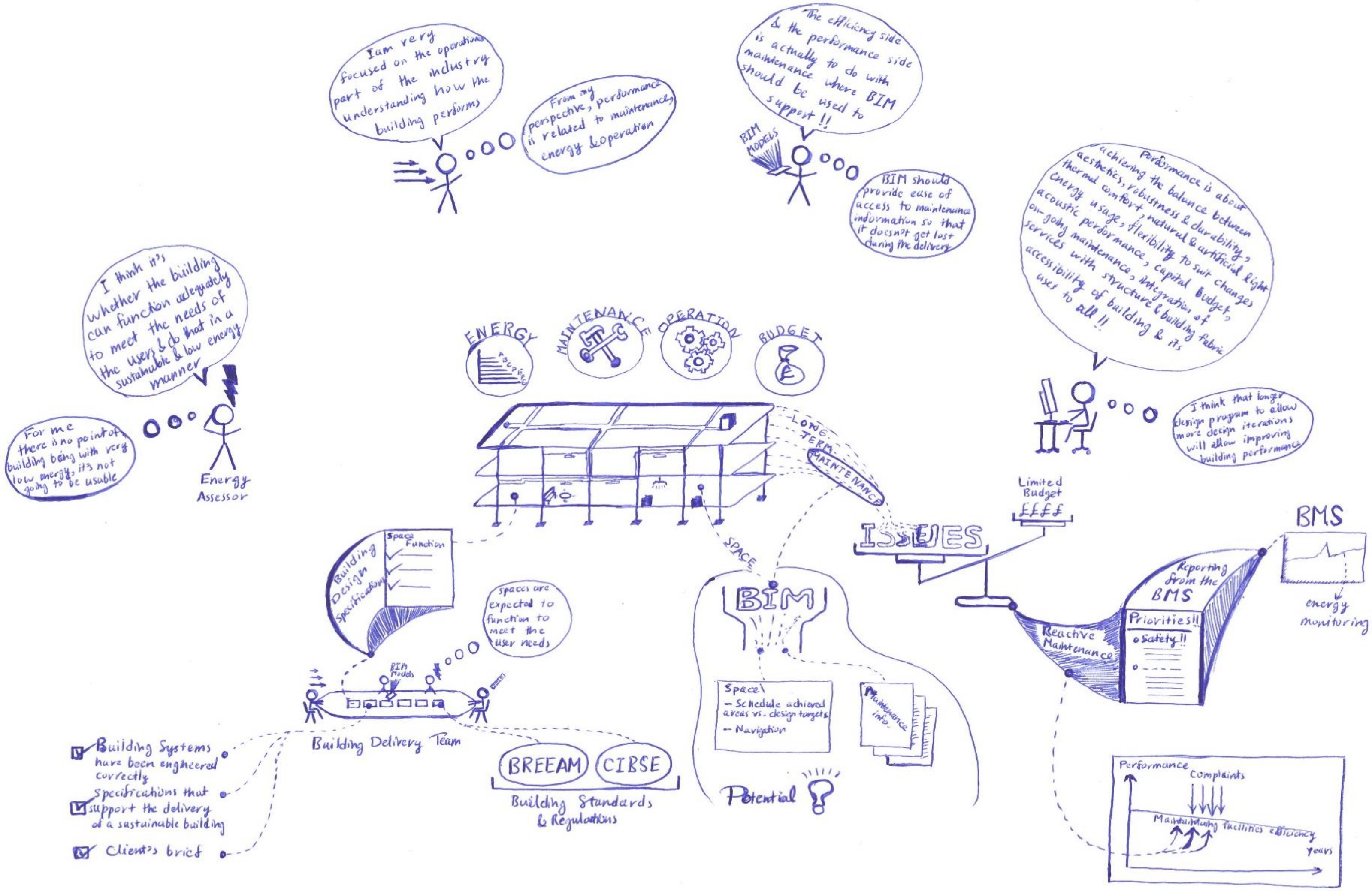

Figure 5.3: A Rich Picture representing the building delivery team Views on building performance in the Educational Building 1 case study.

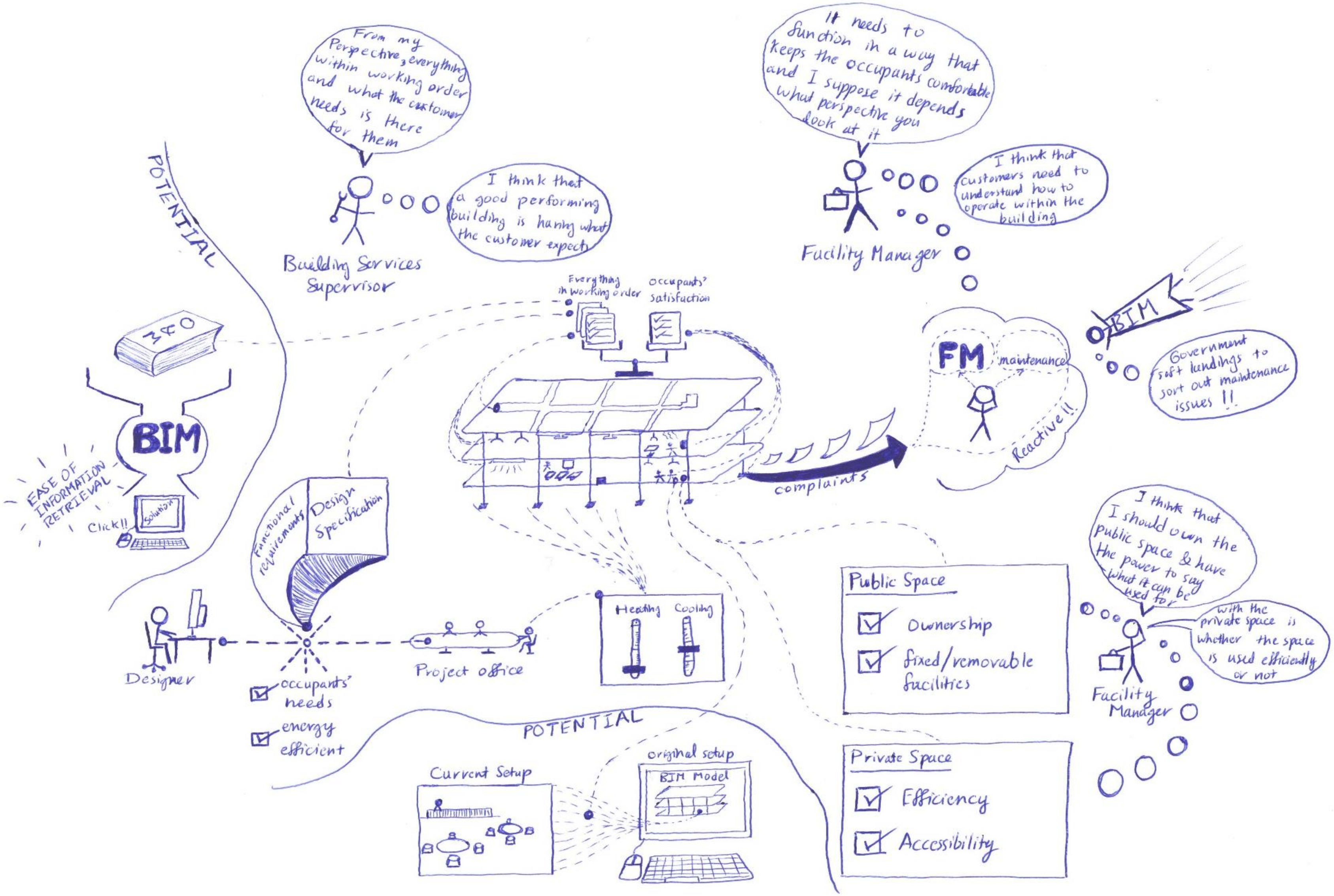

Figure 5.4: A Rich Picture representing the Facility Management Team views on building performance in the Educational Building 1 case study.

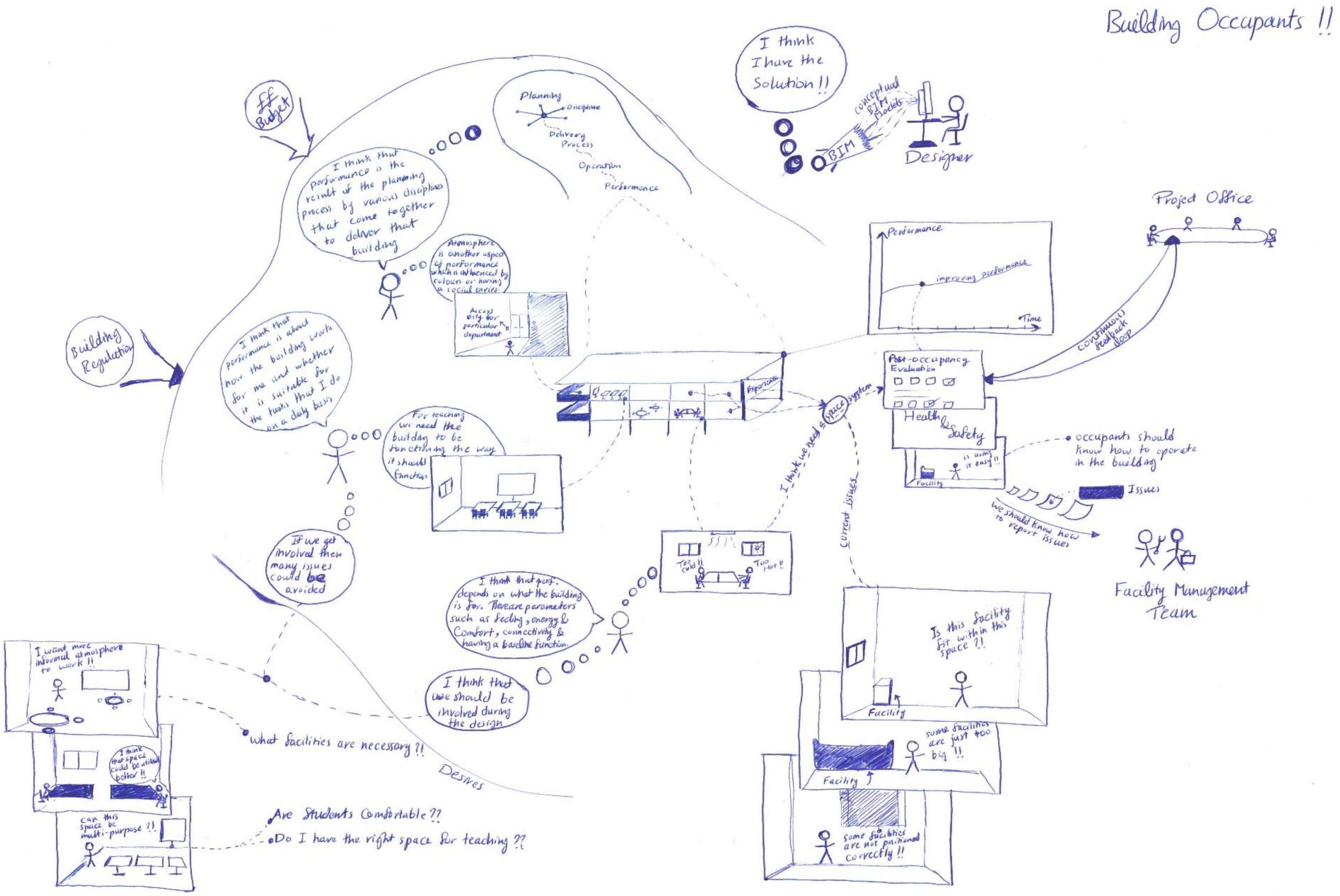

Figure 5.5: A Rich Picture representing the Building Occupants views on building performance in the Educational Building 1 case study.

Respectively, each of the Figures 5.3, 5.4 and 5.5 show the rich pictures of building performance based on the views of building delivery team, facility management team and building occupants from the Educational Building 1 case study. It can be claimed that each rich picture represents a 'purpose', which identifies the worldview of a stakeholder. For example, choosing design specifications that support long-term maintenance (see Figure 5.3). Figure 5.3 represents the rich picture of the building delivery team's views on building performance. It shows that to them, performance is about the delivery of a sustainable building that fits its purpose. Providing the building specifications is essential not only to achieve energy efficient building, but also for long-term maintenance and to satisfy user needs. Figure 5.4 represents the rich picture of the facility management team's views on building performance. It shows that performance from their perspective concerns satisfying both the functional requirements of the building and the occupants' needs. The rich picture also shows that providing information that supports managing the building's systems and spaces is vital in order to ensure that the building satisfies its functional requirements and occupants' needs. Figure 5.5 represents the rich picture of the building occupants' views on building performance. It shows that for these people performance is about having a suitable environment or space that supports their daily tasks. The rich picture shows that participation of the building occupants in the design of space can support the delivery of an environment or space that supports their daily tasks.

5.2.3. CATWOE Analysis and Root Definitions

Beyond the use of 'rich pictures', forming CATWOE analysis and root definitions is the second step in Soft Systems Management (SSM). CATWOE analysis is one of the modelling tools in SSM and it is used to represent different worldviews on building performance by deriving root definitions based on those involved in this case study. The previous section showed three worldviews on building performance. In this section, CATWOE will be used to represent these worldviews in a more simplified way. CATWOE is a useful tool for distilling complex situations to provide descriptions of the problem being investigated. It also supports recognising the necessary transformations required to satisfy different worldviews. *Transformation* is the required process needed to capture a particular perspective. CATWOE analysis also highlights those actors that are involved in the delivery of each of the transformations, and the beneficiaries of each of them.

Table 5.1: CATWOE analysis based on the three stakeholder parties Involved in Educational Building 1 Case Study with respect to their worldviews on building performance.

CATWOE	**Building Delivery Team's Worldview on Building Performance**	**Facility Management Team's Worldview on Building Performance**	**Building Occupants' Worldview on Building Performance**
Weltanschauung	A sustainable building that operates efficiently to satisfy its functional purpose.	A building's functional requirements are in working order and satisfy its occupants' needs.	A suitable space/environment to support their daily tasks effectively.
Transformation	To provide building specifications that support long-term maintenance and satisfy user needs.	To provide building information that supports managing building's systems and spaces.	To provide a means for the potential occupants to participate in the design of space.
Customer	The Client, Facility management team, Building occupants.	Facility management team, Building Occupants.	Building occupants, Client, Facility management team, Building designer.
Actors	Building designer, Project office.	Building Designer, Project office.	Project office.
Environment	Building regulations, Client's brief.	Available tool in BIM, Client's brief	Building regulations, Limited budget, Time, Available tools in BIM.
Owners	Building designer.	Project office.	Project office.

Table 5.1 shows the CATWOE analysis for the different worldviews on building performance. It is important to indicate that both the facility management team and building occupants have not been involved as part of the building delivery process. The transformations required for their worldviews show that communication is a vital element where the project office plays an important role as one of the actors. In this case study, 'project office' refers to the client's team who ensure communicating client's needs and involved in the delivery process. As part of SSM, it is important to establish a root definition for each of the worldviews. Each of the root definitions is represented as a system where each system shows a stakeholder's worldview on building performance. In representing worldviews as systems, another complexity with relation to the parts and the whole will be overcome. This is because the outlined systems represent parts, and achieve a building that satisfies the three stakeholders as a whole.

Table 5.2: Root definition derived from the CATWOE analysis based on worldviews on Building Performance from the Three Parties Involved in the Educational Building 1 Case Study.

Root Definition Based on The Building Delivery Team's Worldview on Building Performance	**Root Definition Based on The Facility Management Team's Worldview on Building Performance**	**Root Definition based on the Building Occupants' Worldview on Building Performance**
A system owned by the building designer, operated by the building designer and project office, to provide building specifications that support long-term maintenance and satisfy user needs, which will benefit the client and the facility management team, in order to deliver a sustainable building that operates efficiently to satisfy its functional purpose, within the constraints of the building regulations and client's brief.	A system owned by the project office, operated by the building designer and project office, to provide building information on building's systems and spaces, which will benefit the facility management team and building occupants, in order to ensure that a building's functional requirements are in working order and satisfy its occupants' needs, within the constraints of the available tool in BIM.	A system owned by the project office, operated by the project office, to provide a means for potential occupants to participate in the design of space, which will benefit the building occupants, client and the facility management team, and building designer in order to meet the needs for suitable space/environment to support doing the daily tasks effectively, within the constraints of the building regulations, limited budget and time, and the available tools in BIM.

Table 5.2 shows the root definitions of the different worldviews on building performance where each root definition is defined as a system. It is anticipated that satisfying each of these systems will result in achieving building performance that satisfies the three parties involved in this case study. To satisfy each of these systems, it is important to satisfy the 'Transformation' process, which was outlined in Table 5.1. Each transformation will require a number of activities that are needed to satisfy the system it belongs to. The proposed activities will be presented as a conceptual model, the next step in soft systems analysis.

5.2.4. Conceptual Models and Consensus Model

The next step will be forming conceptual models, which represent the activities needed to satisfy different systems that represent different worldviews. The aim of a conceptual model is to represent the transformation process required for a system by outlining the required activities and their sequence. Each activity within the conceptual model includes at least one input and at least one output. The input can either be information (e.g. client brief) or an activity (e.g. assess sustainability and maintainability of the design). The performance of a conceptual model is measured through its efficiency, effectiveness and efficacy. These measures indicate that a conceptual model is purposive in nature because the activities are controlled by external measures.

Referring to Table 5.1, the transformation processes are: to provide building *specifications* that support long-term maintenance and satisfy user needs, to provide building *information* that supports managing building's systems and spaces, and to provide a means for the potential occupants to *participate in the design of space*. For each of the conceptual models, the text in red in the Figures represents the input to the process whereas green text represents the output. The conceptual models for each the three transformation processes are respectively shown in Figures 5.6, 5.7 and 5.8.

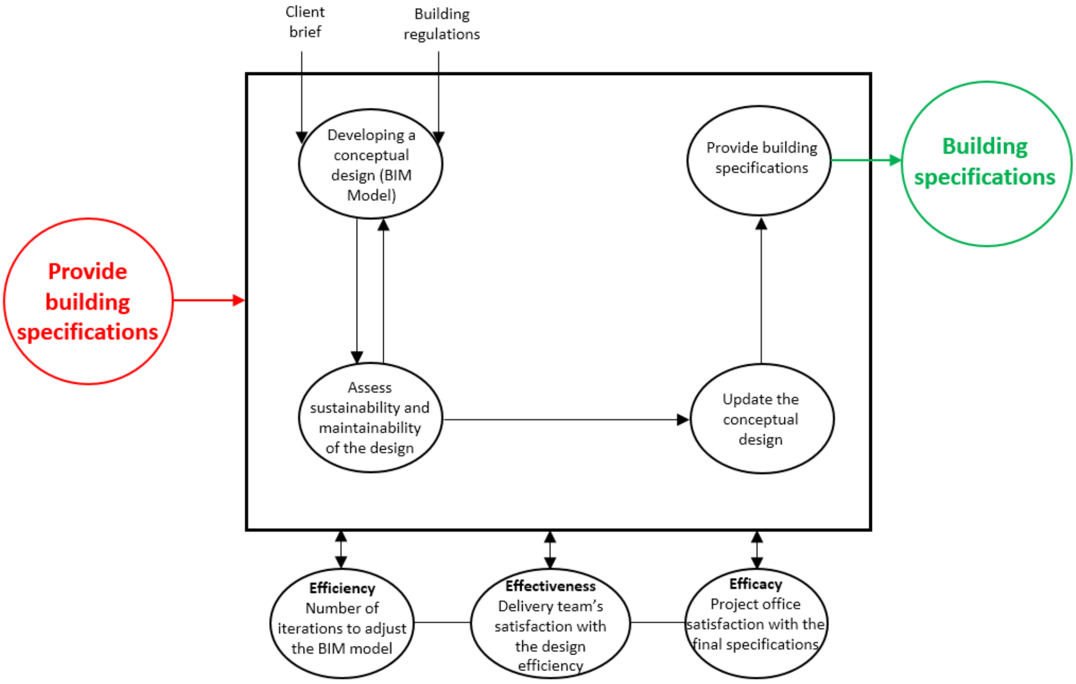

Figure 5.6: Conceptual model to provide building specifications based on the building delivery team's worldview of building performance.

The above conceptual model (Figure 5.6) shows the activities that are required to satisfy the building delivery team's worldview of building performance. It is important to indicate that achieving building performance is currently driven by the building delivery team. The activities outlined in the conceptual model are those that have been applied when considering performance of the Educational Building 1. The above conceptual model represents the current activities used to achieve building performance. For each conceptual model, the activities were proposed on the basis of both the worldview and the feedback obtained from the interviews. The activities highlighted in yellow in the conceptual models (Figures 5.7 and 5.8) are those that have already been outlined and/or carried out by other stakeholders. For instance, the activity 'update the conceptual model' is carried out by both the building designer and the project office.

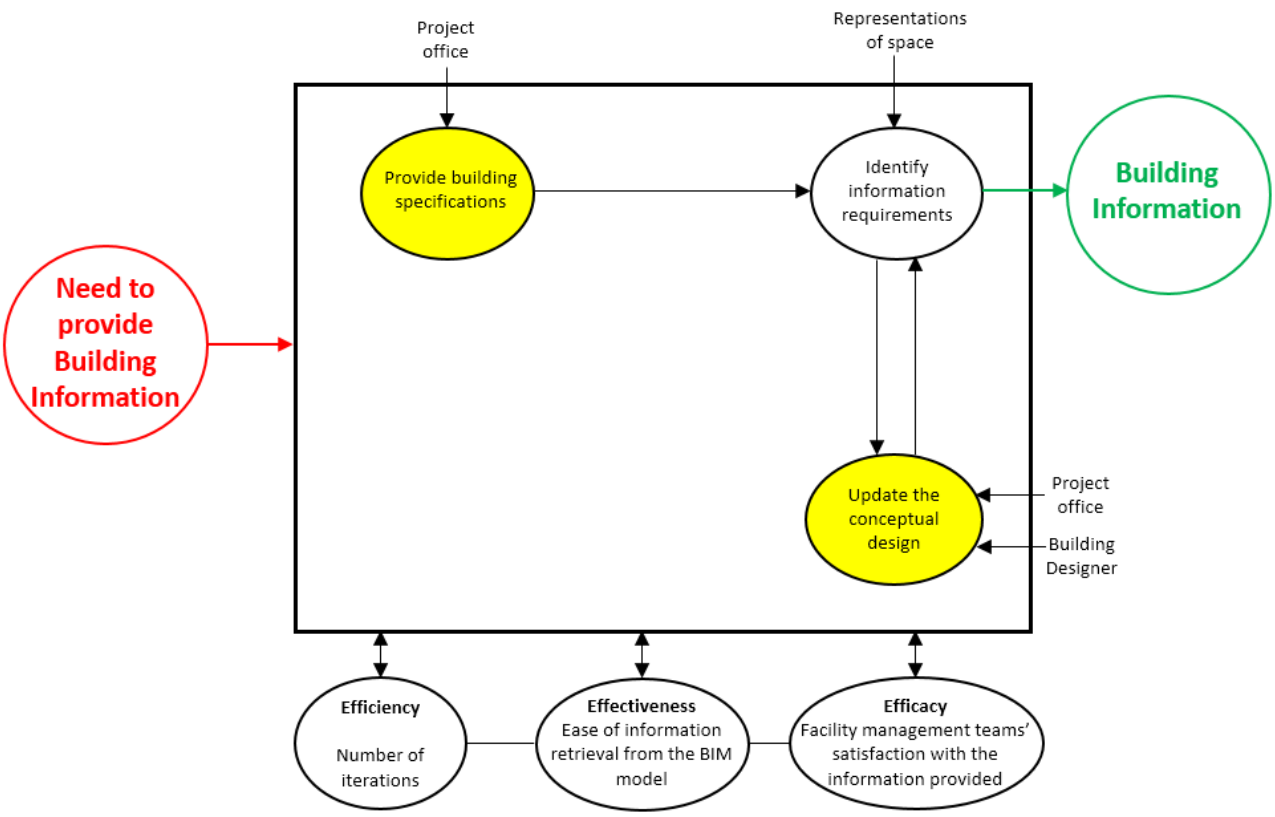

Figure 5.7: Conceptual model to provide building information based on the facility management team's worldview of building performance.

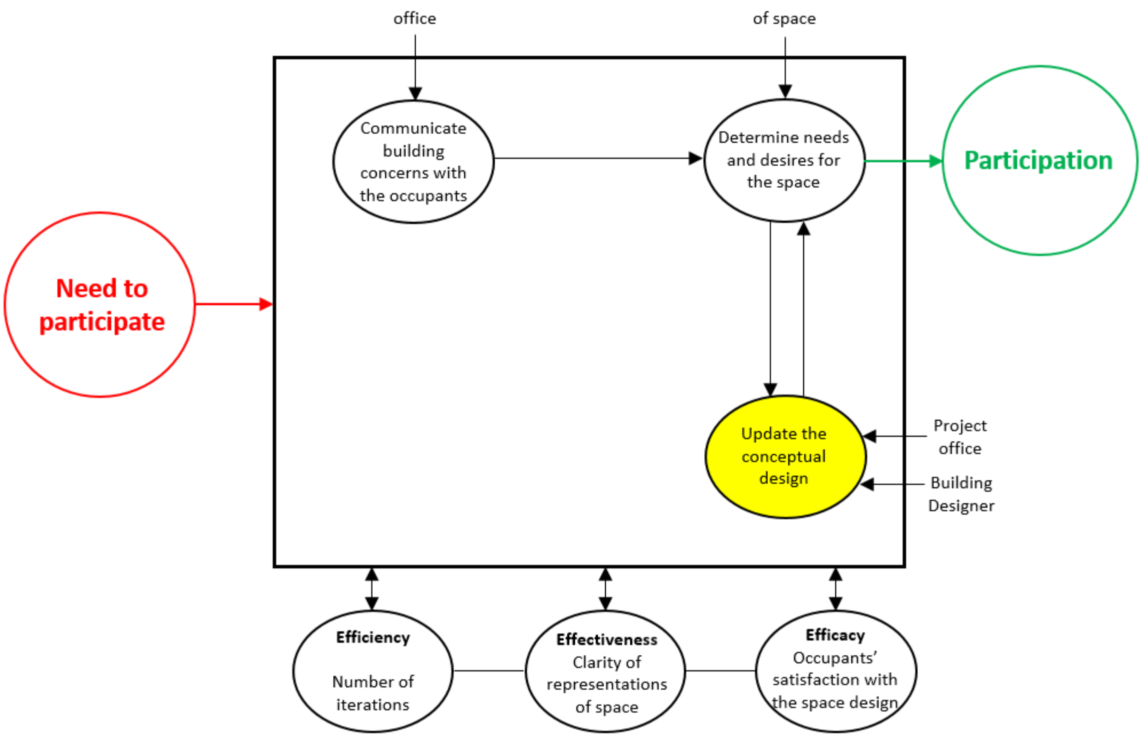

Figure 5.8: Conceptual model to provide means for participation based on the building occupants' worldview of building performance.

Although the proposed activities for each of the conceptual models may lack rigour or consistency, they acknowledge the shortcomings and issues that result from different worldviews on building performance. Following on from the conceptual models, a consensus model was formed (Figure 5.9) to combine all the activities presented in the conceptual models. The aim of the consensus model is to represent a new proposed system that combines the three worldviews on building performance.

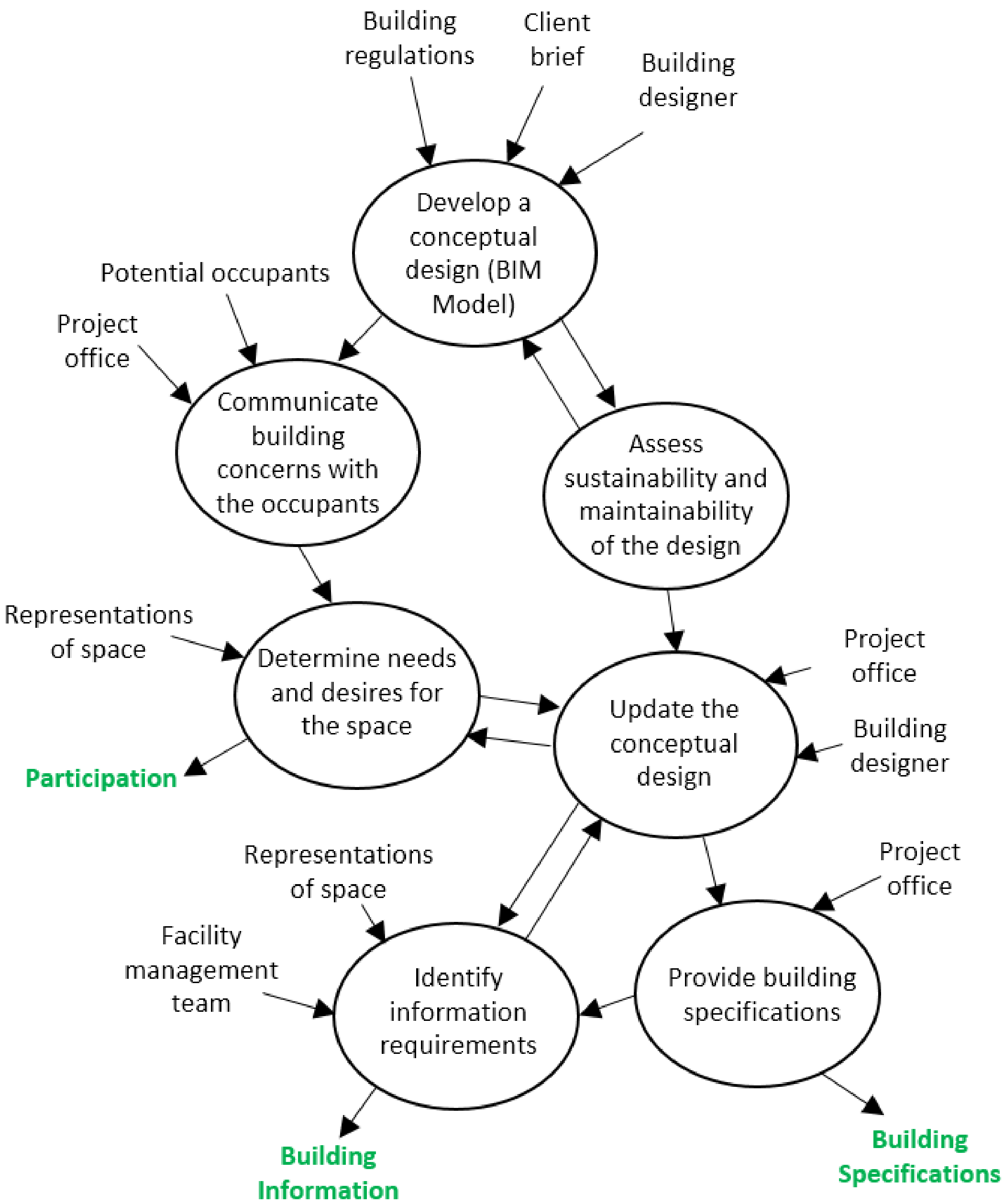

Figure 5.9: The consensus model combining the three conceptual models in the Educational Building 1 case study.

5.2.5. Activities and Information Categories

Following on from the consensus model, the information categories required for each of the activities presented in it are considered. It is important to highlight that each activity requires at least one input and one output, as all the activities represent the processes that form the new system required to satisfy the different worldviews on building performance. The inputs and outputs for each activity are outlined in Table 5.3. The identified inputs and outputs form the information categories (Table 5.4), which then will be used to form the Maltese Cross (Wilson, 1990) that represents both the current and new systems for building performance.

Table 5.3: Activities from the consensus model and their inputs and outputs in the Educational Building 1 case study.

	Activities from Consensus Model			
Role of Information	Develop conceptual design (BIM Model)	Assess sustainability and maintainability of the design	Update the conceptual design	Communicating building concerns with the occupants
Input to the activity	Client's brief Building regulations	Building specifications	Project office Building designer Facilities required (fixtures, furniture and equipment) Building specifications Occupants' needs and desires Facility management team's requirements	Project office Potential occupants Feedback reports
Output from the activity	Representations of space (2D plans, 3D models, rendered images) Building specifications (building systems, design specifications, materials)	Energy performance Operational considerations Maintenance considerations	Representations of space Space requirements (user requirements, health and safety, facilities)	Space concerns (usability, facilities provided, layout)
Measure the performance of the activity	Satisfying client's requirements	BREEAM Excellence Number of iterations	Number of iterations	Communication tools

	Activities from Consensus Model		
Role of Information	Determine needs and desires for the space	Provide building specifications	Identify information requirements
Input to the activity	Space concerns Representations of space	Project office Space requirements Facilities required	Facility management team Representations of space Operational considerations Maintenance considerations Building specifications
Output from the activity	Occupants' needs and desires	Building specifications (building systems, design specifications, materials, space requirements) Representations of space	Building information (space information 'occupancy, functionality, facilities', operational information 'building systems' and maintenance information 'building finishes, building systems specifications') Facility management team's requirements
Measure the performance of the activity	Clarity of representations of space Number of iterations	Communication tools	Clarity of representations of space Number of iterations

Table 5.4: Information categories and their descriptions representing the inputs and outputs of activities in the Educational Building 1 case study.

Information Category	**Description**
Client's brief	Design specifications, User requirements
Building regulations	e.g. CDM (Construction, Design and Management) Regulations
Representations of space	2D plans and3D models, rendered images
Energy performance	e.g. Energy Performance Certificate
Operational considerations	Building systems' mechanism and efficiency
Maintenance considerations	Durability of building assets
Facilities required	Fixtures, Furniture and Equipment ('FFE')
Space requirements	User requirements, Health and Safety, Facilities
Feedback reports	e.g. Previous post-occupancy evaluations
Space concerns	Usability, facilities provided, Layout
Occupants' needs and concerns	Space concerns
Building specifications	Building systems, design specifications, materials, space requirements
Building information	Space information 'occupancy, functionality, facilities', operational information 'building systems' and maintenance information 'building finishes, building systems specifications'
Facility management team's requirements	Building information

Table 5.4 shows both the information categories and their descriptions, derived from both the inputs and outputs for the activities outlined in Table 5.3. Identifying the information categories can be claimed as a step that supports understanding the information requirements needed to achieve performance that satisfies different worldviews. This is because information categories are used to compare the new system with the current system for building performance, which will be shown in the next step using Maltese Cross (Wilson, 1990).

5.2.6. Maltese Cross

The aim of Maltese Cross (Wilson, 1990) is to identify information requirements through comparing both the current and new systems for building performance. The Maltese Cross (Figure 5.8) consists of three main parts; the top part (the new system) represents the activities that are needed to form the new system, which is derived from the consensus conceptual model. The bottom part (the current system) represents the activities that are currently used, which are based on the building delivery team's worldview (Figure 5.6). The middle part represents the information categories (Table 5.4). The left side represents information categories where placing (X) indicates the input to each activity and placing (X) on the right side indicates the output information category resulted from the activity.

New System for Building Performance

Facility management team's requirements	Building information	Building specifications	Occupants' needs and concerns	Space concerns	Feedback reports	Space requirements	Facilities required	Maintenance considerations	Operational considerations	Energy performance	Representations of space	Building regulations	Client's brief	Activity	Client's brief	Building regulations	Representations of space	Energy performance	Operational considerations	Maintenance considerations	Facilities required	Space requirements	Feedback reports	Space concerns	Occupants' needs and concerns	Building specifications	Building information	Facility management team's requirements
												X	X	Develop a conceptual design (BIM Model)				X								X		
		X												Assess sustainability and maintainability of the design				X	X	X								
X		X	X				X							Update the conceptual design			X					X						
					X									Communicate building concerns with the occupants										X				
				X										Determine needs and desires for the space											X			
						X	X							Provide building specifications			X									X		
		X						X	X		X			Identify Information requirements													X	

Current System for Building Performance

Facility management team's requirements	Building information	Building specifications	Occupants' needs and concerns	Space concerns	Feedback reports	Space requirements	Facilities required	Maintenance considerations	Operational considerations	Energy performance	Representations of space	Building regulations	Client's brief	Activity	Client's brief	Building regulations	Representations of space	Energy performance	Operational considerations	Maintenance considerations	Facilities required	Space requirements	Feedback reports	Space concerns	Occupants' needs and concerns	Building specifications	Building information	Facility management team's requirements
												X	X	Develop a conceptual design (BIM Model)				X								X		
		X												Assess sustainability of the design				X	X	X								
		X					X							Update the conceptual design			X					X						
						X	X							Provide building specifications			X									X		

Figure 5.10: A 'Maltese Cross' using activities from the consensus model and information categories for the Educational Building 1 case study.

Figure 5.10 shows the Maltese Cross, which represents both the current (bottom part) and new (top part) systems for building performance. The Maltese Cross supports the recognition of information requirements and the activities required to obtain the information. The current system for building performance is based on the building delivery team's worldview whereas the new system for building performance is based on worldviews of the building delivery team, facility management team and building occupants. By looking at the current (bottom part) system for building performance, it is realised that some information is not taken into consideration such as 'facility management team's requirements' and 'occupants' needs and concerns'. However, some information such as 'operational considerations' and 'maintenance considerations' are produced only when assessing the sustainability and maintainability of the design. However, for the new system, both 'operational considerations' and 'maintenance considerations' are considered to further identify information requirements that are needed to manage the building. Therefore, it is realised that the Maltese Cross is beneficial in recognising the information requirements as well as the activities needed to obtain that information, which can support understanding part of the gap between data and experience. This is because these activities can be considered as the required parts to achieve the building performance (as a whole). However, the information requirements show that further inquiry into experiences is needed, hence the next case study (the Office Building) looks into different experiences and how they influence building performance.

5.2.7. Conclusion for Educational Building 1 soft systems analysis

To sum up, the Educational Building 1 soft systems analysis emphasises the different views that the different people carrying out different roles have of buildings and building performance. Soft systems analysis commenced with developing the 'rich picture' for each of the three types of stakeholder. CATWOE analysis and root definitions identified the transformation process for each of the worldviews. A conceptual model was developed for each of the transformation processes, which were then combined to form a consensus model that represents activities for the three worldviews on building performance. Both inputs and outputs were identified for each of the activities in the consensus model, which then used information categories to form a Maltese Cross (Wilson, 1990), to identify information requirements. The Maltese Cross method supported the identification of additional activities (parts), which can be used to bridge the gap between data and experience. However, the activities that further inquiry into experiences is needed to identify information requirements, which can support bridging the data-experience gap.

5.3. Office Building Soft systems analysis

5.3.1. Introduction

The aim of this case study was to inquire into the performance of space from three targeted groups of stakeholders. It was found that inquiring into different experiences of using space encapsulates different factors influencing performance. Therefore, the soft systems analysis for the Office Building case study aims to address different information requirements that are needed to overcome the divergent views on the performance of space. Figure 4.2 (see section 4.3.5.3 in chapter four) is used to construct rich pictures for the three stakeholders involved.

5.3.2. Rich pictures

Similar to the previous case study, three rich pictures are presented where each refers to the view of a particular stakeholder. The case study showed that 'space' is viewed differently by the client, facility manager and building occupants where feedback showed that different experiences have influenced these views. Hence, rich pictures are separated to represent the different views on space in Figures 5.11, 5.12 and 5.13.

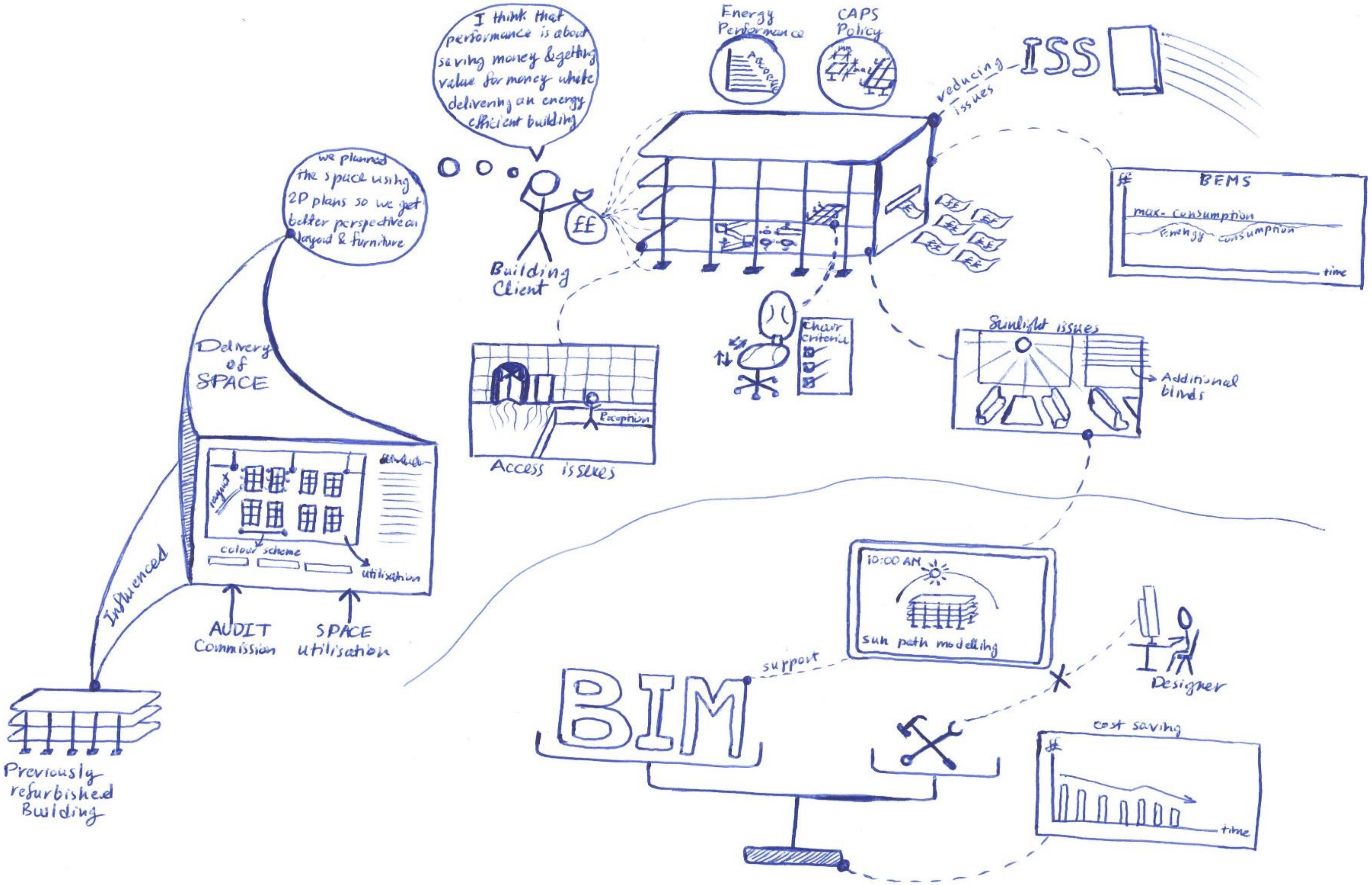

Figure 5.11: A Rich Picture representing the Building Client's view on space in the Office Building case study.

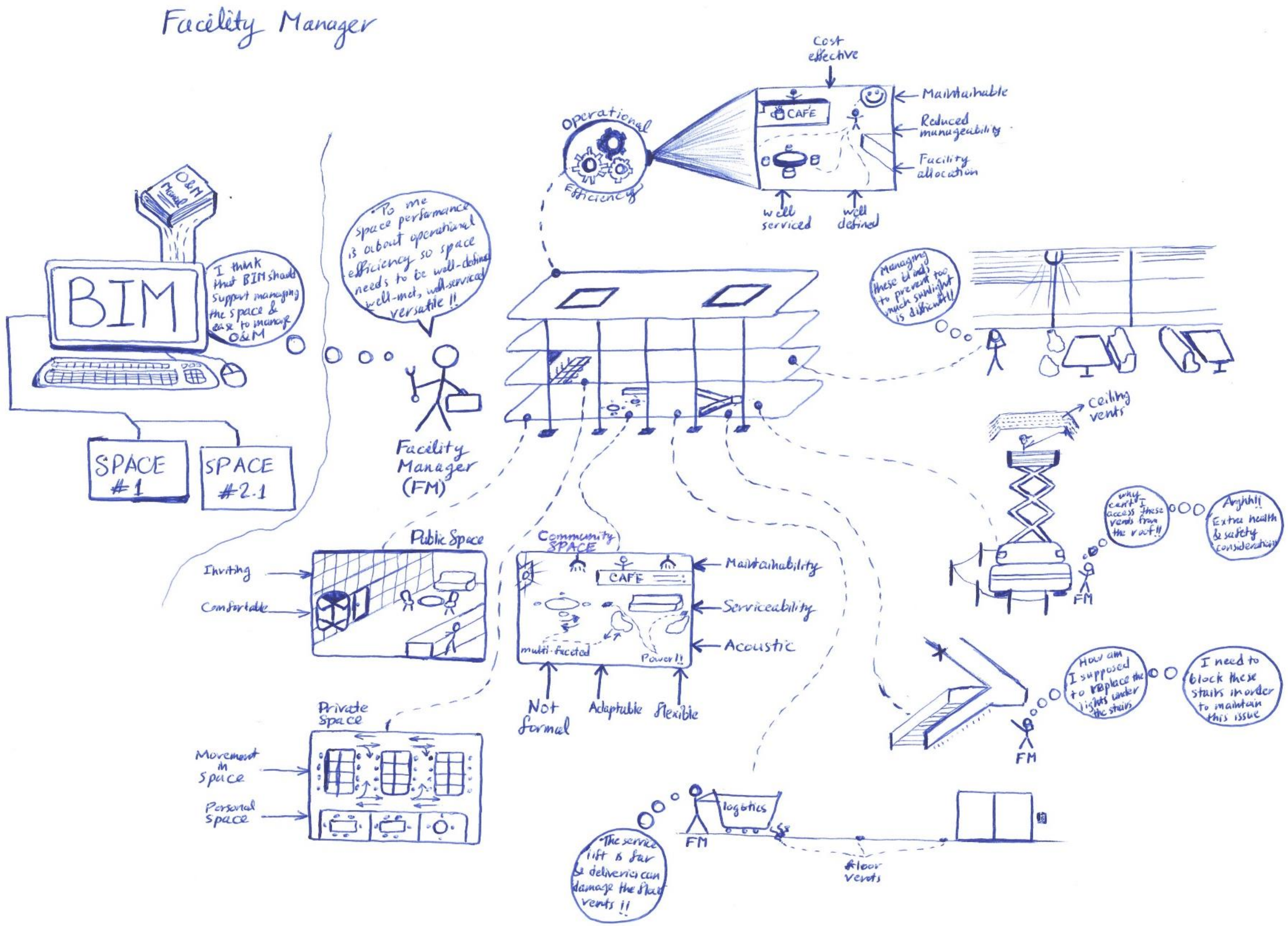

Figure 5.12: A Rich Picture representing the Facility Manager’s view on space in the Office Building case study.

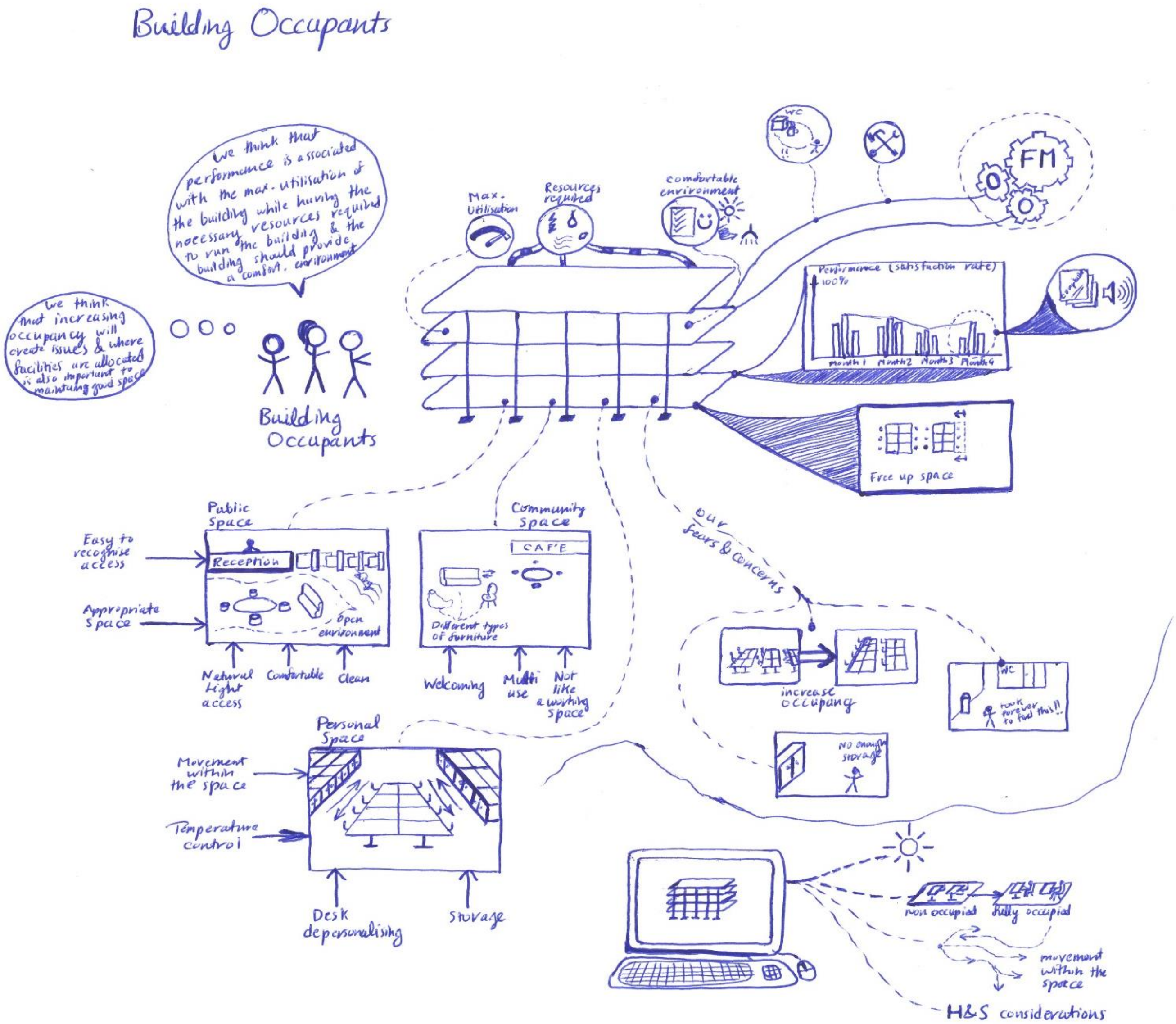

Figure 5.13: A Rich Picture representing the Building Occupants' views on space in the Office Building case study.

Each of the Figures 5.11, 5.12 and 5.13 shows the rich pictures on space based on the three stakeholder perspectives on the Office Building, representing their worldviews. These worldviews can be summarised as below:

Figure 5.11 shows that the building client's view about chiefly concerns ensuring maximum utilisation. This view can perhaps be derived from the rich picture (Figure 5.9), as the client's view on building performance concerns value for money. In achieving maximum utilisation of space, the rich picture shows that it is important to consider the functional requirements, and hence, using appropriate standards along with other aspects (e.g. furniture) that satisfy occupants' needs. Figure 5.12 represents the rich picture of the facility manager's view on space. It shows that space is about ensuring the sufficient versatility required to service different aspects of a space. This can be realised using the rich picture (Figure 5.10) where the facility manager used two different types of spaces (e.g. public and community spaces) to demonstrate different versatility characteristics. To achieve sufficient versatility for space, space information should be provided to manage its serviceability requirements. Figure 5.13 represents the rich picture of the building occupants' views on space. It shows that space is about having a comfortable environment that supports their needs, which influence their experience of the space. For example, looking at the rich picture (Figure 5.11), some of these experiential concerns can be seen (e.g. storage areas in the private spaces).

5.3.3. CATWOE Analysis and Root Definitions

Similar to the Educational Building 1 case study, CATWOE analysis for the Office Building case study recognises the necessary transformations required to satisfy the different worldviews on space. Both the facility manager and building occupants were not involved in the design of space for the Office Building. This is because its design was influenced by a building that was recently refurbished. However, based on the worldviews of both the facility manager and building occupants on space, their involvement in the design of space is vital, because they perceive it differently, and this has influenced their understanding of its performance. Table 5.5 represents the three worldviews on space based on the client, facility manager and building occupants.

Table 5.5: CATWOE analysis based on the three stakeholder parties involved in the Office Building case study with respect to their worldviews on space.

CATWOE	**Building Client's Worldview of Space**	**Facility Manager's Worldview of Space**	**Building Occupants' Worldview of Space**
Weltanschauung	A suitable area that is arranged in a way to ensure its maximum utilisation.	An area that is sufficiently versatile to support its serviceability aspects.	A comfortable environment that is designed to support building occupants' needs.
Transformation	To provide requirements, which can be used to support the functionality of a space.	To provide information on the space, which supports managing its serviceability requirements.	To account usability and desirable concerns that influence occupants' experience at different spaces.
Customer	The client, Building occupants.	Facility manager, building occupants, the client.	Building occupants, facility manager, The client.
Actors	Building Designer, Client.	Building designer, facility manager.	Building Designer, building occupants.
Environment	Building regulations, client's brief, available budget.	Client's brief, available budget, available space information.	Available representations of space, available budget, client's brief, available tools to communicate with the occupants.
Owners	Building Designer.	Facility manager, building designer.	Building Designer, client.

Table 5.5 shows the CATWOE analysis for the different worldviews on space. The views of both the facility manager and building occupants show that their involvement in the design of

space can support overcoming some of their experiential problems they face within the building. The transformation processes for the worldviews of both the facility manager and building occupants clarify part of the complexity with relation to the parts and the whole. This is because it represents the experiential problems that these stakeholders face, which has an impact on the performance of space. It can be argued that selecting 'space' as a reference for performance can simplify understanding the gap between parts and whole. This is because it reduces the complexity of levels (see Figure 5.2) caused by both reductionist and holistic views, and supports situating different meanings by different stakeholders. The next step is to establish a root definition for each of the worldviews, which are shown in Table 5.6.

Table 5.6: Root definitions derived from the CATWOE analysis based on worldviews on space from the three stakeholder parties involved in the Office Building case study.

Root Definition Based on the Building Client's World View	**Root Definition Based on the Facility Manager's World View**	**Root Definition Based on the Building Occupants World View**
A system owned by the building designer, operated by the building designer and the client, to satisfy requirements that can be used to support the functionality of a space, which will benefit the client and building occupants, in order to meet the requirements of a suitable area that is arranged in a way to ensure its maximum utilisation, within the constraints of the building regulations, client's brief and available budget.	A system owned by the facility manager and building designer, operated by the building designer and the facility manager, to provide information on aspects of space, which support managing its serviceability requirements, which will benefit the facility manager, building occupants and client in order to deliver an area that is sufficiently versatile to support its serviceability aspects, within the constraints of the client's brief, available budget and available space information.	A system owned by the building designer and client, operated by the building designer and building occupants, to account usability and desirable concerns that influence occupants' experience at different spaces, which will benefit the building occupants, facility manager and client in order to meet the requirements of a comfortable environment that is designed to support building occupants' needs, within the constraints of the available representations of space, client's brief and available budget and available tools to communicate with the occupants.

Table 5.6 shows the root definitions of the different worldviews on space where each root definition is defined as a system. Each of these systems represents a stakeholder's view of space based on different experiences. Understanding how to satisfy these experiences can potentially support different parts that influence performance of space. The following section studies the activities required to satisfy each of these systems.

5.3.4. Conceptual Models and Consensus Model

Similar to the previous case study, and referring to Table 5.5, three conceptual models are formed where in each the aim is to represent the *transformation* process. The transformation processes are: to provide requirements, which can be used to support the functionality of a space, to provide information on the space, which supports managing its serviceability requirements, and to account usability and desirable concerns that influence occupants' experience at different spaces. The conceptual models for each the three transformation processes are shown in Figures 5.14, 5.15 and 5.16.

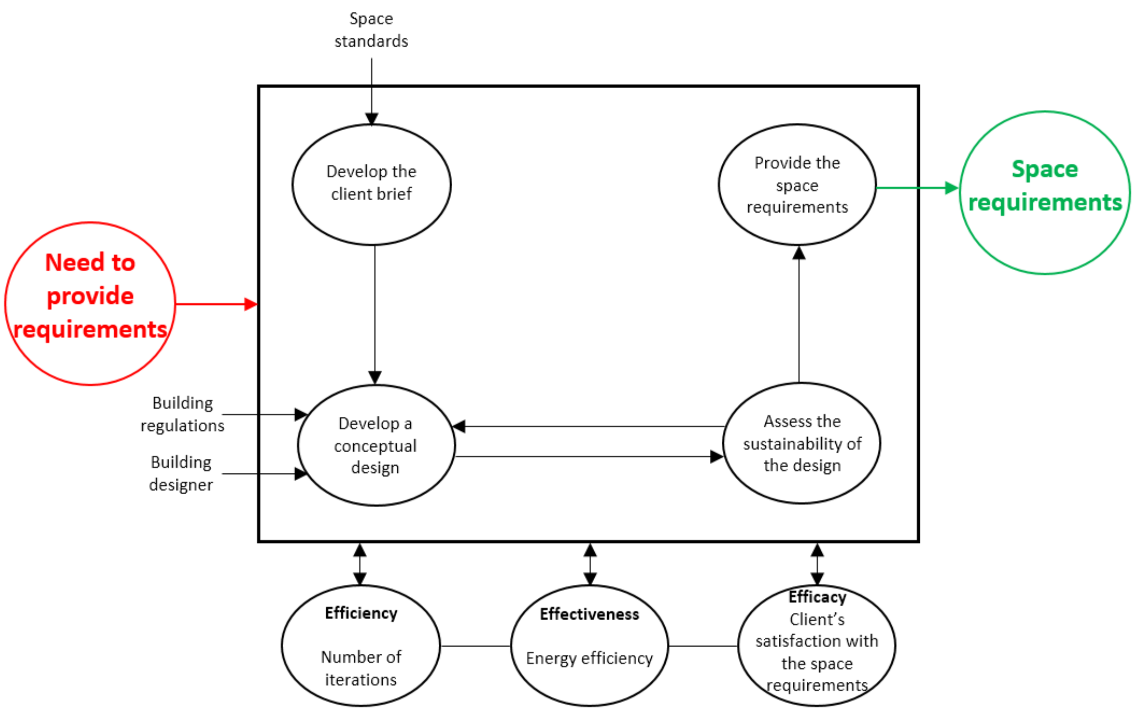

Figure 5.14: Conceptual model based on the building client's worldview of space in the Office Building case study.

The above conceptual model (Figure 5.14) shows the activities that represent the client's worldview of space. It shows that space requirements are driven by standards that are used to form the design/construction brief. Although the activity 'assess the sustainability of the design' may not directly affect space requirements, it may impose a change on the design, which can affect how space was initially planned or how its requirements were defined.

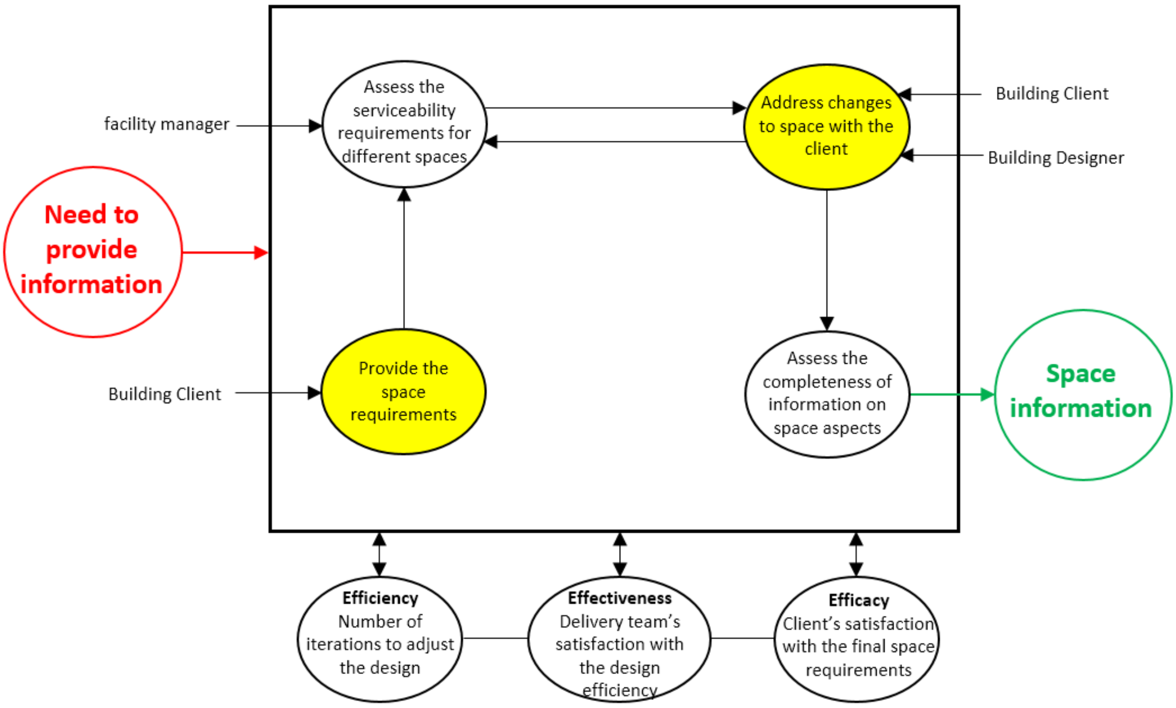

Figure 5.15: Conceptual model based on the facility manager's worldview of space in the Building Office case study.

Figure 5.15 shows the conceptual model that represents the facility manager's worldview on space. The proposed activities show that the facility manager's involvement at an early stage is vital so that the serviceability requirements for space can be assessed. Assessing serviceability for space considers how versatile it is so that it is operational, and maintenance requirements can be fulfilled.

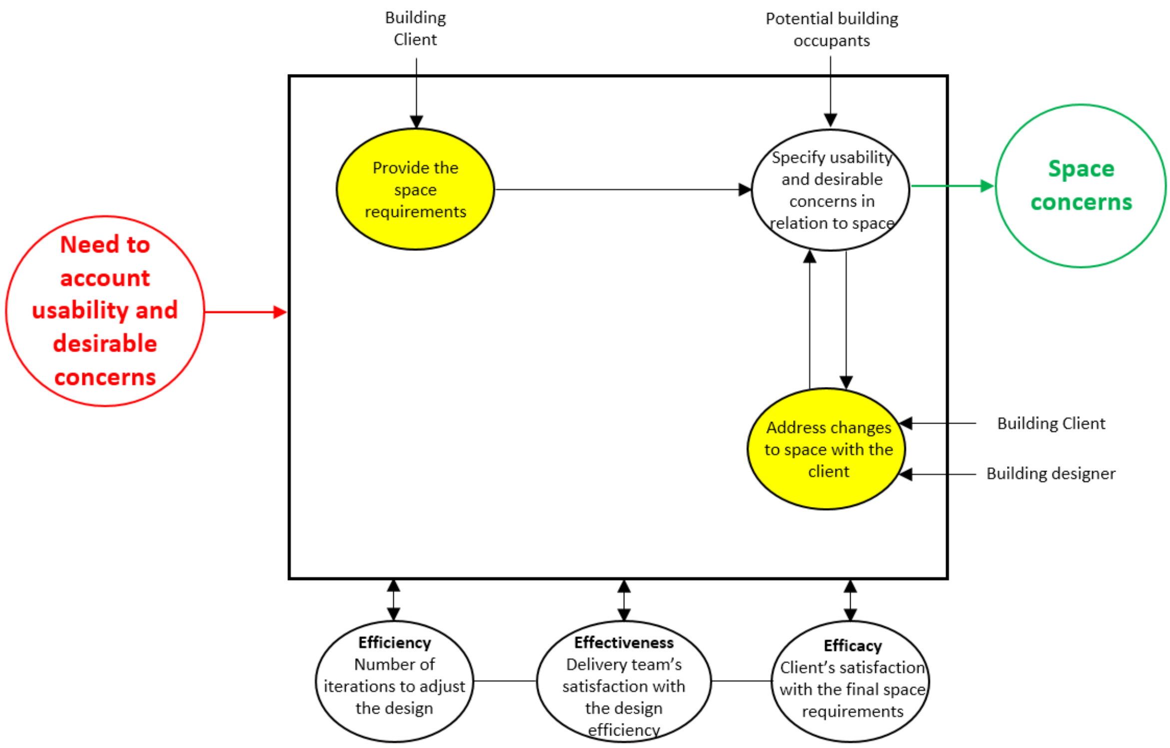

Figure 5.16: Conceptual model to account for usability and desirability based on the building occupants' worldview of space in the Building Office case study.

Similar to the Educational Building 1 case study, activities (Figure 5.16) that represent the building occupants' worldview of space show that specifying their usability and desirability concerns *before* finalising the design is important to avoid issues that may arise when space is occupied. It is important to indicate that both the input provided by both the facility manager and building occupants have to be assessed by the client. This is because their inputs may influence the sustainability of the design or impose additional costs, hence the activity 'address changes to space with the client' is proposed.

A consensus model is then formed (Figure 5.17) to combine all the activities presented in the three conceptual models. In the consensus model, both consistency and setting priorities are vital to ensure satisfying worldviews of space. However, use of the consensus in this case study considers different worldviews in order to achieve an understanding of the performance of space, so that different experiences can be notified when designing the space.

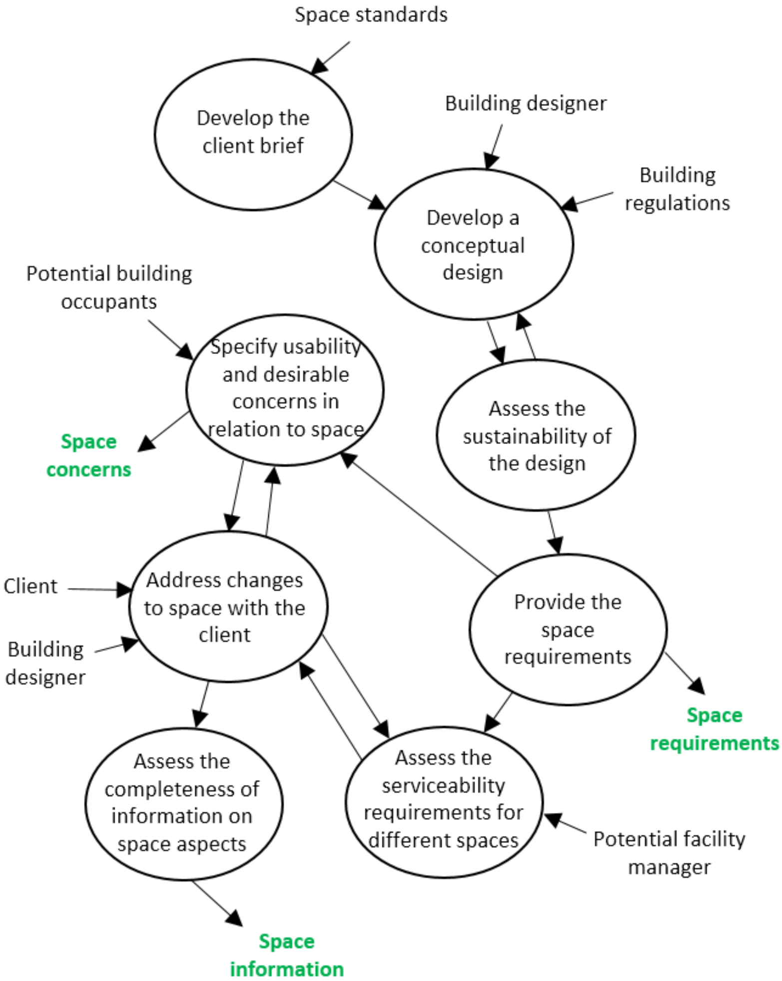

Figure 5.17: The consensus model combining the three conceptual models in the Office Building case study.

5.3.5. Activities and Information Categories

Similar to the Educational Building 1 case study, the consensus model is used to look at the information categories required for each of the activities. The inputs and outputs for each activity are outlined in Table 5.7. Additional (new) activities (e.g. assess serviceability requirements for different spaces) in this case study support further understanding of the parts needed to satisfy the whole (performance of space). Although some of the information categories outlined in this case study may be similar to those outlined in the previous case study, they provide additional corroboration, which can be used to bridge the gap between data and experience.

Table 5.7: Activities from the consensus model and their information categories.

	Activities from Consensus Model			
Role of Information	**Develop the client's brief**	**Develop a conceptual design**	**Assess the sustainability of the design**	**Provide the space requirements**
Input to the Activity	Space standards (e.g. CIBSE) User requirements (aesthetic considerations 'colour scheme', comfort criteria 'lighting, temperature, acoustics, configuration'). Design specifications (Space requirements 'space types, space size, and facilities').	Client's brief Building regulations	Building specifications Representations of space	Facilities required (fixtures, furniture and equipment) Representations of space
Output from the Activity	Client's brief (Design specifications, user requirements)	Representations of space (2D and/or 3D representations, other representations 'physical representation') Building specifications (building systems, design specifications, materials)	Energy performance External issues (sunlight access, draught access)	Space requirements (user requirements, health and safety, facilities, occupancy, functionality) Representations of space
Measure the Performance of the Activity.	Space utilisation User requirements	Overall cost Satisfying client's requirements	BREEAM Excellence Number of iterations	Space utilisation
	Activities from Consensus Model			
Role of Information	**Specify usability and desirable concerns in relation to space**	**Assess the serviceability requirements for different spaces**	**Address changes to space with the client**	**Assess the completeness of information on space aspects**
Input to the Activity	Feedback reports Potential building occupants Space requirements	Space requirements Potential facility manager	Operational concerns Maintenance concerns Usability concerns Desirable concerns Building designer	Representations of space.
Output from the Activity	Usability concerns (temperature control, facilities available 'location, movement, type') Desirable concerns (storage, personal space, privacy, atmosphere, finishes).	Operational concerns (systems' control, users' behaviour, available facilities 'hard facilities, soft facilities, logistic management). Maintenance concerns (location of facilities, movable/fixed hard facilities, soft facilities 'cleaning accesses, hard/soft walls, hard/soft flooring', and hard facilities information).	Representations of space	Space information (occupancy, functionality, facilities, operational and maintenance information)
Measure the Performance of the Activity.	Accountancy of possible concerns Communication tools	Accountancy of possible concerns Communication tools	Number of iterations	Information available

Table 5.8: Information categories derived from activities from the consensus model in the Office Building case study.

Information Category	Description
Space standards	CIBSE (Chartered Institution of Building Services Engineers) (e.g. office standards for space)
Design specifications	Space requirements 'space types, space size, and facilities'
User requirements	Aesthetic considerations 'colour scheme', comfort criteria 'lighting, temperature, acoustics, configuration'
Client's brief	Design specifications, User requirements
Building regulations	e.g. CDM (Construction, Design and Management) Regulations
Representations of space	2D plans & 3D models, Rendered images
Building specifications	Building systems, Design specifications, Materials, Space specifications
Energy performance	e.g. Energy Performance Certificate
External issues	Sunlight access, draught access
Facilities required	Fixtures, Furniture and Equipment (FFE)
Space requirements	User requirements, Health and Safety, Facilities, Occupancy, Functionality
Feedback reports	e.g. Previous post-occupancy evaluations
Usability concerns	Temperature control, Facilities available 'location, movement, type'
Desirable concerns	Storage, Personal space, Privacy, Atmosphere, Finishes
Operational concerns	Systems' control, Users' behaviour, Available facilities 'hard facilities, soft facilities, Logistic management
Maintenance concerns	Location of facilities, movable/fixed hard facilities, Soft facilities 'cleaning accesses, hard/soft walls, hard/soft flooring', and Hard facilities information
Space information	Occupancy, Functionality, Facilities, Operational information, Maintenance information

Table 5.8 shows the information categories derived from both the inputs and outputs for the activities outlined in Table 5.7. Some information categories have a further description when

compared to the previous case study. These further descriptions support providing further clarity on the parts that influence the performance of space. In this next case study, the influence of representations of space in terms of identifying further parts is considered. The identified information categories will be used to construct a ‘Maltese Cross’ (Wilson, 1990).

5.3.6. Maltese Cross

Similar to the previous case study, the Maltese Cross (Wilson, 1990) tool in this Office Building case study seeks to identify information that engenders understanding of what influences the performance of space. The top part of the cross shows the new system proposed to deliver space, which is represented by the activities shown on the consensus model (Figure 5.17). The bottom part shows the current system used to deliver space, which is based on the building client’s view (Figure 5.14).

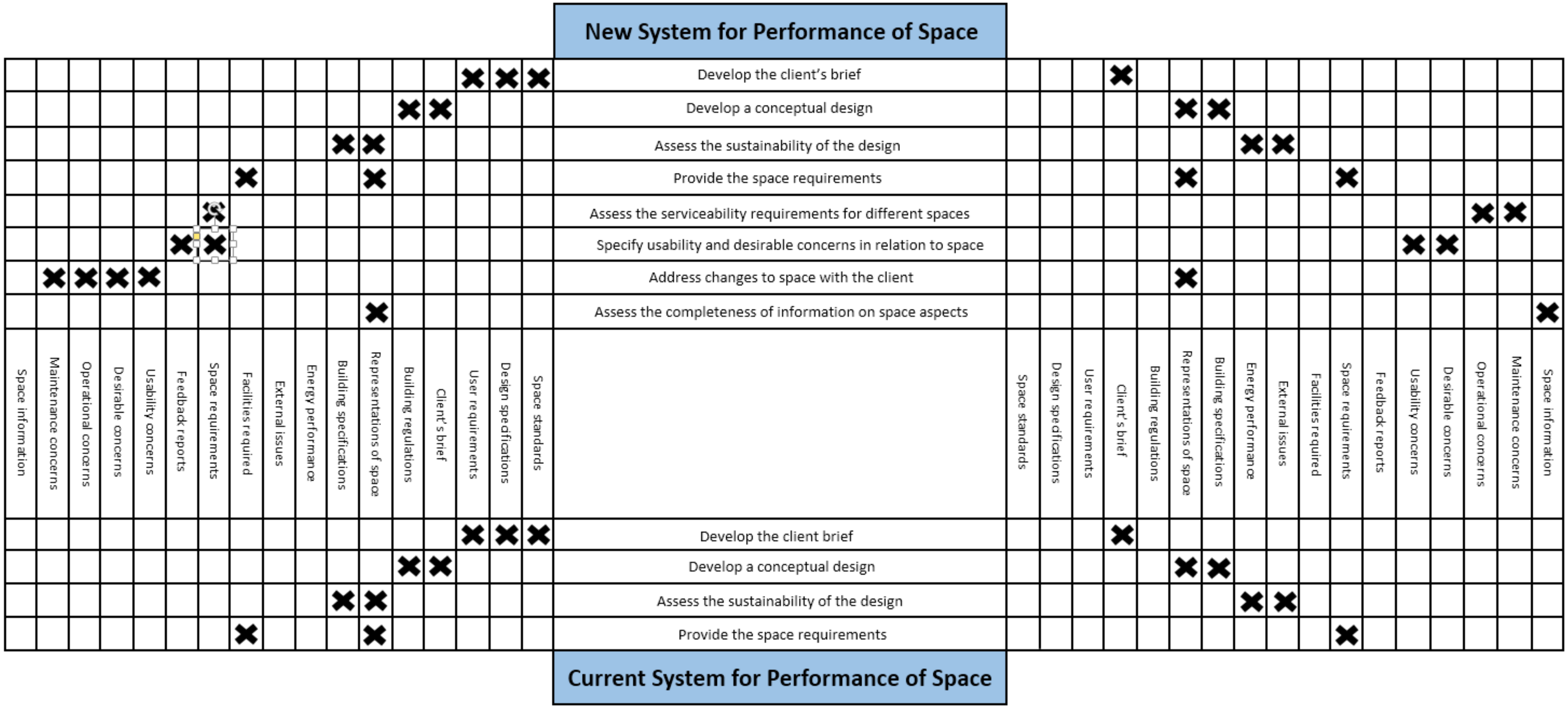

Figure 5.18: A 'Maltese Cross' using activities from the consensus model and information categories in the Building Office case study.

It is realised that the current system (Figure 5.16) to achieve the performance of space includes similar activities to those mentioned in the system mentioned to achieve building performance (see Figure 5.8) in the previous chapter. However, the slight difference is in the detailing of ‘assess the sustainability of the design’, because the client’s concern (‘parts’) was based on the energy performance and external issues on the building. External issues were acknowledged, as the client highlighted that such issues have imposed additional requirements for space (e.g. blinds to control the sunlight levels). The new system (Figure 5.17 and bottom part of the Maltese Cross ‘Figure 5.18’) to achieve the performance of space shows that using it as a reference for building performance reveals many concerns that influence other stakeholders’ experiences. These concerns were shown as operational, maintenance usability, and desirability concerns, which were derived according to the view of the facility manager and building occupants. Although some of these concerns may have been addressed by the client and the designer, the feedback gathered shows that there are many concerns that require the involvement of both the facility manager and building occupants. The new system also shows that ‘representations of space’ forms a vital input for most of the activities. The Maltese Cross shows many parts that can be used to understand what influences the performance of space. The next case study examines the use of representations of space in revealing further parts that can support bridging the gap between data and experience.

5.3.7. Conclusion for Office Building soft systems analysis

The aim of soft systems analysis in the Office Building case study was to address different information requirements that need to be embraced when considering the divergent views on the performance of space, derived from different experiences. Soft systems analysis showed that using space as a reference for performance supports further understanding of the parts and the whole. This is because it simplifies the levels of complexity between the reductionist and holistic views. The conceptual models reveal further information that which supports situating meanings about the parts that influence experiences (as a whole) in space. This became apparent using the Maltese Cross (Wilson, 1990) approach that compared current and new activities to achieve performance of space. The analysis also provides further information requirements that can be used to support bridging the gap between data and experience. The next case study (the Educational Building 2) further looks into the performance of space, taking into consideration the views of stakeholders on representations of space.

5.4. Educational Building 2 soft systems analysis

5.4.1. Introduction

The aim of this case study was to further inquire into the performance of space from three targeted stakeholders. The study shows that representations of space need to be information-rich to capture different experiences of a space. Soft systems analysis in the previous case study (the Office Building) also showed that representations of space can potentially support exploring many concerns that influence the performance of space. Therefore, the soft systems analysis for the Educational Building 2 case study aims to further look into information requirements, to take into consideration the different experiences of representations of space. Figure 4.3 (see section 4.4.5.5 in chapter four) will be used to construct the divergent views in this case study.

5.4.2. Rich pictures

Similar to the previous case study, the rich pictures in this case study represent the views of the building designer, facility management team and building occupants. However, they further show different experiences of space representations, which was not part of the previous case study. The reason to separate the rich pictures here is to demonstrate the significance of both the views on space and the role of space representations for different stakeholders. Rich pictures are shown in Figures 5.19, 5.20 and 5.21.

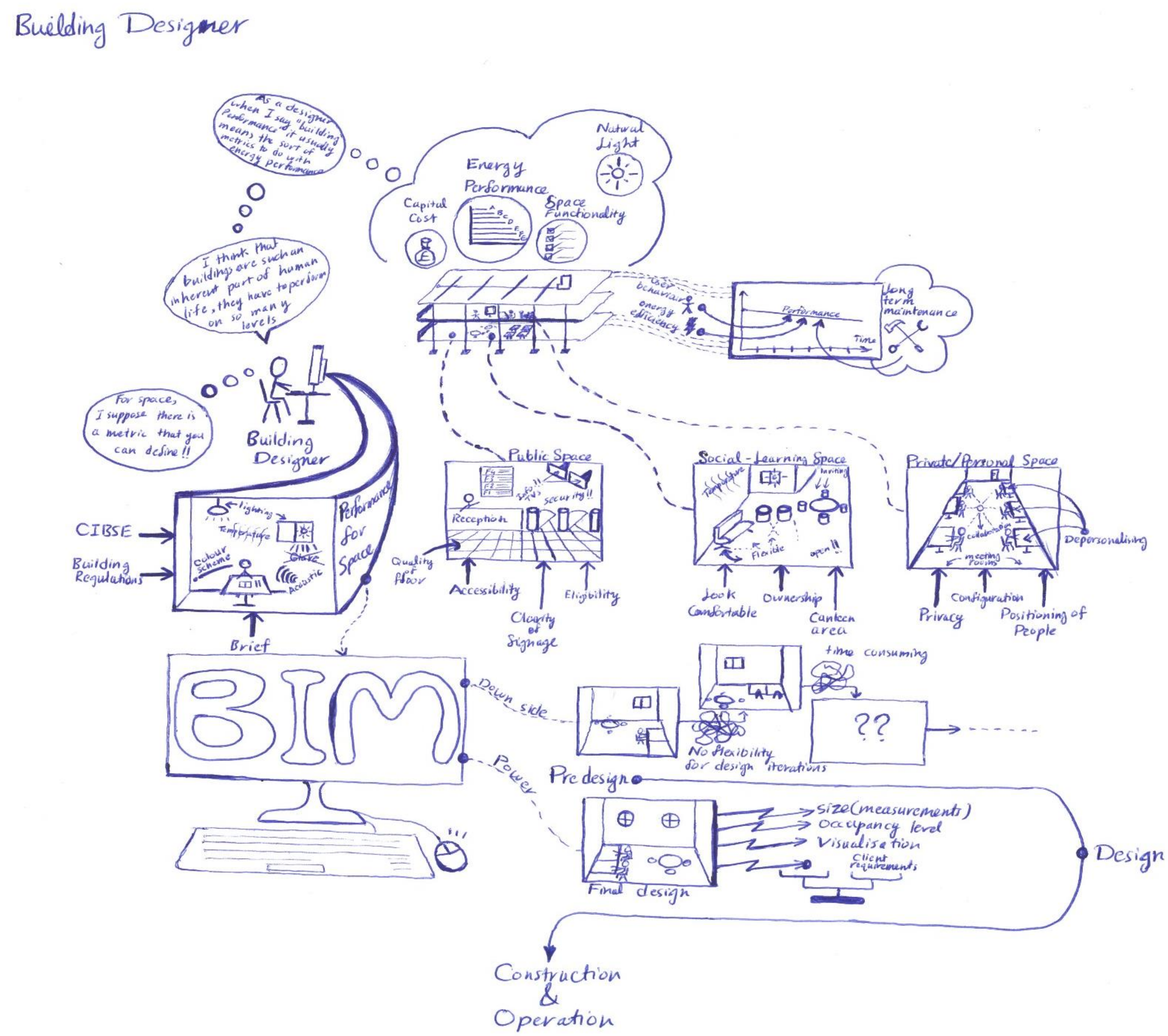

Figure 5.19: A Rich Picture representing the Building Designer view on space for the Educational Building 2.

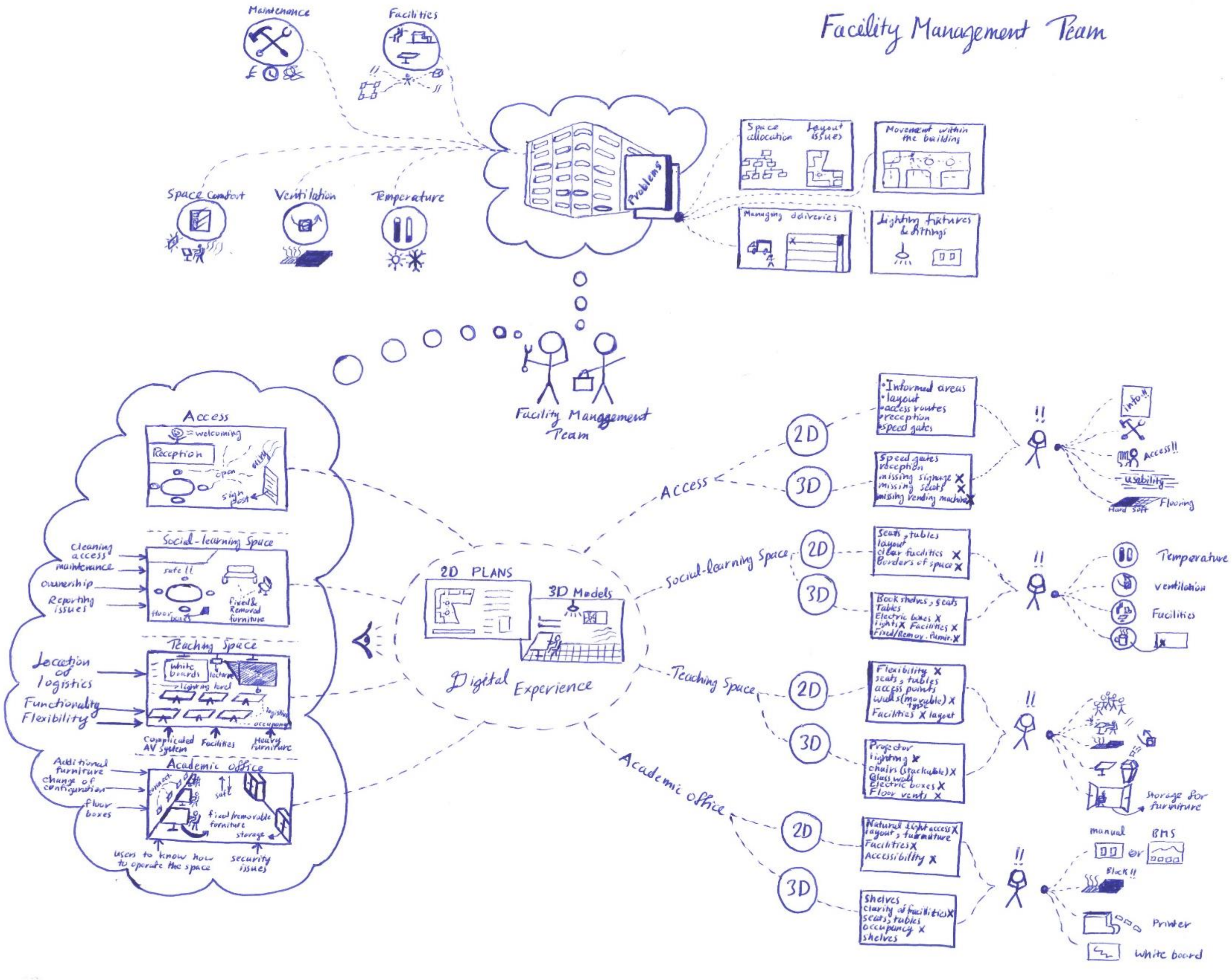

Figure 5.20: A Rich Picture representing the Facility Management Team’s views on space in the Educational Building 2.

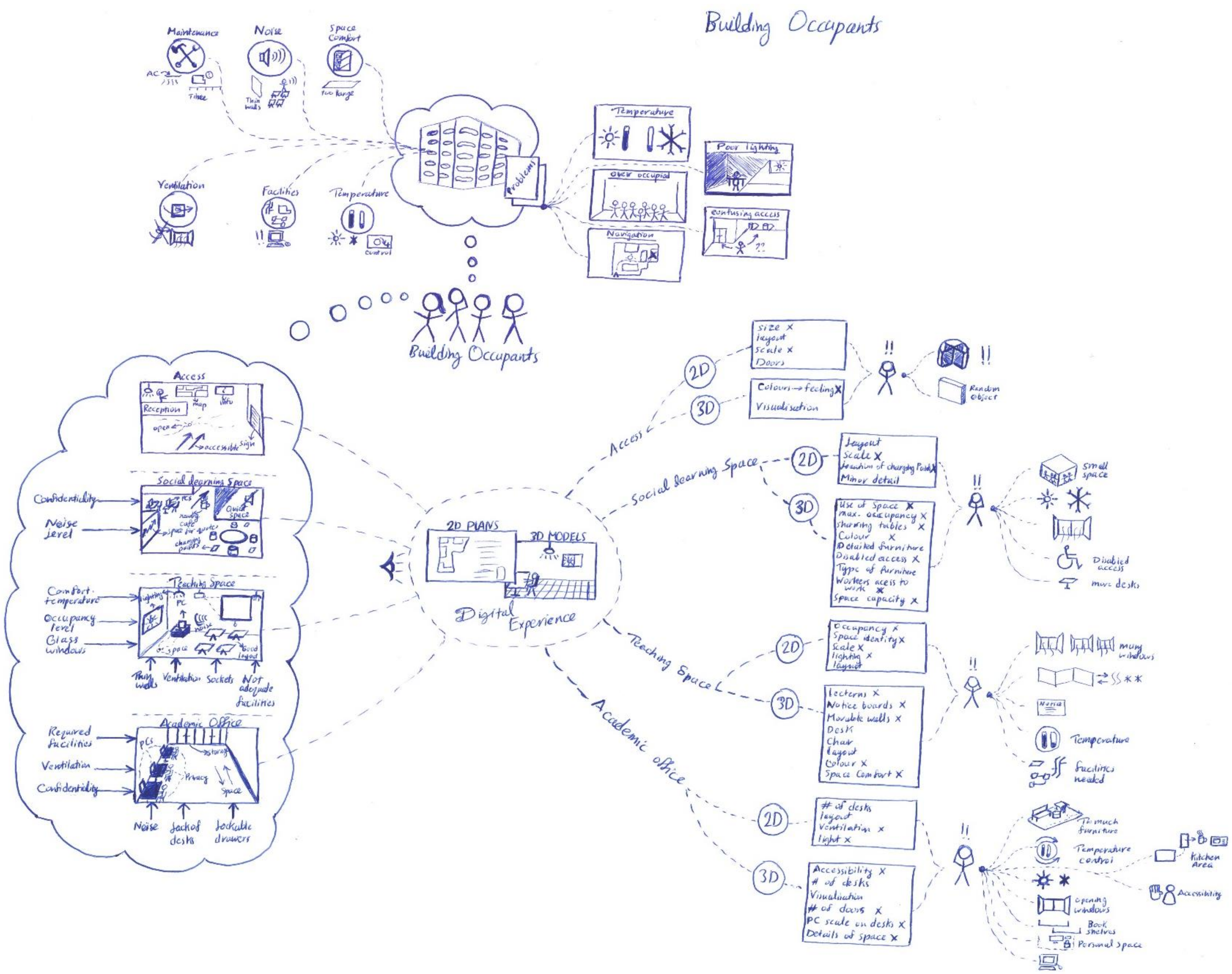

Figure 5.21: A Rich Picture representing the Building Occupants' views on space in the Educational Building 2.

Respectively, each of the Figures 5.19, 5.20 and 5.21 shows the rich pictures of space and space-representations based on the views of building designer, facility management team and building occupants on Educational Building 2. Figure 5.19 shows that space, in this perception, is about ensuring that there is a functional area that can be used by occupants of the building. 'Functional' from the designer's view is about satisfying different aspects such as lighting, temperature, acoustics and colour scheme. This also incorporates both the client's needs and appropriate building regulations. In achieving functionality for space, the building designer's view showed that it is important to identify different characteristics of space in order to satisfy its purpose.

Figure 5.20 (facility management team) shows that space is about having a baseline functionality so it can be managed effectively. An example of baseline functionality can be derived by looking at the left side (inside the cloud shaped border) of the rich picture that shows different requirements needed for different spaces. The right side (feedback on 2D and 3D representations) of the rich picture shows the influence of information derived from the representations. Thus, in achieving a baseline functionality, it is important to provide space information that supports managing its functional requirements.

Figure 5.21 represents the rich picture of the building occupants' views on the space and their experiences of space representations. It shows that space is about having a place designed to function in a way that serves their needs. In this context, the function of a space refers to what space offers, ranging from facilities, social values (privacy, confidentiality, etc.), and other characteristics such as those mentioned by the designer in order to support their activities within a space. Some of their needs can be seen by looking at the right side on the rich picture based on the information they captured and concerns they raised from 2D and 3D representations of difference spaces. Thus, in addressing their needs, it is important to specify their needs and desires, which can support their experiences within different spaces.

5.4.3. CATWOE Analysis and Root Definitions

CATWOE analysis (Table 5.9) for the Educational Building 2 case study recognises the necessary transformations required to satisfy the different worldviews on the building space. It is important to indicate that the facility management team were involved at later stages after the design of the building was finalised. Therefore, worldviews of the facility management team and building occupants were similar to those mentioned in the previous case study (the Office Building).

Table 5.9: CATWOE analysis based on the three stakeholder parties Involved in the Educational Building 2 case study with respect to their worldviews on space.

CATWOE	**Building Designer's Worldview of Space Performance**	**Facility Management Team's Worldview of Space Performance**	**Building Occupants' Worldview of Space Performance**
Weltanschauung	A suitable area that is designed to function in a way that serves the needs of those of who use it.	An area with defined baseline functionality that can be managed effectively to serve its functional purpose.	A place designed to function in a way that serves the building occupants.
Transformation	To achieve the characteristics that can be used as a baseline to satisfy the purpose of a particular space.	To provide space information that supports managing its functional requirements.	To specify usability and desirable concerns that support building occupants' experience for different spaces.
Customer	The client, Building occupants.	Facility management team, building occupants, the client.	Building occupants, facility management team.
Actors	Building Designer, Client, Client's representatives	Building designer, facility management team.	Building Designer, Client's representatives, building occupants.

Environment	Building regulations, client's brief, the capability of the design tools, available budget.	Available representations of space, client's brief, available budget.	Available representations of space, available budget, client's brief, available tools to communicate with the occupants.
Owners	Building Designer.	Facility management team, building designer, client's representatives.	Building Designer, client's representatives.

Table 5.9 shows the CATWOE analysis for the different worldviews on the space. Similar to the previous case study, the worldviews of both the facility management team and building occupants indicate that they wanted to be involved during the design process to satisfy their requirements. However, satisfying their requirements is influenced by the available representations of space and, for the occupants, the availability of tools for communication. Although such influences have been mentioned in the previous case study, the impact of these influences is more apparent here.

Table 5.10: Root definitions derived from the CATWOE analysis based on worldviews on space from the three stakeholder parties involved in the Educational Building 2 case study.

Root Definition Based on the Building Designer Worldview	Root Definition Based on the Facility Management Team Worldview	Root Definition Based on the Facility Management Team Worldview
A system owned by the building designer, operated by the building designer, client and client's representatives, to achieve the characteristics that can be used as a baseline to satisfy the purpose of a particular space, which will benefit the client and building occupants, in order to meet the requirements of a suitable area that is designed to function in a way that serves the needs of those who use it, within the constraints of the building regulations, client's brief, capability of the design tools and available budget.	A system owned by the facility management team, building designer and client's representatives, operated by the building designer and the facility management team, to provide space information that support managing its functional requirements, which will benefit the facility management team, building occupants and client in order to meet the requirements of an area with defined baseline functionality that can be managed effectively to serve its functional purpose, within the constraints of the available representations of space, client's brief and available budget.	A system owned by the building designer and client's representatives, operated by the building designer, client's representatives and building occupants, to specify usability and desirability concerns that support the building occupants' experience for different spaces, which will benefit the facility management team and building occupants in order to meet the requirements of the place, within the constraints of the available representations of space, client's brief and available budget and available tools to communicate with the occupants.

Table 5.10 shows the root definitions of the different worldviews on space where each root definition is defined as a system. The following section represents these systems as conceptual models. Similar to the previous case studies, each *transformation* within a system requires a number of activities that are needed to satisfy the system it belongs to.

5.4.4. Conceptual Models and Consensus Model

There are three conceptual models that will be formed in this section, which are going to be based on the three transformation processes. The transformation processes are: to embody certain characteristics, which can be used as a baseline to satisfy the purpose of a particular space, to provide space information that supports managing its functional requirements, and to specify needs and desires that support building occupants' experience for different spaces. The conceptual models for each the three transformation processes are shown in Figures 5.22, 5.23 and 5.24.

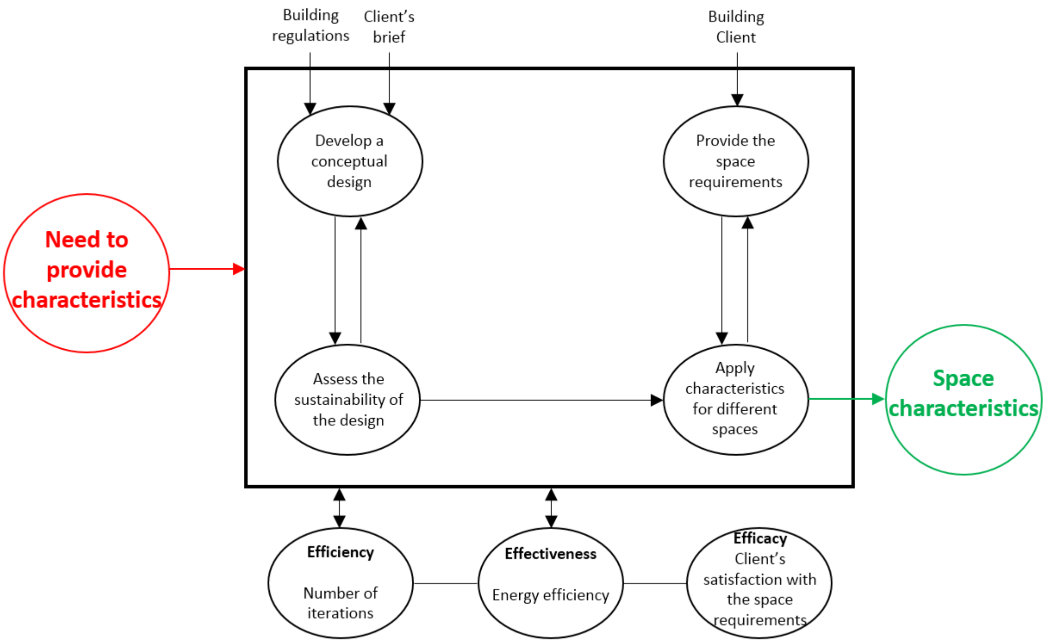

Figure 5.22: Conceptual model to provide space characteristics based on the building designer's worldview of space in the Educational Building 2 case study.

The above conceptual model (Figure 5.20) shows the activities that represent the building designer's worldview of space. The model is very similar to the one that represents the client's worldview of space in the previous case study, but it involves an extra activity that is 'apply characteristics for different spaces'. Although it is anticipated that some of these characteristics are applied when developing a conceptual design, adding the activity of applying characteristics includes additional user requirements (e.g. usability requirements and desirable requirements). These additional characteristics are then provided as space requirements, which need to be discussed and approved by the client.

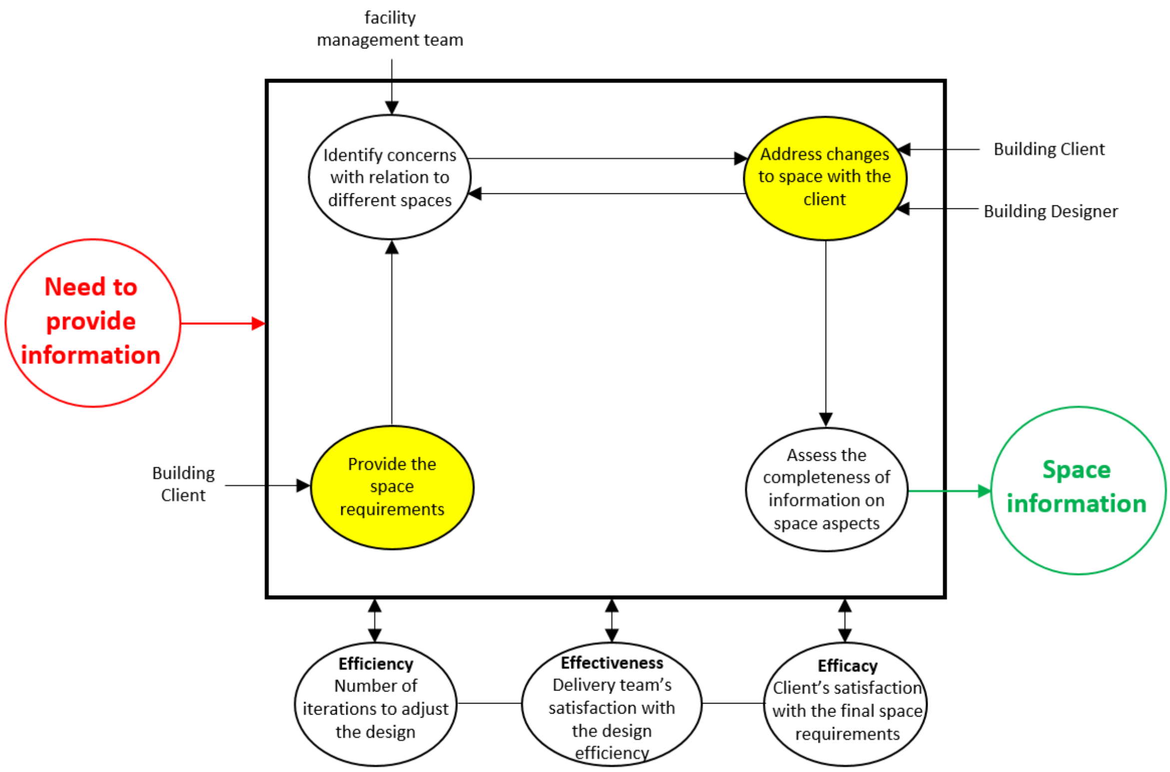

Figure 5.23: A conceptual model to provide information based on the facility management team's worldview of space in the Educational Building 2 case study.

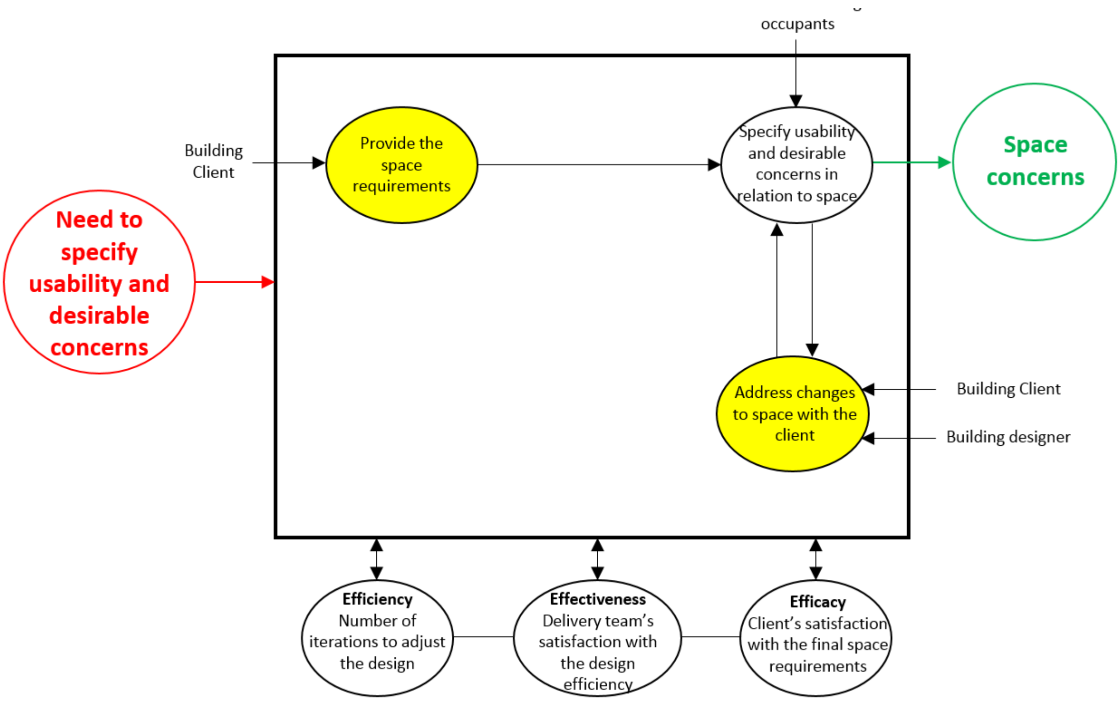

Figure 5.24: A conceptual model to specify usability and desirable concerns based on the building occupants' worldview of space in the Educational Building 2 case study.

Although the worldviews shown in Figures 5.23 and 5.24 are similar to those mentioned in the previous case study, they differ in some of the inputs, which is shown in Table 5.11. Similar to the previous case study, a consensus model was formed (Figure 5.25) to combine all the activities presented in the conceptual models.

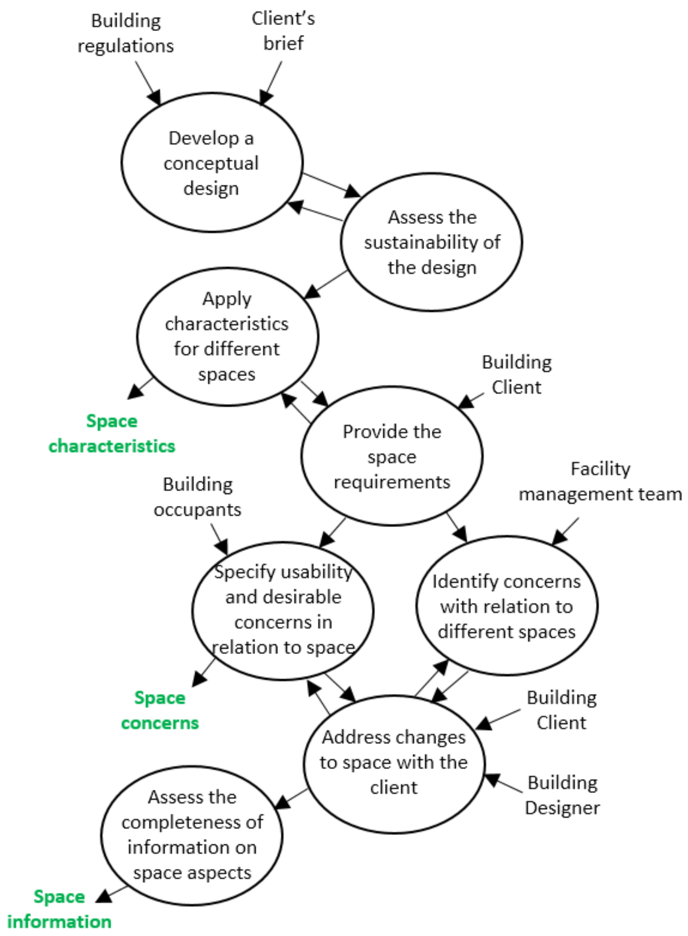

Figure 5.25: The consensus model combining the three conceptual models in the Educational Building 2 case study.

5.4.5. Activities and Information Categories

In this case study, the information categories (Table 5.11) are similar to those mentioned in the previous case study. However, some information categories have further descriptions. This is because this case study has considered the role of representations of space on views of space from different stakeholders. Also, due to the building designer's involvement in this case study, an additional activity is added, which implied adding new information categories.

Table 5.11: Activities from the consensus model and their information categories.

	Activities from Consensus Model			
Role of Information	**Develop a conceptual design**	**Assess the sustainability of the design**	**Apply characteristics for different spaces**	**Provide the space requirements**
Input to the Activity	Client's brief Building regulations	Building specifications Representations of space	Usability requirements (comfort criteria, accessibility, personal needs) Intangible requirements (atmosphere ,colour scheme, environment)	Facilities required (fixtures, furniture and equipment) Space characteristics Representations of space
Output from the Activity	Representations of space Building specifications	Energy performance	Space characteristics (usability and intangible requirements)	Space requirements (space characteristics, user requirements, health and safety, facilities, occupancy, functionality) Representations of space
Measure the Performance of the Activity	Overall cost Satisfying client's requirements	BREEAM Excellence Number of iterations	Number of iterations	Space utilisation
	Activities from Consensus Model			
Role of Information	**Specify usability and desirable concerns in relation to space**	**Identify concerns with relation to different spaces**	**Address changes to space with the client**	**Assess the completeness of information on space aspects**
Input to the Activity	Feedback reports Building occupants Space requirements Representations of space	Facility management team Space requirements Representations of space.	Usability concerns. Desirable concerns. Operational concerns. Maintenance concerns. Building designer.	Representations of space
Output from the Activity	Usability concerns (temperature control, facilities available 'location, movement, type, orientation', windows control, lighting '# of windows, glazed walls', facilities operating instruction, disabled access, connectivity 'charging points, Wi-Fi', configuration 'noise levels') Desirable concerns (storage, personal space, privacy, atmosphere, finishes, accessibility, confidentiality, occupancy level, health and safety, connectivity to other facilities 'toilets, kitchen, cafě).	Operational concerns (systems' control, users' behaviour, available facilities 'hard facilities "fixed/movable, inside/outside", soft facilities', logistic management 'storage', accessibility 'disabled access, eligibility', ventilation, lighting, layout). Maintenance concerns (location of facilities, movable/fixed hard facilities, soft facilities 'cleaning accesses, hard/soft walls, hard/soft flooring', hard facilities information 'maintenance procedures', location of windows 'cleaners' access', hard/soft walls, hard/soft flooring)	Representations of space	Space information (occupancy, functionality, facilities, operational and maintenance information)
Measure the Performance of the Activity	Accountancy of possible concerns Clarity of representations of space Communication tools	Accountancy of possible concerns Clarity of representations of space Communication tools	Number of iterations	Information available

Table 5.12: Information categories derived from activities from the consensus model.

Information Category	Description
Client's brief	Design specifications, User requirements
Building regulations	e.g. CDM Regulations
Representations of space	2D plans and 3D models, Rendered images
Building specifications	Building systems, Design specifications, Materials, Space specifications
Energy performance	e.g. Energy Performance Certificate
Usability requirements	Comfort criteria, Accessibility, Personal needs
Intangible requirements	Atmosphere ,Colour scheme, Environment
Space characteristics	Usability and Intangible requirements
Facilities required	Fixtures, Furniture and Equipment
Space requirements	User requirements, Health and Safety, Facilities, Occupancy, Functionality
Feedback reports	e.g. Previous post-occupancy evaluations
Usability concerns	Temperature control, Facilities available 'location, movement, type, orientation', Windows control, Lighting '# of windows, glazed walls', Facilities operating instruction, Disabled access, Connectivity 'charging points, Wi-Fi', Configuration 'noise levels''
Desirable concerns	Storage, Personal space, Privacy, Atmosphere, Finishes, Accessibility, Confidentiality, Occupancy level, Health and safety, Connectivity to other facilities such as toilets, kitchen, café
Operational concerns	Systems' control, Users' behaviour, Available facilities 'hard facilities, soft facilities, Logistic management 'storage', Accessibility 'disabled access, eligibility', Ventilation, Lighting, Layout
Maintenance concerns	Location of facilities, movable/fixed hard facilities, Soft facilities 'cleaning accesses, hard/soft walls, hard/soft flooring', and Hard facilities information 'maintenance procedures', Location of windows 'cleaners' access', Hard/soft walls, Hard/soft flooring
Space information	Occupancy, Functionality, Facilities, Operational information, Maintenance information

Table 5.12 shows many information categories that have been acknowledged in the previous case study such as usability, desirable-, operational- and maintenance-concerns, and further descriptions (information requirements). These further descriptions are useful in representing the significance of different parts for different stakeholders (e.g. location of facilities).

5.4.6. Maltese Cross

A Maltese Cross (Wilson, 1990) will show both the new and current systems to achieve the performance of space. The current system is the designer's worldview (Figure 5.22) whereas the new system is the consensus model (Figure 5.25) combining all the worldviews.

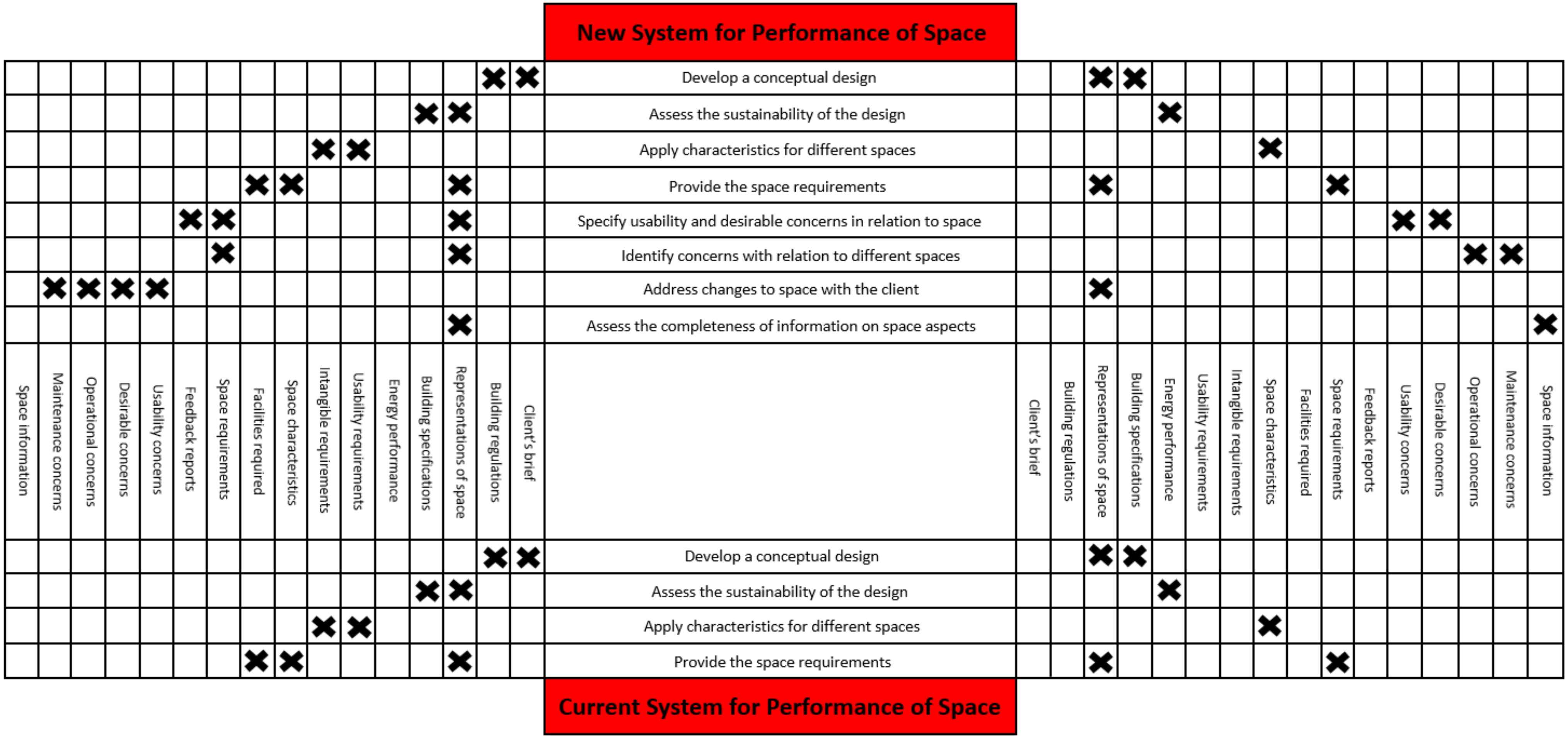

Figure 5.26: A Maltese Cross using activities from the consensus model and information categories.

The above Maltese Cross (Figure 5.24) shows similar activities to those mentioned in the previous case studies. The current system shows similar activities to those mentioned by the client in the previous case study. However, it additionally includes 'apply characteristics for different spaces', which the designer embeds when designing space before finalising the space requirements that will be taken forward when construction commences. Within this additional activity, the designer tends to embed some of the concerns that building occupants may have, hence, both 'usability requirements' and 'intangible requirements' are embedded when designing the space as 'space characteristics'. Although embedding characteristics may overcome many of the building occupants' experiential concerns, the significance of the parts considered is influenced by the designer's worldview. Hence, usability and desirable concerns are still included as part of the new system because the significance of the parts considered can differ between the designer and building occupants. Similarly, it is realised that there are some common descriptions between the information categories, which shows that they may overlap, but their significance differs depending on the stakeholder's worldview. For example, the location of a facility is mentioned within 'usability concerns' and 'maintenance concerns', because the impact of this part is different on both the facility management team and building occupants. The use of representations of space acknowledges the shortcomings of models in providing information for different stakeholders.

5.4.7. Conclusion for Educational Building 2 soft systems analysis

This case study looked at soft systems analysis for the Educational Building 2 case study. The aim of soft systems analysis was to further look into information requirements that are needed to overcome the divergent views on the performance of space. The role of representations of space on different views of space was also considered. Soft systems analysis showed that looking into representations of space has increased identifying further understanding of what influences performance of space. This is because it showed that representations have limitations in terms of representing different experiential concerns. Conceptual models showed that communicating representations of space to those who use the building is vital in order to capture different concerns, and represent the significance of different parts (e.g. location of a facility as part of usability and maintenance concerns). The analysis provides further information requirements, which can be used to bridge the gap between data and experience. The findings from soft systems showed that there is a need to represent space in a way that supports recognising the significance of different parts in order to inform the performance of space at an early design stage.

5.5. Conclusions

This chapter addresses soft systems analysis for the three case studies in this thesis: the Educational Building 1, Office Building and Educational Building 2 in the UK. Findings from the previous chapter showed that there is a gap between data and experience. This gap means that it is difficult, if not impossible, to represent experience through data, and this problem is made more complicated because the stakeholders have different perspectives using reductionist and/or holistic views of the building in different ways. Soft systems analysis was conducted to understand the problem and support bridging the gap between data and experience. The motivation to bridge this gap is to investigate different information requirements in order to supplement the data requirements in BIM so it supports the delivery of performance for buildings.

Findings from the previous chapter are used to elaborate both the reductionist and holistic views of a building based on the stakeholders involved in the study. The building delivery team often specify the 'parts' based on the whole. For instance, if the whole is a sustainable building, then they specify the building systems (data) that support the delivery of a sustainable building. For example, ensuring that building systems (parts) function adequately to ensure different characteristics such as energy and operation so that it meets user needs (see 'PS, 4.2, 2, PD' in

Section 4.2.5.1), or reduce as many issues as possible to get value for money (see 'WC, 4.5, 2, BC' in Section 4.3.5.1). This example shows that the building delivery team's view of a building is reductionist. The facility management team of a building is equally influenced by the parts *and* the whole. This is because they do not only use the building (whole), but also manage and monitor its different parts (e.g. building systems) to ensure its functional purpose and satisfy occupants' needs. For example, a reductionist view is the ability to maintain different parts of a building (see 'WC, 4.6, 3, FM' in Section 4.3.5.1) whereas an example of a holistic view is ensuring that the building operates effectively to meet the user needs (whole) (see 'PS, 4.3, 2, BSS' in Section 4.2.5.1). Therefore, based on the above examples, it can be argued that the facility management team's view of a building can be both reductionist and holistic where each view is driven by nature of the situation they experience in the building. Building occupants are influenced by the whole, and they only become aware of the parts when they experience the whole, for example, the way a building allows an occupant to carry out their job in a space (see 'PS, 4.4, 2, O2' and 'PS, 4.4, 2, O3' in Section 4.2.5.1). Based on the previous example, the building occupants' view of a building is holistic, because they only become conscious of the part (e.g. opening the window) when an emergent characteristic (e.g. comfort) influences their experience. The above examples show that different stakeholders have different views of perceiving the building because they see the parts and the whole differently. This demonstrates the complex nature of the parts and the whole, which play a role in the gap between data and experience.

Soft systems analysis for the Educational Building 1 case study show the need to consider different worldviews in order to achieve building performance that satisfies the three targeted stakeholders. Identified information requirements showed the need to consider further activities, which involve the views of those who manage and use the building. It also showed that space was key to the views of stakeholders who use and manage the building, hence the second case study further looked into different experiences of space. In the second case study (the Office Building), soft systems analysis showed the importance of considering different experiences of space in order to demonstrate the significance of different parts that influence the performance of space. Identified information requirements showed that many parts influence the experience of space differently for different stakeholders. Soft systems analysis for the third case study (Educational Building 2) further looked into parts that influence the performance of space, but additionally with consideration of the role of representations of space. It also showed that representations of space need to be information-rich in order to support recognising the significance of different parts for different stakeholders.

Although the use of soft systems analysis provided a holistic view of the gap between data and experience, seeking to identify information requirements can be argued to be reductionist. However, identifying information requirements is useful, as recognises the current shortcomings with the use of modelling technologies such as BIM in supporting the delivery of performance for buildings. In the next chapter, an approach that supports recognising the significance of different parts identified in this chapter, and how it supports informing data requirements in BIM models to support the delivery of performance, is discussed.

Chapter Six - Discussions

6.1. Introduction

The aim of this thesis is to explore the problem of achieving better designs of buildings from the point of view of building performance. Initial findings from Chapter 4 showed that different stakeholders associate different meanings with building performance. The later findings showed that different *experiences of space* have influenced views about it, recognising what influences building performance. Other conclusions drawn showed that different experiences of *representations of space* recognise that the current interpretations lack a determination of what influences the performance of space. Thus, there is a gap between data and experience. Chapter 5 attempts to gain a deeper understanding of this gap through a framework (see Figure 5.1), which showed that the division between data and experience is seen as a problem between the *parts* and the *whole*. Systems thinking was then used to explore this problem between the parts and the whole where the building was viewed as a designed physical system, and a human activity system (see Section 3.6.3.1). A designed physical-system view of a building was described as reductionist, whereas viewing a building as a human activity system was described as holistic (see Section 3.6.3.1). Evidences from chapter four showed that different stakeholders have different views of the building. It was shown that the building delivery team's view of perspective is reductionist. For example, ensuring that building systems (parts) function adequately to ensure different characteristics such as energy and operation so that it meets user needs (see 'PS, 4.2, 2, PD' in Section 4.2.5.1), or reduce as many issues as possible to get value for money (see 'WC, 4.5, 2, BC' in Section 4.3.5.1). The facility management team's view of a building can be both reductionist and holistic. For example, a reductionist view is the ability to maintain different parts of a building (see 'WC, 4.6, 3, FM' in section 4.3.5.1) whereas an example of a holistic view is ensuring that the building operates effectively to meet the user needs (whole) (see 'PS, 4.3, 2, BSS' in Section 4.2.5.1). The building occupants' view of a building is holistic where they described performance, based on what influences their experiences, for example, the way a building allows an occupant to carry out their job in a space (see 'PS, 4.4, 2, O2' and 'PS, 4.4, 2, O3' in Section 4.2.5.1). The difference in views between different stakeholders shows the complexity between the parts and the whole, which influences the gap between data and experience.

It has been argued that current modelling approaches lack the capability to represent expected experiences. Although modelling represents the building as a designed physical system, and an expected human activity system, the *expected experience* is limited to the data used for the model. This is due to the fact that the modelling approach itself is reductionist, as it uses data to support representing the expected experience in a building. Therefore, a more-holistic approach that looks at the building as a whole is required, hence the use of 'soft systems analysis' was proposed. The use of soft systems was applied as an analytical tool, which used findings from Chapter 4 to look at the gap between data and experience. Soft systems analysis was applied for each of the case studies: the Educational Building 1, Office Building and Educational Building 2. The primary aim of soft systems analysis was to look at the problem in each case study holistically, and to identify information requirements that bridge the gap between data and experience. Conceptual models support identifying the activities (parts) that are needed to fulfil each transformation process whereas the Maltese Cross method (Wilson, 1990) helps identify additional parts, which demonstrate a multiple significance of the information required. Soft systems analysis has supported the recognition that current representations of space have limitations, and better representations are needed. It also facilitates an approach to bridge the gap between data and experience.

The aim of this chapter is to discuss the implications of using of soft systems to support informing data requirements in BIM to support achieving better building performance for buildings. The chapter elaborates on both the findings from Chapter 4 and analysis from

Chapter 5. The present chapter begins with a discussion of the problem of different abstractions of performance. It elaborates on the early findings from Chapter 4, which shows that different stakeholders have different views of building performance and shows how soft systems have supported understanding these different abstractions of performance. The present chapter then addresses the problem of representations of performance, which is a highly complex topic, as a result of different abstractions of performance. The limitations of representing performance in the form of designed physical system and why there is a need for richer representations are highlighted. Space as a reference for performance, and the role it plays in understanding the problem between the parts and the whole, which was considered in Chapter 5 is also further explored. The chapter concludes with the proposal that information about space can be used as a way of bridging the gap between data and experience. A space strategy model is proposed as an attempt in recognising different information requirements that support capturing different parts that influence experience at an early design stage.

6.2. Abstractions of performance

Chapter 4 showed that different stakeholders have different meanings for buildings and building performance. These different meanings by different stakeholders can perhaps be described as abstractions. ‘Abstraction’ can be described as soft conceptual idea; it does not have a unique definition or specific rules; it cannot be applied without context (Hazzan and Tomayko, 2005). Abstractions provide a description of an idea, concept or theory, but can never represent the whole. For example, an abstraction of energy performance in a building could be energy bills, but they do not provide a representation of the whole, as energy performance can be influenced by other factors that are difficult to be measured such as human comfort. Thus, it can be argued that abstractions are merely representations of parts. It can be argued that the stakeholder’s meanings of building performance are derived by a stakeholder’s view of the world, which can either be reductionist, holistic or both. A certain view can support indicating the parts that let to that particular view. Parts can be influenced by other factors, which can be personal (e.g. mood, feeling), organisational (e.g. leadership, management) or environmental (e.g. budget, regulations).

The building delivery teams often specify the *parts* based on the *whole*. For instance, if the *whole* is creating a sustainable building, then they specify the building systems (data) that support the delivery of a building designed and constructed with sustainability in mind, for example, ensuring that building systems (parts) function adequately to ensure different characteristics such as energy and operation so that it meets user needs (see 'PS, 4.2, 2, PD' in Section 4.2.5.1), or reduce as many issues as possible to get value for money (see 'WC, 4.5, 2, BC' in Section 4.3.5.1). This example shows that the building delivery team's view of a building is reductionist. The facility management team of a building is equally influenced by the parts and the whole. This is because they do not only use the building (whole), but also manage and monitor its different parts (e.g. building systems) to ensure its functional purpose and satisfy occupants' needs. For example, a reductionist view is the ability to maintain different parts of a building (see 'WC, 4.6, 3, FM' in Section 4.3.5.1) whereas an example of a holistic view is ensuring that the building operates effectively to meet the user needs (whole) (see 'PS, 4.3, 2, BSS' in Section 4.2.5.1). Therefore, based on the above examples, it can be argued that the facility management team's view of a building can be both reductionist and holistic where each view is driven by the nature of the situation they experience in the building. Building occupants are influenced by the whole, and they only become aware of the *parts* when they experience the whole, for example, the way a building allows an occupant to carry out their job in a space (see 'PS, 4.4, 2, O2' and 'PS, 4.4, 2, O3' in Section 4.2.5.1). Based on the previous example, building occupants' view of a building is holistic because they only become conscious of the part (e.g. opening the window) when an emergent characteristic (e.g. comfort) influences their experience. The above examples demonstrate the complex nature of building performance as different stakeholders have different views of perceiving the building because they see the parts and the whole differently.

Based on the above views, it can be argued that it is difficult to have a universal way of assessing performance. Current performance assessment approaches focus on assessing the parts such as structural safety or measurable emergent characteristics such as energy performance. Although some studies have looked into assessing some of the emergent characteristics that influence experience, the focus is often on measurable characteristics. For example, Amin et al. (2015) has investigated how architectural designs can affect ‘sick building syndrome’ through evaluating thermal comfort. Although the study included some subjective measurements by conducting surveys, it focused on measurable characteristics, which then can be used to inform the architectural designs. Similar studies have also been conducted by Leamann et al. (2008) and BSRIA (2011) where the focus was on measurable characteristics. The main shortfall of such studies is their reductionist approach, which focuses on how to enhance a certain part. However, the findings showed that many of the emergent characteristics that influence performance are hard to measure or be determined. The performance mandates proposed by Hartkopf et al. (1986) have identified some of the emergent characteristics that are hard to measure, such as privacy and interaction for occupants in a building. However, many studies have used the identified emergent characteristics from the performance mandates to aid evaluating performance. For example, Sui et al. (2012) used the performance mandates to aid the design of a school in China. This approach is limited, as performance (whole) becomes limited to the identified characteristics (parts) within the performance mandates. However, the use of performance mandates has decreased with time due to the emergence of Information Technology, which influenced the focus of performance to be more dependent on quantitative/measurable characteristics such as energy performance.

Designing a building from a performance perspective requires a more-holistic approach, which goes beyond the consideration of measurable characteristics. The current approaches in designing for performance are reductionist, where the parts drive the whole. Reductionist views impose the view that performance is driven by the designed physical system where specifying parts (e.g. building systems) determines the emergent characteristics view, which negatively (referring to reductionist view) impact experience when the building is occupied. Therefore, designing for performance of a building should also take in consideration the experiential issues, and propose early solutions to avoid negative perceptions. This means going beyond defining what the building is required to do (Gibson, 1982; Sexton and Barrett, 2005) to involve the views of those who use the building. The use of soft systems analysis has showed that it is important to involve the views of those who experience the building (see Section 5.2.2). This is because it reveals parts that support the understanding of what influences experience. For example, in the Educational Building 1 soft systems analysis, it was shown that additional activities such as 'determine needs and desires for the space' (see Figure 5.9). Therefore, designing performance should follow a holistic approach that looks at the building as a human activity system. Therefore, the value of multiple perspectives when designing for performance is vital, which supports identifying many of the expected issues that influence experience.

6.3. Representations of performance

As a result of different abstractions of performance, it is important to look at how this influences representations of performance. Findings from the Chapter 4 showed that the use of current technologies such as BIM to achieve performance is influenced by their abstractions of performance. For example, from the Educational Building 1 case study, the building delivery team stated that BIM cannot fully support energy performance for the building (refer to Educational Building 1 data: energy assessor's response on 'value of BIM for energy, space and maintenance' in the appendixes) even on an abstraction like energy, which is well described by a calculation between measurable parts. Similarly, the client from the Office Building case study stated that BIM should provide evidence on the potential cost savings on building maintenance. Generally, from the findings in the case studies, the facility management team's view of BIM was influenced by how it supports their experiences in a building. For example, in the Educational Building 1 case study, the facility management team stated that a digital technology such as BIM can represent different information with relation to building systems. Also, the facility manager from the Office Building case study stated that the value of BIM lies in the information it provides to overcome different issues such as maintenance of building systems and management of space. The building occupants' view of technology was also influenced by how it supports improving their experiences within the building. For example, building occupants from the Office Building case study stated that representations of space can be useful to detect possible issues before moving into a new building. It can be argued that the representations of performance rely on the stakeholders' involvement, as they do not have a consistent set of abstractions of performance. This is because their view of the building and building performance is different, which was explained in Section 6.2.

Many studies show that much of the current BIM focus is on energy and sustainability (Park *et al.*, 2012; Jalaei and Jrade, 2015). Although the literature shows that there is no limit to the information type that BIM can incorporate (McArthur, 2015), accounting for many emergent characteristics still relies on its geometrical properties. For example, this can be realised when referring back to the designer's response from the Educational Building 1 case study when responding to the value of BIM for space where it was stated that BIM is useful to gauge a client's requirements, which mainly looked at space sizes, numbers and types. Current BIM capabilities show that it can add much information (see Figure 6.1) to allow it to be more computational. However, it is not clarified how such information can support performance of space, and otherwise how this information can support the experience of those (stakeholders from the facility management team and building occupants) in the building.

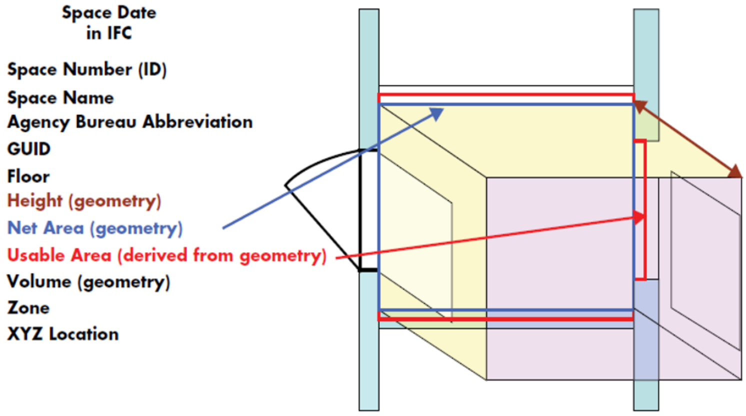

Figure 6.1: Space accountancy in BIM (Hagan, 2014).

Although the use of advanced technology aims at trying to understand a more holistic way of dealing with the interaction between people and the building they inhabitant (Clements-Croome, 2014), it is rather difficult to derive the *experience*, which can be used to design better buildings. According to Allen (2009), it has been stated that many characteristics of a building, especially those that rely on experience, cannot rely on representations. This is because the experience in a building involves many phenomena, which if representation tries to simulate them, will never be able to capture them completely. This is because representations of a building presume stable objects, which tend to diminish and trivialise the experiential complexity of the realised building. The use of the Maltese Cross (Wilson, 1990) in the previous chapter showed that there are additional activities (parts) that affect achieving performance when comparing the new and current systems for building performance (see Figure 5.10). The use of Maltese Cross demonstrates that many information requirements are not currently considered, which influences experiences of those who use the building. Although some of this information, such as space information, operational and maintenance information (see Table 5.4) can be obtained from the BIM models, it is not evident how their current representation can support those who use the building. This is because such information was identified by facility management teams that are not involved in the process of designing the building.

The problem of poor experiential consideration is one of the building delivery team's approaches when addressing performance, which is reductionist. This is because it uses parts (e.g. building systems) that limits the recognition of many emergent characteristics. A holistic approach to performance is therefore required in order to gain richer perspective of the emergent characteristics, which are often experienced once a building is occupied. The use of soft systems provides a holistic approach, which supports many of the emergent characteristics (e.g. ease of access, maintainability and flexibility) that influence experiences of building users (facility management team and building occupants) and recognises the significance of different parts and how they influence the performance (whole), which is complex. With relation to most of the experiential problems, space can act as a reference for performance because it simplifies the complexity of the gap between the parts and the whole. This is because it supports situating different meanings of buildings for different stakeholders. Furthermore, it simplifies the levels of complexity (see Figure 5.2), which allows a medium to communicate emergent characteristics and different parts in a building.

6.4. Space as a reference concept for performance

Initial findings from Chapter 4 show that many of the experiential problems are 'within space'. Hence, the second and third case studies focused on both performance of space and inquired into it through experiences of space and representations of space. 'Space' as a concept itself is complex, and has been undertaken by different researchers differently. For example, Lefebvre (2000) argued that the word 'space' is used without understanding the intended meaning behind it, and hence he produced a spatial triangular diagram that describes space by way of three cornerstones. Fayard's (2012) perspective of space is that it is not an empty extension to be filled in, but it is constantly constructed, which emerges from the relationships and practices of people living, working and interacting in space. Although Fayard's work on space acknowledged experience, his approach can be claimed to be reductionist as it assumes predefined parts of the space. Experiences in space are complex, and have been undertaken by many researchers. For example, Tuan (1977) described experience in space as 'place'. Malpas (1999) has developed the concept of place as one that integrates time and space. In addition, his views have offered a subjective and objective view of spaces. While this is useful, as it acknowledges the value of experience within the space, it did not acknowledge the nature of experience in terms of the factors that influence it. Massey (2005) rejected Malpas's views and described space as a *process*. This is because he argued that many external factors such as policies may influence experience of space.

Space as a concept in itself is complex, and perhaps influenced by different standpoints. However, this research presents space as a performance-focused concept while not diminishing its richness. This is because it supports capturing the emergent characteristics that influence experience while recognising the parts that influence that experience. For instance, from the Office Building case study, the facility manager described that maintainability issues within the community space as influencing different characteristics such as accessibility and occupants' comfort. Also, at the Office Building, the building occupants claimed that some of the issues they currently face relate to usability requirements such as storage and movement within the space. The use of soft systems showed that space has supported richer understanding of different experience for those who use the space. For example, CATWOE analysis (see Table 5.5) from the Office Building soft systems analysis showed that the facility manager would want to have space information in order to manage serviceability requirements for different spaces. The use of soft systems also supported capturing that different parts have different significance for different stakeholders. For example, locations of facilities (see Table

5.8) is part of both usability concerns for the occupants and maintenance concerns for the facility manager.

Current representations of space such as 2D and 3D are useful when it comes into constructing the space in the built environment. Although they form two different perspectives, one cannot deny the function of the other. The traditional 2D representation provides a perspective over the general layout, access routes, different types of spaces, and distribution of different facilities. Amstel *et al*, (2014) used 2D plans to expand the representation of user activity in a hospital environment. However, it is mainly designers who appreciated its value, as it still remains within the sphere of design and construction coordination. The perspective of 3D is the one that tends to be preferred by different users. The 3D environment is the one providing the Euclidean framework of human perception to recognize spatial relations (Richards, 1975). In addition, it allows the observer to frame their mental image of space. 3D models have widely been used for several purposes, but mainly to allow better visualization of the built environment and particularly space.

The present research has examined the use of representations of space to gain an understanding of what influences experiences in space. It can be argued that the impact of these representations has differed from one participant to the other. For example, the facility management teams provided feedback on both the parts that influence experience and some of the emergent characteristics that may influence occupants' experience, whereas occupants' feedback was much more focused on the emergent characteristics, which are influenced by their previous/current experiences in the building. Loomis *et al*. (1992) stated that, in the study of visual space, it has been assumed that an observer has an internal representation of surrounding physical space, and then attempts to measure the properties of visual space to establish how well various properties of physical space are preserved in the mapping to visual space. Hartfield (2003) examined the visual experience, which presents a visual space in relation to the physical space. He argued when human perception takes place, that the world itself is shaped (or very close to) a three-dimensional Euclidean structure, a veridical visual representation. This veridical visual representation describes the 'experience' in which people visualize a representation of reality. On the one hand, the distance between the people's representation/knowledge of reality and the visualisation/model of reality is referred to as the semantic distance (Cox, 2014). On the other hand, the distance between a model of reality and reality itself, is referred to as the 'articulatory distance' (see Figure 6.2). Acknowledging these two distances when visualizing the space, the designer attempts to reduce the articulatory distance by including more information in the model, and this is where, for example, the value of BIM can be realised. However, the use of soft systems shows that current representations of space (2D/3D) need to provide more information. Although these representations have supported capturing different concerns (see Table 5.12), they showed that current modelling approaches have limitations in terms of providing rich representations of many emergent characteristics in the building. The importance of emergent characteristics can mainly be recognised when experienced. Some of the emergent characteristics in space have received major attention such as space syntax, as their value is important for the built environment.

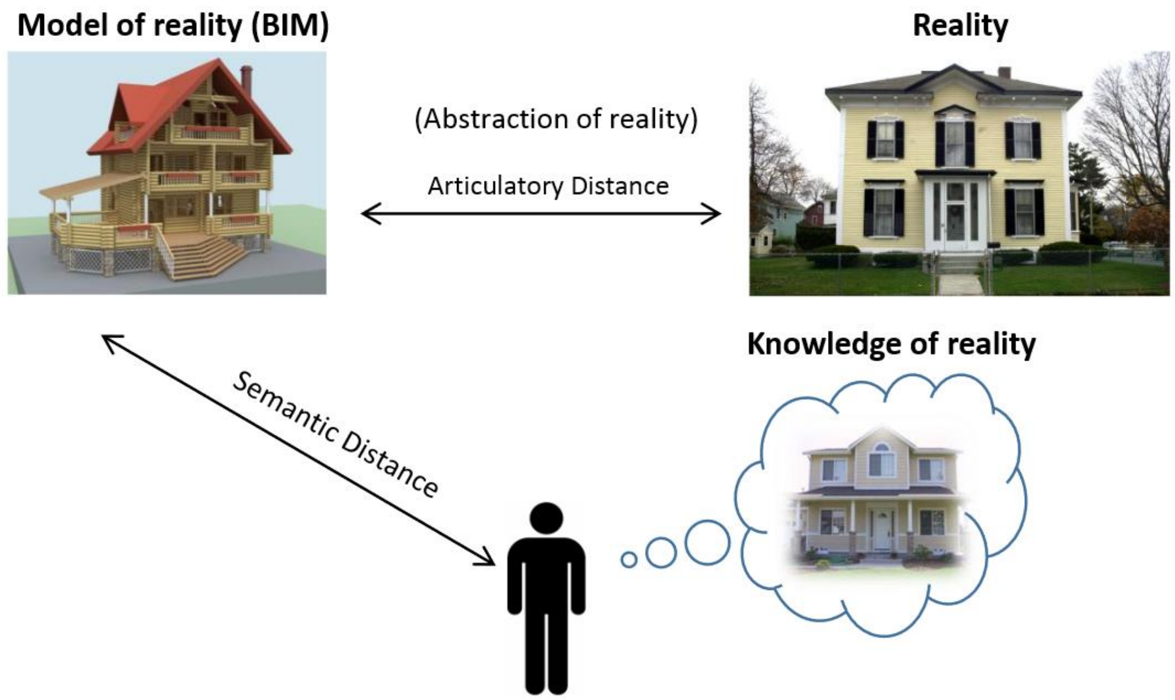

Figure 6.2: Semantic and articulatory distances, adopted from Cox (2014).

In realizing the value of the shape of the built environment, space syntax (Hillier, 1996) has emerged as one of the spatial theories. The theory proposes an understanding of design through a system of diagrammatic representation. It intends to resolve a small system of interacting and conflicting forces through the representation of an abstract pattern of physical relationships (Robertson, 2011). These interactions and conflicts have been acknowledged by Hillier (1996) and are claimed to be 'configurations', which are formed by a group of people. The value of space syntax well received, as it supported the quantification of the interrelationship between the built environment and social life. Although the concept of space syntax has extensively been used on an urban scale, it has been applied on a building scale to improve design solutions (Jeong and Ban, 2011). It is undeniable that the use of space syntax has improved the accounting for spatial relations and their effect on configuration, which impacts part of the experience of space. Nonetheless, space syntax seems to discard metric information of space. Metric information is what constructs the space, considering its tangible and intangible attributes. Therefore, if we are to appreciate the value of space syntax, its identity should be embedded within the bigger picture (rich picture) of space, bearing in mind this will be influenced by the nature of the building type as well as to the type of space.

It can be argued that the current representations of space are merely representations of a designed physical system of the building. Although many current technologies such as BIM or advanced visualisations have attempted to provide representations of the building as a human activity system, they cannot be perfect. The reason is that all these tools are utilised in a reductionist way, which means it is assumed that *parts* can represent the *whole*. The use of soft systems as a holistic approach has shown a richer understanding of the parts in order to support achieving the whole. More importantly, identifying these parts through soft systems has supported looking into the information required, which can be used to support bridging the gap between data and experience. Although the identification of information required at the end of each soft systems analysis in the previous chapter may represent a reductionist approach, it mainly serves to identify current shortfalls of BIM models and whether the identified information can be incorporated to achieve better performance for buildings.

6.5. Space as information

The present research showed that there is a gap between data and experience. Soft systems analysis was conducted on the Educational Building 1, Office Building and Educational Building 2 case studies in order to investigate the significance of different parts. The use of soft systems recognises the significance of different parts for different stakeholders. The previous chapter concluded by highlighting the need for a way to inform the data requirements in BIM, so that it supports representing the experiential significance of different parts. Therefore, and using the identified information requirements from the previous chapter, a space strategy model is proposed, which suggests that design of space should be 'informated' in order to support recognising the significance of different parts. 'Informating' was proposed by Zuboff (1988), and it assumes that technology generates information about an underlying process through which an organisation accomplishes its work. The process in this is referred to as ‘informate’, which is to capture the aspect of a technology that may include, but go beyond, automation. Automation is simply what tools such as BIM do where data is processed in a certain way to represent information. Whereas automation has supported enhancing the process that rationalise work and decreased the dependency on human skills, it was stated that technologies that informate a process increase the explicit information content of tasks (Jones, 2015). It can be argued that ‘informating’ is richer than automating because it supports empowering people with information so that they can use it to solve problems.

The aim of introducing the space strategy model is to propose a way that supports bridging the gap between data and experience. Proposing such a model can potentially support exploring whether BIM models are capable of ‘informating’ so that it supports achieving better performance for buildings. The model uses the information categories outlined in the Maltese Cross (Wilson, 1990) from each of the case studies. Each information category included different data requirements. The model represents these different data requirements using entities and attributes. An entity is a representation of an object in the real world whereas an attribute is a description of an entity. The use of entities and attributes supports acknowledging the experiential significance of different parts, which also can be referred to as ‘intangibles’. This is because the significance of different parts is only experienced once the building is occupied, and they hard to be measured or assessed, hence referred to as ‘intangibles’.

This section commences with explaining the space strategy model and how it is developed using the information requirements identified in Chapter 5. It then looks at use of the model in terms of acknowledging the intangibles and informing multiple perspectives. The section concludes with looking at ‘space as information’ explaining how such an approach can support informing data requirements in BIM models.

6.5.1. Model development

The model is developed using the information requirements identified using soft systems analysis for each of the case studies in Chapter 5. These information requirements are included under the information categories identified at the end of each soft systems analysis in the previous chapter (Tables 5.4, 5.8, 5.12). The initial step was to gather all the information categories in a single table (Table 6.1). Some information categories have been identified more than once, but their descriptions may have differed, hence, such information categories are mentioned once, but merged in all the descriptions identified in each of the soft systems analyses.

Table 6.1: Identified information categories and their descriptions from Chapter 5.

Information Category	**Description**
Space standards	CIBSE (Chartered Institution of Building Services Engineers) (e.g. office standards for space)
Design specifications	Space requirements 'space types, space size, and facilities'
User requirements	Aesthetic considerations 'colour scheme', comfort criteria 'lighting, temperature, acoustics, configuration'
Client's brief	Design specifications, User requirements
Building regulations	e.g. CDM (Construction, Design and Management) Regulations
Representations of space	2D plans and 3D models, Rendered images
Energy performance	e.g. Energy Performance Certificate
Usability requirements	Comfort criteria, Accessibility, Personal needs
Intangible requirements	Atmosphere, Colour scheme, Environment
Space characteristics	Usability and Intangible requirements
Operational considerations	Building systems' mechanism and efficiency
Maintenance considerations	Durability of building assets
External issues	Sunlight access, draught access
Facilities required	Fixtures, Furniture and Equipment

Space requirements	User requirements, Health and Safety, Facilities, Occupancy, Functionality
Feedback reports	e.g. Previous post-occupancy evaluations
Usability concerns	Temperature control, Facilities available 'location, movement, type, orientation', Windows control, Lighting 'number of windows, glazed walls', Facilities operating instruction, Disabled access, Connectivity 'charging points, Wi-Fi', Configuration 'noise levels''
Desirable concerns	Storage, Personal space, Privacy, Atmosphere, Finishes, Accessibility, Confidentiality, Occupancy level, Health and safety, Connectivity to other facilities 'toilets, kitchen, café
Operational concerns	Systems' control, Users' behaviour, Available facilities 'hard facilities, soft facilities, Logistic management 'storage', Accessibility 'disabled access, eligibility', Ventilation, Lighting, Layout
Maintenance concerns	Location of facilities, movable/fixed hard facilities, Soft facilities 'cleaning accesses, hard/soft walls, hard/soft flooring', and Hard facilities information 'maintenance procedures', Location of windows 'cleaners' access', Hard/soft walls, Hard/soft flooring
Space requirements	Usability, Facilities provided, Layout
Occupants' needs and concerns	Space concerns
Building specifications	Building systems, Design specifications, Materials, Space specifications
Space information	Occupancy, Functionality, Facilities, Operational information, Maintenance information
Building information	Space information 'occupancy, functionality, facilities', operational information 'building systems' and maintenance information 'building finishes, building systems specifications'
Facility management team's requirements	Building information

The next step was categorising the information requirements into entities where each entity consists of a number of attributes. For example, if one of the entities is 'facilities' then the attributes can be location, orientation, and so on. It is important to indicate that there can be multiple approaches to represent the gathered information categories. More importantly, for any model to be applicable, it needs testing and validating, which is not the aim of this research study. Therefore, the proposed model intends to offer a solution, which can support bridging the gap between data and experience.

The model incorporates the views of the three stakeholders involved in the study, which are the building delivery team, the facility management team and building occupants. In order to demonstrate their needs within the model, each attribute within the model is tagged with an abbreviation (see Table 6.2) to show a stakeholder's relation to that attribute.

Table 6.2: Abbreviations used in the Space Strategy Model with respect to different stakeholders.

Stakeholder	Experience in Space	Abbreviation used in the model
Building delivery team	Requirements	R
Facility management team	Operation	O
	Maintenance	M
Building occupants	Usability	U

Considerations of experience in space from the view of the building delivery teams are based on the delivery of ***requirements***. This is also because their view of the building is reductionist, which assumes that the parts support achieving the whole. Although experiences of the facility management team and building occupants were considered, the use of soft systems analysis supported identifying characteristics that can aid understanding what influence their experiences. Soft systems showed that many of the facility management team's concerns are related to ***operation*** and ***maintenance*** within different spaces. It also showed that building occupants' concerns are related usability and desires within different spaces. However, desires are influenced by many factors, which can be personal, organisational or environmental and they differ from one building to another, hence, only ***usability*** related concerns were included in the model.

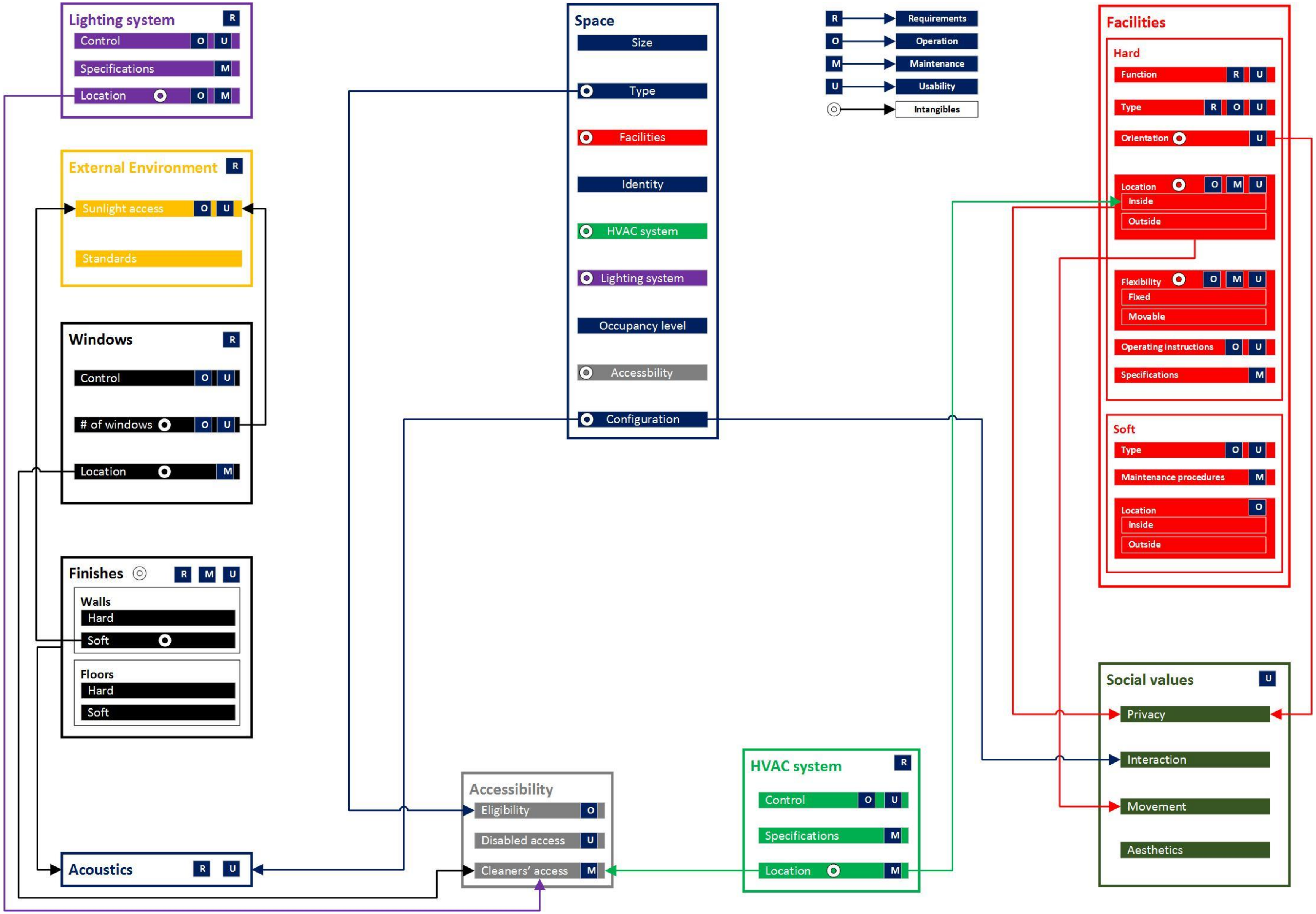

Figure 6.3: The proposed Space Strategy Model

6.5.2. Richer representations of the emergent characteristics

The space strategy model (Figure 6.3) show different entities and attributes constructed using the information requirements identified through the use of soft systems analysis. Significance of the above model lies in showing the significance of different parts, which support identifying many of the emergent characteristics and how they influence different stakeholders. The use of abbreviations indicates how different parts influence different stakeholders. For example, the entity 'HVAC system' shows that it is a requirement for the building delivery team, where its attributes such as control and specifications have different impact on both the facility management team and building occupants. An attribute such as 'control' is treated as a multiple implication attribute because it impacts different stakeholders in different ways. Therefore, the use of abbreviations enables the significance of such parts to be identified, which becomes vital when the building is occupied.

The model also shows a white (doughnut-shaped) circle placed on different attributes. These white circles indicate that an attribute has an emergent characteristic when connected with another attribute. These connections are often not recognised and only become apparent when experienced, hence, attributes that exhibit possible connections with other attributes are tagged with a white circle, referred to as 'intangibles'. For example, 'Intangibles' were mentioned by the designer in Educational Building 2 case study, which refers to the emergent characteristics that influence occupants' experiences, which are hard to measure. In the space strategy model, intangibles refer to the emergent characteristics that result from the combination of more than one attribute. Another example is the connection between the 'Location' attribute under 'HVAC system' entity and 'Cleaner's Access' under the 'Accessibility' entity. In the Office Building case study, the air ventilation units are placed at the top of the atria within the building. In order to carry out the maintenance procedures for this kind of ventilation unit, a tower crane access is required. However, when cleaning is required, the cleaners can manage to clear these ventilation units only via the top floor inside the building. This requires using private spaces, which can be restricted depending on the nature of the building. More importantly, cleaners' access will be limited to times when building occupants are not using the building, to minimise the level disturbance as much as possible. It is important to indicate that more attribute-to-attribute connections can be derived from the space strategy model, but the intention was to provide a model that supports bridging the gap between data and experience. The next sections discuss the potential value of representing space as information and how BIM can use such information to aid the delivery of better performance for buildings.

6.5.3. Stakeholders' Feedback on the Space Strategy Model

The space strategy model presented in Figure 6.3 aims to capture the data needed to provide information about factors affecting experience in buildings. The aim of the space strategy model is to enhance data requirements in BIM and whether such approach towards the design of spaces can be implemented in BIM. The model elicits connections or implications, which are too complex to be obvious in the busy schedule of designers. It is anticipated that the space strategy should act as a guide for the designers when designing space. As stated previously (section 6.5.1), the model incorporates the views of the three stakeholders involved in the study, which are the building delivery team, the facility management team and building occupants. This section aims to demonstrate the value of 'informating' using the space strategy model as a way to bridge the gap between data and experience. To demonstrate this, feedback on the information presented in the space strategy model from the three stakeholders was gathered. This feedback does not represent a 'validation' of the model, as its current form can be argued to be a model that represents a middle way between the real and computerised world, hence, this space strategy model can be claimed as an 'inquiring system' (Churchman, 1971). Thus, the intention of the feedback is to demonstrate the value of 'informating', which the space strategy model intends to represent within its current form.

In order to obtain useful feedback from the three stakeholders, the use of the model indicated in the previous section (section 6.5.2) will be used to demonstrate the use of the space strategy model. The model contains a logic which allows it to be used as an inquiring system (Churchman, 1971). To test this, the model was used to inquire into the thinking of the stakeholders, this was undertaken by selecting two design areas, and asking the stakeholders questions about what they could appreciate more fully from using the model. There were three purposes to this testing:

1. Discuss how far the logic correctly identifies both the technical and experiential connections.
2. Determine whether the use of model reveals emergent aspects (of what?) that inform the stakeholders.
3. Discuss how the stakeholders believe the model can be improved.

Based on the above purposes, three questions were asked to the three stakeholders:

A. What can you interpret from the connections indicated by the model?

B. What extra aspects does the model help you to identify?

C. How could the model be improved?

To answer the above proposed questions; two designs area were choses: 'HVAC system' and placing furniture in a location. The first design area of the model demonstrates the use of the abbreviations within one of the entities (HVAC system) in the model: requirement (R), operation (O), maintenance (M) and usability (U). The second design area demonstrates the use of connections between different attributes through a case scenario, which support identifying 'intangibles'. The feedback was gathered from three stakeholders representing the building delivery team, facility management team and building occupants, which respectively are: building designer, facility manager and two building occupants. The purpose of the space strategy model was first briefly explained. For both, the building designer and the facility manager, a brief walk through the model was provided in order to understand the aim and use of the model. The occupants were briefed about the intention of the space strategy model, and then asked to reflect about their experiences within the context of the examples mentioned above. Although the model was not designed for occupants, they were interviewed through the model in order to confirm its logic. The section concludes with providing the value of the space strategy model in improving BIM models for the delivery of spaces for better building performance.

Design area (1): HVAC system

The entity 'HVAC system' (heat, ventilation and air conditioning system) shows that it is a requirement for the building delivery team (see 'R' tag in Figure 6.4). The 'HVAC system' was selected because it impacts the experience of the three stakeholders in multiple ways, and perhaps can be communicated in different ways. This entity includes three attributes: 'control', 'specifications' and 'location'. Using the abbreviations (R, O, M & U), the model shows that each of these attributes influence different stakeholders differently. For example, the attribute of 'control' shows that it impacts both operation (O) and usability (U). In this example, the building delivery team was asked about the considerations taken for an 'HVAC system' within a space. The facility manager was asked about the considerations and concerns with relation to 'HVAC system'.

The building occupants were asked about their concerns with relation to ‘HVAC system’ within a space. Both the building designer and the facility manager were asked about how the model can be improved to represent information based on this example.

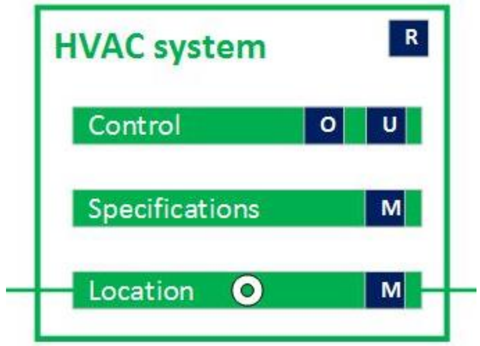

Figure 6.4: HVAC system entity (extracted from Figure 6.2)

The building designer

The feedback began by asking about the extent to which the model captures the relevant data about ‘HVAC system’ from the designer’s perspective. On responding to this, the building designer stated:

“*An HVAC system is a requirement in a building, so our optimum aim is to satisfy building users, but other things like those mentioned in the model such as location and specifications only become important when a problem arises*”

The above quotation shows that the aim of the ‘HVAC system’ is to satisfy the function of the building, however, the detail of the location and specification of the system becomes significant when a problem arises; this problem arises only when the building is in use and performing. This demonstrates the value of the space strategy model in terms of identifying an *emergent* aspects during the early stage during design of the space but which arises later. The building designer was then asked about the space strategy model in terms of its role to identify additional considerations for an 'HVAC system':

"*The model provides sort of flexible way of looking at different bits of information that influence the facility management people and users. I mean, it is a requirement to have an HVAC system, controls are either going to be facility manager or users, and obviously that would depend on the specifications anyway, and maintenance specifications will be driven by the design ultimately, which have come from the requirement, and the location is obviously from the requirement anyway, so it makes sense that they are linked to each other*"

The above quotation shows that the space strategy model has supported the designer in identifying how different information (e.g. location, specification) related to 'HVAC system' impacts on different stakeholders. This shows the usefulness of abbreviations within the space strategy model, in demonstrating how different aspects are *connected* to different stakeholders. The designer was then asked about how the model could be improved to represent information (e.g. location, specifications) so that it supports decision-making:

"*You could reorder the information under HVAC system to show how they kind of cascade down in terms of like 'knock on effect' so for example, the first one is the requirement for HVAC system, or is the first one actually the location, maybe two of them combined create a requirement, then you get a specification then you get a control who uses that, so maybe there is some sort of cascading of different stakeholders' requirements*"

The above response shows that the model supported identifying different information, which effects other stakeholders. The response also showed that some attributes such as specifications cannot be known without the identification of other attributes like location. Thus, from the designer's perspective, the model can be *improved* by setting a hierarchy of the attributes within the model. This demonstrates a problem, however, as it is an understanding the model from a reductionist perspective; thus, the inquiring aspects of the model need to be emphasized more.

The facility manager

The feedback from the facility manager began by asking the extent to which the space strategy model in terms of identifying the considerations and concerns for an 'HVAC system' within a space. On responding to this, the facility manager stated:

"*As a facility manager, it is my duty to ensure that HVAC system functions and operates to satisfy building users. In this building for example, the HVAC system is controlled by the building management system, so we set the temperature in a way that is comfortable for building users and also efficient in terms of energy use. So definitely operation of the HVAC system is important so that we don't get complains, and understanding how we can maintain the system when it breaks is a key so I need to know about the specifications, and different locations of access*"

The above response shows that the space strategy model has supported identifying the concerns that the facility manager has with relation to 'HVAC system' within a space. It showed that the identified attributes (control, specification and location) with relation to 'HVAC system' respond to some of the technical (e.g. specification) and experiential (e.g. control) *connections* within the building. The facility manager was then asked about whether the representation of information within the model can be improved in order to simplify identifying different needs and concerns with relation to space:

"I think that the model is clear, but perhaps a slight change of layout can support setting sort of hierarchy of information. So I am talking about some sort of information flow, for example, say

depending on the type of a space, what information should be considered first, so if we take one of the spaces used on a frequent basis such as the canteen, what information from the HVAC system do I need first, so I would for example be looking at control as a top priority, but other spaces I may be looking at location as priority"

The above response shows that the facility manager could use experience of some of the emergent aspects to derive importance of particular information, which are influenced by experience. This shows that different spaces have different priorities for information attributes. Although the model includes most of the required information, future work of the model could explore how access paths through the model are prioritised depending on the type of space in a building that is being explored.

Building occupants

For building occupants, the feedback began by asking the occupants about their concerns with relation to 'HVAC system' within a space. A brief introduction on the intention of the proposed model was given. For example, the researcher explained the purpose of an 'HVAC system' in a space, so that occupants could relate it to their experience when providing feedback about the appropriateness of the model. On responding to the concerns with relation to 'HVAC system', the feedback was as follows:

"*The main thing is that the space should be set to comfortable temperature, it will always be good to control the temperature, but obviously the side effect of that is if everyone controls, then this will not be good for people's health in an office, or dynamic environment as people might fall out of it*"

"*I would like the temperature to be set to a comfortable degree, but I am more concerned about having access to fresh air, as this does affect my experience as a user. I mean, if I can open a window even for a little bit, it will have a major positive impact on my comfort level as a user in a space*"

The above responses show that 'control' is an important attribute for users as part of the considerations within 'HVAC system'. However, the type of the environment may influence how an 'HVAC system' should be controlled, which was mentioned by one of the users. Also, one of the users pointed out the importance of having a window to gain access to fresh air as one of the factors that influence comfort level within a space. The feedback demonstrated the value of the space strategy model in terms of identifying some of the experiential *connections* within a building.

Design area (2): Placing furniture in a location

The entity 'Facilities' includes sub-entities, which are 'hard' and 'soft'. This example seeks to identify different considerations taken for one of the 'hard' facilities in a space, which in this case is location of a furniture. To simplify this, an example of a piece of furniture was used to gather feedback from the three stakeholders. The case scenario seeks to identify the importance of connections (see figure 6.5) between different attributes, which aim to identify the 'intangibles' within a space. For this scenario, the building designer was asked about the use of the space strategy model for identifying different considerations required for a piece of furniture in a space. The facility manager and building occupants were asked about their concerns with relation to a piece of furniture within a space. Similar to the previous example, the building designer and the facility manager were asked how the model can be improved to represent connections between different attributes based on this example.

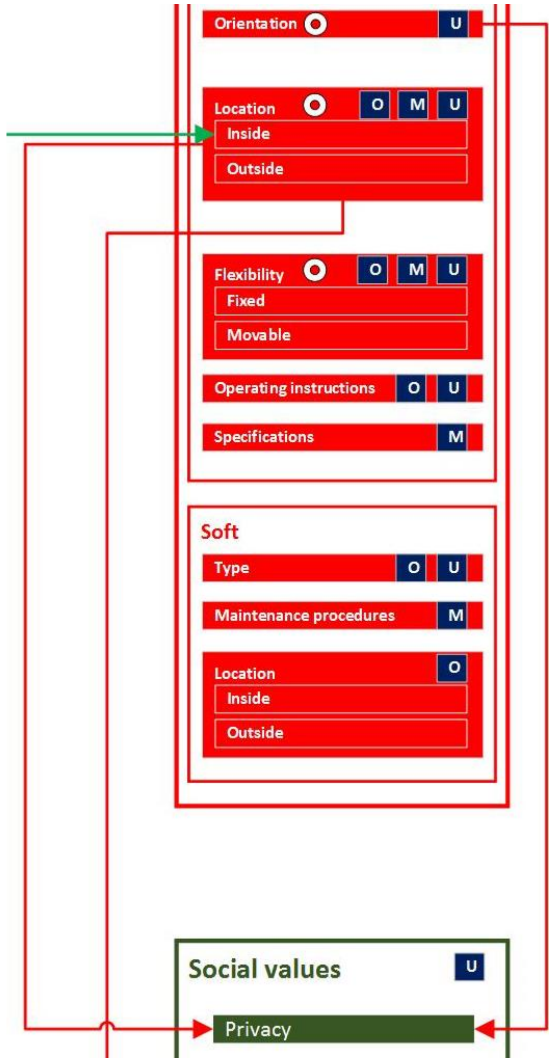

Figure 6.5: Connections between different attributes (extracted from Figure 6.2)

The building designer

For the building designer, the feedback began by asking about the suitability of the space strategy model in terms of supporting the identification of different connections related to a piece of equipment such as furniture within a space. On responding to this, the building designer stated:

"*Yes, definitely, because as a designer, it kind of help to determine some of the other things that you don't often think about, which is not only what we need for a meeting of table and six chairs for example. You actually start thinking, do we need some privacy, and how will that affect how the space is going to be used. I think the connections within the model act like an 'alert' for things that we usually don't think of when we design*"

The above response shows that the connections between different attributes within the space strategy model can potentially support identifying different considerations for a space such as privacy. This demonstrates the use of the space strategy model in identifying some of the *emergent* aspects (e.g. privacy). The building designer further commented on how these connections can also be useful to bring other stakeholders' needs at an early stage:

"*If you are bringing together the architectural aspects, the types of aspects that an architect would look at and the types that an M&E engineer would look at and the IT engineer, the architect then can see how their decisions impact on everybody else's decisions. So for example, in terms of flexibility, you can achieve the requirement by having a fixed TV, you know fixed to the wall, which means you need to have a wall, so you will have kind of looping back decisions based on whose discipline it is as well*"

The above response shows an additional value of the space strategy model in terms of providing a medium for communicating different stakeholders' needs and how they influence each other during the process. This can perhaps be useful to set an early design stage of the building, so that technical and experiential *connections* can be tracked and checked when designing a space. The designer was then asked about how the connections between different attributes within the model can be further improved:

"*I think cascading these connections will be useful, I mean for example, in terms of privacy and interaction, a small meeting room with a table of six chairs. The table and six chairs are requirements, but they need a location, so the location can be answered using a floor plan, which affects then type and the orientation of this type of table and chairs*"

The above response shows that one the improvements for the connections within the space strategy model, is influenced by the way that attributes are prioritised, which can potentially support setting a level of importance for the connections within the model.

The facility manager

For the facility manager, the feedback began by asking the value of the space strategy model in terms of supporting identification of different connections related to a piece of equipment such as furniture within a space. On responding to this, the facility manager stated:

"*I think these connections can act like a prompting tool when the designer design a space. I mean, as a facility manager, these connections represent the source of many issues within different spaces, I mean if we look at a piece of equipment within a lecture hall, me as a facility manager need to know the services it needs, where they come from, is it maintainable on place or does it need to be taken out, so yea, these connections are very useful*"

The above response shows that the connections between different attributes have represented many of the *emergent* aspects that the facility manager is familiar with in a space. The facility manager was then asked about how the connections between different attributes within the model can be further improved:

"*I think like I said previously, rearranging information here in a way that makes it look like an information flow, because in this way, it will help me as a facility manager to identify operational and maintenance requirements for different spaces*"

The above response show the facility manager's perspective on how to *improve* the space strategy model. This improvement was proposed to identify how information within the model can support managing operational and maintenance, which can be considered as *emergent* aspects for a space.

Building occupants

For building occupants, the feedback began by asking about different concerns related to a piece of equipment such as furniture within a space. The researcher had to provide examples, to explain how the model could be used. On responding to different concerns related to a facility in a space, the occupants responded:

"*In a work situation, I think the positioning of a facility, say a desk, is ultimately important, as some people have sensitive data, I mean ideally everybody might prefer to sit in a corner, but that's not realistic*"

"*That totally depends on what space I am in, in our office space for example, I think some facilities need to be fixed in terms of location so people do not move it around, definitely where a facility is located is important because it will affect how people move, which can cause disturbance*"

The above responses show that different attributes such as positioning (orientation), location and flexibility are important for building occupants. It also showed, based on one of the occupant's example, how a location of a facility may affect movement within a space, which shows the value of different connections between attributes within the space strategy model. The feedback demonstrated the value of these connections in terms of identifying some of the *emergent* aspects.

Value of the space strategy model to improve BIM

As part of the aim in this thesis, which investigated how BIM can be improved to deliver better building performance, the potential value of the model to enhance BIM was explored. To investigate that, the building designer was asked about value of the space strategy model in terms of identifying data requirements for a space. On responding to this, the building designer stated:

"*There is a lot of work to be currently done in terms of categorising the information within BIM, so obviously we got information embedded in our models, all which are chucked into one pot. So if I refer back to the HVAC system example, your model can help categorising different information related to HVAC system, which we currently cannot embed in our models. For example, in terms of control it is telling where that piece of kit is controlled from, as you know, there are loads of kits in a building, but the BIM model cannot help you in identifying how each kit is controlled, so it is very useful information for a technician who will need at some point to check or repair that piece of kit*"

The above response shows that BIM currently lacks a way of representing information, which is used differently by different stakeholders. Thus, it can be stated that the proposed space strategy model provides a flexible way to look at different information and its impact on different stakeholders, and how this could support enhancing future BIM models.

Summary of the feedback gathered on the space strategy model

The feedback gathered on the space strategy model showed only a limited 'validation'. The current space strategy model was shown to be useful as an 'inquiring model', however, it requires further development and use in practice before it can be fully validated. This development can include transforming the model into a computerised model, which then can be used for inquiring into enhancing building performance during design at which stage it can be tested for validation.

6.5.4. Concepts of space as information

The use of soft systems analysis in the previous chapter showed that current representations of space are limited, as they do not support representing many emergent characteristics that influence experience. Perhaps, the primary purpose behind this limitation was picked by Holzer (2011) who argued that once an architect's knowledge is conveyed/expressed in drawings, it becomes difficult to explicitly represent the useful knowledge that can contribute towards the decision-making process. Even with advanced architectural technologies, the representation of space information is complex and often tends to be implicit. Robertson (2011) stated that the heterogeneous phenomenon of space implies that its information is constructed by combining different spaces of information, which he called as 'semantic space', 'screen space' and 'interaction space' (explained in section 2.5.2). However, it is not clear that this categorisation of space information proposed by Robertson (2011) can support decision making, as it is more related to the capability of the technology used to represent space. On the other hand, it represents a reductionist view of space where the combination of these three categories (parts) should drive the whole, which has limitations.

The information of space within BIM are mainly held within its IFC (Industrial Foundation Class) structure or in native model structure, which is difficult to present using 2D/3D representations. It then becomes the issue of whether this embedded information is used at all, and how. The argument created in this thesis is supported by the literature that considers BIM as an aggregation of semantic, topological and geometric information. A recent work by Lin (2015) suggested that one of the shortcomings of space semantics within BIM is its capability to represent the topological characteristics (e.g. adjacency, overlapping and separation) within the space. Although, the topological characteristics are easily detected by the architect, it is difficult to represent them within the BIM environment. The consideration of such characteristics and many others is important, as they influence different experiences within the space. The representation of such characteristics within BIM models often require a special algorithm (or multiple algorithms), which then can be used to represent a certain characteristic (or multiple characteristics). These algorithms will always be not completely sufficient because they have a particular focus, and do not provide a holistic view over experiences within a space. Although identifying information requirements through the use of soft systems can be argued to be reductionist, the nature of soft systems in providing a holistic view has supported identifying the bigger problem, which is about acknowledging the value of parts through understanding the whole.

6.5.5. Framing informating perspectives of space

The space strategy model presented earlier (Sections 6.5.1 and 6.5.2) provided an attempt to inform different stakeholders' views of space. The information used was derived from those identified using soft systems analysis in the previous chapter. It can be argued that the proposed space strategy model provides a richer representation of different stakeholders' views of space. This is because it provides a way of identifying how different parts influence different stakeholders. Each representation dictates a certain level of information, derived from data presented in that representation. Knowledge is not easy to elicit from the digital representations, as it is gained when experiencing that representation in reality. Although it is acknowledged that many psychological studies on space have made it more dynamic and tangible, knowledge cannot be gained unless living or experiencing it.

The use of soft systems has allowed a holistic view of space through identifying additional parts that support the delivery of the whole. In this sense, space became a richer characteristic where people's experiences are acknowledged while raising the significance of different parts that influence these experiences. This is essential, as the technical capability of those who were involved in this research has varied. This has been demonstrated by Kotiadis (2007) who used SSM to determine simulation study objectives, where there was a need to explicitly describe different processes involved was essential to establish a trust link between the client and the modeller. However, the study conducted by Kotiadis (2007) have followed Checkland's (1999) approach where a conceptual model was produced to be compared with the original system whereas in this research, Wilson's (1990) approach was employed, as this would support framing different information perspectives. Following on Wilson's work on soft systems, his methodological approach has supported analysing space as a soft system, but also supported defining different information categories, which supported constructing the space strategy model described earlier in Sections 6.5.1 and 6.5.2. As a result, forming this information mode of space has provided a more coherent view of space, and more significantly, the impact of parts on different experiences has become more recognisable.

6.5.6. Informating performance of space in design

The primary aim of this research was to enhance performance in buildings, and use BIM to aid achieving this better performance. The space strategy model provides a way of representing information in a way that supports recognising the significance of different parts and how they influence different experiences. The use of such model can be in terms of 'informating' decisions about the designs of space using BIM. The concept of 'informating' proposed by Zuboff has been used in sensitive sectors such as the pharmaceutical sector (Kaiserlidis and Lindvall, 2004) where a study conducted on both customers and end-consumers showed how the use of 'informating' has supported increasing knowledge about a disease and related aspects to the disease. It can be argued that BIM in its current form lacks the capability to represent the significance of different parts that influence the performance of space in a building. This is because BIM models are automated and information is gained depending on both the capability of the software application used and the data provided. Therefore, a proposed solution such as the space strategy model can act as a prompting and inquiring tool to support adding further data requirements, and modify decisions at an early design stage. The use of entities and attributes to categories information within the SSM can support recognising the current shortfalls of BIM and perhaps propose a new way of handling information that supports recognising the significance of different parts.

Chapter Seven - Conclusions and Future Work

7.1. Introduction

The aim of the present research is to explore how the use BIM (Building Information Modelling) can support the delivery of better performance in buildings. Findings show that there is a gap between *data* and *experience*. Systems thinking was used to understand the nature of this gap, and showed that it could be related to a problem about 'the parts' and 'the whole'. Soft systems analysis was used to provide a holistic understanding of the problem. The use of soft systems identified the information requirements that can bridge the gap between data and experience. Chapter 6 (the discussion chapter) provides a richer view by exploring a number of themes.

The first theme shows that there are different 'abstractions' of performance experienced by different stakeholders, which results from different understandings of the parts and the whole, and shows how the use of soft systems helps understand these abstractions by providing a holistic view of the problem.

The second theme looks into representations of performance, and shows that current tools such as BIM lack the capability of representing many emergent characteristics that influence experience. It was emphasized how the use of a Maltese Cross (Wilson, 1990) in representing information requirements has provided a richer view of what influence different experiences.

The third theme shows the value of considering 'space' as a reference for *performance,* because, as a concept, it simplifies levels of complexity between the parts and the whole, and provides a medium where different meanings by different stakeholders can be situated. It was argued that the current representations of space are merely representations of a designed physical system of the building, which do not provide rich understanding of the whole. Soft systems analysis considers the significant of different parts that influence space and identifies information requirements that can support bridging the gap between data and experience.

The final theme looked at 'space' as *information*, and used the information requirements identified using soft systems further to propose a solution that can support bridging the gap between data and experience. The proposed solution was a Space Strategy Model, which was constructed using the information categories identified from soft systems analysis and represents different information requirements using *entities* and *attributes*. The model proposes the method of 'informating' (Zuboff, 1988), which supports recognising the significance of different parts and provides better recognition of the emergent characteristics that influence experiences for different stakeholders.

This chapter aims to explain the achievement of the research objectives, provide research contributions and outline research limitations and opportunities for future work.

7.2. Research Objectives

In this thesis, four research objectives were outlined: (i) to review the theory and practice of building performance, (ii) to determine the perspectives of the building delivery team, facility management team and building occupants on performance and different performance aspects (iii) to explore the role of BIM in the delivery of different performance aspects from the perspectives of the building delivery team, facility management team and building occupants, and (iv) to propose a model that acknowledges the perspectives of the building delivery team, facility management team and building occupants on performance in order to synthesise an approach that informs data requirements in BIM to support the delivery of better performance for buildings.

7.2.1. The theory and practice of building performance

This objective was achieved using secondary data obtained from the literature review. The literature provided a review of theories and practices of building performance, and included gathering insights into the evaluation methods as well as performance's various aspects. Theories of building performance claim that performance is a complex concept and does not have a unique definition, as it is a perspective-based concept. Many performance evaluation methods and techniques (e.g. POE, BPE and TBP in section 2.2.2) were reviewed, and showed that they are timely, impose additional costs, lack accuracy and do not handle information well. The use of Information Technology such as BIM overcomes many of the difficulties that are inherent in the performance evaluation techniques. Many BIM-based applications and tools that are used to evaluate performance for buildings were reviewed, which showed that BIM provides a way of handling multiple information from different stakeholders. It was argued that BIM applications often excel in evaluating quantitative based aspects, which do knowledge the holistic nature of performance.

7.2.2. The perspectives of the building delivery team, facility management team and building occupants on performance and different performance aspects

This objective was achieved using the secondary data from literature and primary data using interviews with the targeted stakeholders. The literature provided insights into different stakeholders' views of performance and showed that building performance mainly emanates from stakeholders who are in the building delivery team such as designers and clients. The literature review also highlighted studies that incorporate the views of those who use the building such as building users, but these views are principally obtained using feedback gathered from methods such as POE. Building users are not currently sufficiently involved in considering building performance. Semi-structured interviews were conducted to inquire into building performance from the views of the building delivery team, facility management team and building occupants. It initially targeted three performance aspects: energy, space and maintenance, but later focused on ‘space’, as it provides a reference where different meanings on building performance by the three targeted stakeholders can be situated.

7.2.3. The role of BIM in the delivery of different performance aspects from the perspectives of the building delivery team, facility management team and building occupants

This objective was achieved through using the primary data gathered using interviews with the targeted stakeholders. Although the literature provided an overview of current BIM role for building performance, it was important to get the views of different stakeholders on how BIM can facilitate the delivery of different performance aspects. The interview questions partly aimed to get the views of the three targeted stakeholders on the value and barriers of BIM in achieving performance for different aspects. The initial inquiry has looked into the role of BIM for energy, space and maintenance, but as the research progressed, it mainly focused on performance of space, as space was chosen to be a reference for performance. The findings showed that the value of BIM for different stakeholders is different, particularly where this depended on how BIM could satisfy their needs. The building delivery team claimed that BIM is useful to incorporate multiple pieces of information, but currently has limitations in terms of satisfying the client’s needs. The facility management team claimed that BIM Models should be a reference where information on the building can be obtained, and that it should allow their views to be incorporated at an early design stage. The building occupants’ view of BIM was in terms of how it enhances their experience.

7.2.4. To synthesise an approach that informs data requirements in BIM to support the delivery of better performance for buildings

This objective was achieved through the development of the Space Strategy Model. The model has different information requirements using entities and attributes. It allows the significance of different parts by different stakeholders to be recognised. Feedback on the space strategy model showed that it supported recognising different information requirements and concerns by different stakeholders. The feedback also showed how the space strategy model provided better recognition of the emergent characteristics, which are often experienced when the building is occupied. Such emergent characteristics were referred to as 'intangibles' because they are hard to identify unless experienced. The model also supported identifying potential improvements for data requirements in BIM through categorising information and identifying how they affect different stakeholders. Thus, based on the feedback of the model, it can be suggested that data requirements in BIM should be 'informated' (Zuboff (1988) in order to recognise the significance of different parts and support richer recognition of emergent characteristics that influence different experiences within a building.

7.3. Research Contributions

This thesis aimed to explore how BIM can help achieve better performance for buildings. The main contributions are: an information strategy that supports a richer understanding of experience and data, an overview of the innate challenges of building design to meet expectations of building performance, and greater understanding of the cognitive and perceptual views of stakeholders in building performance.

7.3.1. Information strategy for building performance that supports richer understanding of experience and data

The research identified a gap between data and experience, which showed that current modelling approaches for building performance, such as BIM models cannot fulfil. This is because current BIM models ‘automate’ information, which although they support delivery of the building, they limit how the generated information impact different stakeholders. In doing this, experiential considerations are limited to the data incorporated in the models. The use of soft systems analysis provided a holistic approach that supported richer understanding of the gap between data and experience. This is because it recognises the significance of the parts, and identifies information requirements that support fulfilling these parts to support bridging the gap between data and experience. The space strategy model provides a way, which suggests that data requirements in BIM should be ‘informated’ to recognise different stakeholders’ experiential needs and concerns. Proposing Zuboff’s concept of ‘informating information’ over ‘automating information’ would allow further insight into new knowledge, which can potentially support the effectiveness of future BIM models.

7.3.2. Innate challenges of building design to meet expectations of building performance

The research found that current building designs often restrict the ability to account for emergent characteristics that influence experience. This is because these building designs define the parts, which assume that they will assure the delivery of building performance for a building. Although BIM has a degree of flexibility to embed information in multiple forms, it has limitations in terms of meeting expectations of building performance. Like other modelling tools, BIM is automated, which means that it processes data in certain ways to represent information. This automated process is limited through its ability to acknowledge information that influences experience. The use of soft systems indicated that current design representations need to be information rich in order to meet performance expectations. The limitation of data requirements in BIM through holistically inquiring into the parts that influence the whole show that recognising the significance of parts requires going beyond current automated BIM processes. The use of soft systems as an analytical tool in this research, which often is applied methodologically, provided a way that can be used to overcome challenges when delivering building performance.

7.3.3. Greater understanding of the cognitive and perceptual views of stakeholders in building performance

Understanding different stakeholders' interpretation of building performance is complex, as views, because they are influenced by the perspective of an individual and the context. The use of systems thinking supports the understanding that views of stakeholders on building performance can be reductionist, holistic or both. This shows that stakeholders have different views of the parts and the whole. Although this has supported understanding the perceptual views of different stakeholders, managing these perceptual views is not a simple matter because there are many levels of complexity between the parts and the whole, which are difficult to situate in accordance with different perceptual views. Thus, choosing 'space' as a reference concept for performance was beneficial, as it supports situating these different views, and provides a medium where the parts and different emergent characteristics that influence the whole can be communicated. The use of soft systems showed that using space as a reference concept has supported richer understanding of the parts and their significance based on different views on building performance.

7.3.4. Proposing a richer way to tackle complexities in delivery of the built environment

The use of systems thinking to tackle the complex nature of building performance has provided a richer way of handling expected complexities in the delivery of buildings. This thesis has supported identifying the potential significance of several research areas within the literature. The area of information modelling is rich in its nature, and been acknowledged through several research contributions, but through the use of soft systems within this thesis, it provided a richer way to tackle complexities in delivery of the built environment. Buildings are complex environments, hence theories and concepts have been created to manage these complexities, which the literature have acknowledged in areas such as building performance and space. However, the transformation of these theories and concepts within the digital era require a rich understanding of the information world in order to solve the complexities in a situation. Thus, it can be claimed that this thesis has supported acknowledging the value of information world to investigate complex areas such as building performance, and discover the limitations of automated technologies such as BIM.

7.4. Limitations and future work

This research provides a rich understanding of the problematic nature of building performance, and shows that data requirements in BIM need to be 'informated' in order provide richer recognition of many emergent characteristics that influence different experiences. However, there are some limitations, which future research could be address. These limitations can be summarised as following:

- The Space Strategy Model proposed 'informating' as an approach that supports recognising the significance of different parts and richer understanding of the emergent characteristics in a building. However, the model has not been validated with the targeted stakeholders, so additional information may be required. This information can be additional entities, attributes or more connections between different attributes.

- The research has provided a review of the role of BIM applications in meeting different performance aspects of buildings. However, the research did not look into the *technical* capability of different BIM applications. For example, interoperability and the flexibility to embed different types of information. Future research is needed to identify whether many of the types of information identified in the Space Strategy Model can be incorporated using different BIM applications.

- The number of projects (case studies) and participants (targeted stakeholders) were limited, and future research should investigate the issues of 'performance' with wider audience and variety of building types.

- Although the use of soft systems analysis has provided a rich understanding of the problem being investigated in this research, the developed 'rich pictures' and 'conceptual models' were not validated with the targeted stakeholders in this research.

- Future research will seek to investigate further implications of soft systems thinking on identifying different stakeholders' needs and requirements within a construction project, and whether it can be used as an efficient medium for collaboration at an early stage.

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Appendices

The appendixes includes the data gathered, which was referred to in chapter four. The colour coding is also been referred to in chapter. For the purpose of clarity, an example will be given:

"***I think it's about saving money, so what we are looking for is a cost effective building, value for money, deliver what we want for the occupants, and try and reduce as many issues as possible***" (WC, 4.5, 2, BC).

The above quotation refers to 'Office Building, Table 4.5, Question 2, Building Client'.

The colour coding used on the left column in each table refers to the 'theme'. For example, in table 4.2: the green shaded questions refer to responses towards the theme 'definitions of building performance'

Educational Building 1 Case Study Data

Table 4.2: Extracted responses from the interviews conducted with the building delivery team for Educational Building 1 case study

Question focus	Energy Assessor (EA)	Project Director (PD)	BIM Coordinator (BC)	Designer (D)
Role in the project 1	BREEAM Assessor, responsible for carbon and energy reduction.	The Project Director.	A BIM coordinator for the project and that involved keeping an eye on the designers and the contractor.	Architect and BIM Manager. Lead designers through RIBA stage A to E, and to contractor as their architect for stages F to K.
Perspective on performance 2	***It is whether the building can function adequately to meet the need of the users and do that in a sustainable and low energy manner***. ***For me, there is no point of building being with very low energy, it's not going to be usable***.	***My background is actually maintenance, so I am very focused on the operational part of the industry understanding how the building perform***, ***how the long longevity within them so the quality of the building itself and its effect on the long-term maintenance***. ***From my perspective, building performance is related to maintenance, energy and operation, and also all the systems within the building, so it's about maintaining all the level of understanding control and maintenance.***	There is an understanding that building performance is to do with ***energy efficiency*** etc., which to some degree **you can use BIM to start to measure that before you start to build**. For me, ***the efficiency side and performance side is actually to do with maintenance*** **and the ability that BIM gives you to be able to save time, and hopefully time, resource, money would allow access a lot better and more accurate information and even design information from the BIM models.**	So many different criteria to assess and ***achieve a balance between:*** ***aesthetics***, ***robustness*** and ***durability***, ***thermal comfort***, ***appropriate levels of natural and artificial light***, ***energy usage***, ***flexibility to suit changing uses***, ***acoustic performance*** (both teaching and specialist), ***capital budget*** and ***ongoing maintenance costs***, ***brand identity for the university***, ***clarity of building diagram*** and ***organisation of spaces to avoid clutter of imposed signage***, ***integration of services with structure and building fabric***, ***accessibility of building*** and ***its uses to all***.
Improving building performance 3	The main starting point is ***if the building is being designed correctly***.	***We would like to deliver a building that performs to its optimum capability with the constraints, budget, time, etc. so it's just about***	***From my perspective, and using BIM to be able to do that, we are able to very quickly access information considering that speed that BIM can provide you and from my view to be able to***	***Longer design program***, ***allowing for more design iterations***, ***including testing***.

	In the case of Educational building 1: the input to the design process is important, ***making sure it is low energy built, constructed according to the design, the high quality aspects have not been value engineered out, managed properly, systems have been maintained correctly, and work efficiently, the users know how to operate the space,*** **for example, they don't open windows if it's too hot, the occupants also need to know how to operate complicated systems like lighting.** ***In terms of usability, the space has to function as designed to meet the needs of the users so there is a sort of building services there as well.***	***maintaining at that level of performance***.	***access that information***, **which is many, you can get to the manufacturer information, maintenance information**. ***It's also about not losing information during the design of the building.***	***Better integration between design and analysis software*** to ***reduce lag of analysis results behind design, allowing for faster iterations of design***.
Achieving building performance for users, facilities and clients 4	***Obviously Facilities management is critical because a lot of the work that we do which also my colleagues at the estates department is quite reactive So if the building does not perform***, ***then it won't meet the user needs***.	***It is important, as we are investing in clients, the students, also the staff that work within that space***, ***so it's all driven around what they need***.	**We currently use our BIM models that were produced for the design and building to become the version of the truth** where estates manage these models and then that ***information automatically gets pushed out to everybody else who needs that information***.	The university ***own and maintain their own building stock***, ***and so need to maximize their assets for most efficient usage***. Also, the results of the "Student Satisfaction" survey are an important factor in attracting and retaining students.

Standards incorporated to achieve performance for energy, space and maintenance in the building 5	***Specific standards, as we obviously got to comply with the building regulations.*** ***For Educational building 1, Educational building 2 and other big project that we do, we will design them to BREEAM excellent.*** ***My role is to reduce the amount of energy that university uses so I will attempt to influence designs down the road.*** ***For maintenance, how well we maintain our estate is determined by how much money we've got***, ***so you've got to prioritize the safety stuff, got to make sure that fire alarm works, the emergency lighting works.***	***There are always minimum standards (the building regulations) and that's actually been the main driver for us, it's driven by building control, there is a building consultancy, and it is a regulatory requirement, that along with guidance with lots of CIBSE and other organisations, so it tends to take a fairly balance approach against what legislative requirements ask us to do and then where we are asked to optimize them, we'll look at that in a bit more detail***, ***but the problem we always get is where we sit against the budget, so it's how you brief the design team to deliver something that's above the norm***. ***So what we look to do the optional principles that bring us forward to BREEAM excellent, which at the time that we are committed that's quite difficult to achieve.*** ***It wraps the whole issue of energy performance, sustainability, and operational issues.*** ***Maintenance wise, we tend to try to drive the specification to a need,*** ***so what we are really controlling over not necessarily legislative side, but more of a specification side.*** **For Educational building 1, for example, as we wanted accessibility to**	***Certainly energy***, ***because this is part of the British standards***, ***but the university has its own space standards***, ***but in terms of space, they are not tight if that makes sense as the British standards.*** ***In terms of space, we are talking about the amount of people you can fit in within the space***.	***Energy***: ***BREEAM***, ***EPC*** (Energy Performance Certificate) ***Space***: ***Client's space brief*** / ***schedule of areas required***; ***SMG (space monitoring group)*** typical areas for teaching spaces, workplace regulations for office areas. ***Maintenance***: ***25 year building life span (components) and 50 year (structure). Design for robustness as BREEAM Mat7.***

		<u>**services, we went for a raised access floor.**</u>		
Value of the BIM model to achieve effective performance for energy, space and maintenance 6	***It has the potential to be useful, very powerful tool, and its main strength is one place where all information can reside***. ***So if you have incomplete information in the model then it wouldn't be for any use, but if you use it well with its capacity, then you can get appropriate properties about room, its main functions, facilities and so on.*** ***BIM is less of an energy tool than it is a facilities management tool, so there is probably sort of scope to increase the energy relevance at BIM.***	***It certainly contributes towards it, but it can't so just on its own, not on its current form. The things we found from a design point of view, not operationally, it doesn't link through some of the energy performance, energy control models that we have to produce, and it's more of a software issue I think.*** ***BIM can potentially contribute towards maintenance,*** **but energy wise** ***we haven't quite got compatibility between BMS (Building Management System) system and the model itself***. ***Space tends to be fairly static, so you can for instance move walls around, but once you got pass the design stage, it's all about the operations and systems within those spaces.***	***Certainly maintenance and space, not so much energy at the moment, but we are looking at how we can start to bring energy data and looking at whether we can get energy data into the models.***	***Energy***: ***Modelling the whole building in 3D allows for visual checks of continuity of insulation on complicated junctions***. ***Simple early stage analysis (Vasari) on concept massing allows window and shading sizes to be optimized for building orientation and solar gain.*** ***Space***: the ***BIM can schedule achieved areas or volumes against a design target set in the brief and display shortfalls graphically*** (i.e. coloured rooms on plan that fall below the required targets). ***The facility for the user to "walk" the building in the BIM*** (Navisworks Freedom) ***allows them to assess the spatial requirements, including furniture, which often gives users more of a "feel" for the space then viewing traditional 2D plans and section drawings***. ***Maintenance***: ***Modelling of required access zones for plant maintenance or replacement allows optimisation of layouts***.

Barriers of BIM from being an effective tool to deliver building performance for energy, space and maintenance 7	***It is the information you put in, but also the quality of the build for the BIM model itself*** **I think that BIM have the potential to provide structured data if it can export out reports as in this is how much energy used by a particular space of the maintenance task or the average temperature**.	***The BMS should be linked to energy performance monitoring***. ***Spatially, it's quite restricted what you can do beyond an appreciation for the space itself, so one thing is that BIM in its current iteration lack is that visual connectivity to the building itself so it gives you an understanding of the form and shape but not necessarily how to actually physically looks.*** ***When you get the maintenance people familiar with the model itself and they're people who are going to look at it daily, and it's about having that streamlined approach to get that information, BIM can be very powerful tool for maintenance people.***	***I don't think that BIM can look at qualitative aspects of a building, because you've got so many different aspects to building and not all buildings are the same***. We are not making another building of the same building, or the building components or the materials, all interact completely different anyway, and that's the job for the architect to make all that work. **For example, window could have a bit of a write up how it performs, and that actually sits within Revit, and you probably could schedule that out within Revit as a document.**	***Energy***: ***Lack of compatibility between BIM authoring software and analysis packages limit number of iterations of a design to achieve optimal solutions***. ***Space***: ***Accurate briefing on predicted space use – rooms designed as a 2-person office may overheat if used as a 6-person meeting room.*** ***Maintenance: timely confirmation of FM requirements so that they can be built into the model from the outset, and not added later in the process.***

Table 4.3: Extracted responses from the interviews conducted with the facility management team for Educational Building 1 case study

Question focus	Building Services Supervisor (BSS)	Facility Manager (FM)
Role in the project 1	I am the campus services supervisor.	***I am the facility manager for the building, so I look after the cleaning, some aspects of security. I am the advocate for the building users, I do fault reporting, I make sure maintenance is done on the building, I make sure the building is setup correctly, basically it needs to be fit for purpose*** or **for teaching, and for seminars, or for activities which needs move furniture around, but basically it needs to be fit for purpose, or whatever the event has to be.**
Perspective on performance 2	***From my perspective, everything operates within working order and what the customer needs is there for them. I think that a good performing building is having what the customer expects.***	***It needs to function in a way that keeps the occupants comfortable and I suppose it depends what perspective you look at it.***
Improving performance 3	***I really think it comes back to the specification and it comes down to what the customer wants*** because I have been part of the **user group in BIAD form of all the heads of departments, technicians, so that they can take the form, take the message to the architects, to the estates department as in this is what we need within the boundaries and the size of the building**.	***That it just works***. **As for Educational building 1, it is functioning better but because of the energy consumption requirements then certain tolerances have been put into the building so not all the building is mechanically cooled. So there is aspect of the building, which is south facing, which are not mechanically cooled**. ***In my opinion, I think that customers need to understand how to operate within the building***.
Importance of facilities management, occupants and the owner 4	***I think it's very important, because we have to know how the systems work obviously, because once the soft landings people have gone, it's all down to us, electrical, mechanical***. **Educational building 1 is the first time we've been involved in the input as to what type of carpet goes down, what kind of flooring goes down, not me personally, but the senior management, they are the ones who gave the architect the specifications for what we want, you know, simple things that are even down to bins (recycling bins), that is the kind of input**.	***I think it is very important because I am the advocate***, **in this setting; facilities management and the maintenance contract with estates are in difference command chain, so they are in different silos. I think it would help if they have the same boss so that we would work together more, but sometimes you get it from both sides, the customers don't really appreciate that you are in their side because you are not solving their problems, and then estates who you are trying to get to solve the problem they don't get it first hand, so they are not necessarily always on your side either, so you in a battle with the customer even though you tell them I am on your side, but you are in a battle with the estates as well because they are not doing things quick enough or responding quick enough.**

		With Educational building 1, I suppose things have been a lot more easier because we have had the soft landings
Standards incorporated for facilities to achieve performance for energy, space and maintenance in the building 5	***Energy, we rely on the users for a certain extent, but also I need the customers to be comfortable****; the heating system has got to be adequate*. *As for space, it's been a problem since they moved*, **because people have failed to realise that this building is not built for events, this building was built for BIAD and PME to house them, give them better facilities, that's what the building was built for, but it wasn't built for events, so when we get room bookings, for us campus services, it's a logistic problem because we have to remove furniture because they want a room say for instance fashion have got these big cutting tables**. **I think one of the main things as well was when the building was built and before occupancy, people were coming around and say yea look at that space, we could use that area for so and so' not thinking that in six months' time when the building is occupied, the area is not going to look like that. It's going to be full of tables and workbenches.** *As for maintenance, we have this reactive maintenance system*. It is basically reporting faults and you go on the system and students use it or they should be able to use it like at the all residences.	*Space, we don't have any space standards*, **I know that in Educational building 1 they did some space standards per desk space because of going from central offices to open plan offices so I think there was a space standard, but generally within this building, or throughout the university, often when they construct something new, I don't think we have space standards where we say ok you can't be in that massive office because really you are wasting space**. ***With the public space it is ownership, who has ownership and that's something they are trying to define at the moment. For me, the facilities manager, I should own that space and we should be able to say, yea you are allowed whether you can do something or you don't, that is not 100% defined at the moment, yes a lot of people do come to me to ask if we can do various different things.*** **There are other things that happen where I don't see the direct correlation where it is going to benefit the students so the public space is definitely ownership and also keeping it in an orderly fashion, so for me within the design of the public space, I would have had a lot of furniture secured so it can't be moved because students love moving stuff and they never put anything back. I think ownership is the major issue because you have offices next to the public space then you get offices that send letters to complain to me.** ***As with the private space, the only problem I have with the private space is whether the space is been used efficiently or not*** **because if you walk around some of the academic offices, there seem to be a lot of empty desks for me. In Educational building 1, the problem they had was getting used not having separate offices, getting used to be in an open plan spaces and also the problem we have with private spaces as well is people get very territorial and because over here we had the**

		problem and over there we were going to have the problem until I said no, because it is a swipe access into the office space. ***For maintenance, Educational building 1 has been quiet good because we have got soft landings which means that for the next three years to sort out any issues, any problems,*** I saw what planned maintenance are meant to do in the building and they seem to be following that, we haven't had any major issue really. **I think we are going to get some issues like light bulbs and stuff like that just because of the way it has been designed because architects always design buildings for a static pleasure, but they never design stuff that with taken in account how you are going to change stuff like light bulbs.**
Value of the BIM model to achieve effective performance for energy, space and maintenance 6	I am not familiar with BIM, I have heard about it, but don't know its capabilities.	***Hopefully it would provide an accurate record, it will be easy to find what you need to find,*** **because at the moment with O&M (operation and management) manuals we have huge amount of information which could be smoother and easier to manage through BIM**. *I* ***have seen the BIM models, and I know what we were supposed to achieve with BIM, but I don't think we're there yet; it is still a working progress*****.** **I think they finished mapping the building where how much maintenance information in there I haven't been shown, and** ***it would have been interesting to see how much maintenance information are in there and how accurate it is, and how easy is to get the information.*** ***For me, the ease of retrieval will be the biggest thing*** **because as I said before when you get massive O&M manuals that will be too much of trouble trying to find the right value, trying to look through divided by section, even if you get indexes, still it is a problem**. ***If you can just put in a search into BIM and it will come up and show you with the specification and it can show how things were in the building and how they are now when you changed them, then that would be great.***

Desire to be involved and provide input for a new building 7	***I think so, we have always said that we should be involved from day one; from they pour the concrete*. *The reason is that we always want to please the customers*, *and the same time we can't*, the customers are fine and they understand, we are just doing what we can.**	***For me I would like to know all about the finishes, all about the over Mechanical and Electrical systems and I would like to know about their layouts.* *I would also like to know about occupancy levels* <u>because you get a lot of complaints with people in a room saying it's too hot in here while the room is designed to only hold three people and you have 20 people in there then of course it is going to be hot in there or whatever because your room hasn't been designed for 20 people but it's been designed for three</u>.** **<u>A lot of information seems to get lost as the room use change or people change the setup of the room so you don't know how the room has originally been designed just by counting how many chairs are in there because it is not static enough, it is too portable to keep that information, but when you are looking back how the room was designed and with what occupancy level, you can't ever find that information</u>.**

Table 4.4: Extracted responses from the interviews conducted with the building occupants for Educational Building 1 case study

Question focus	Occupant 1 (O1)	Occupant 2 (O2)	Occupant 3 (O3)
Role in the building 1	I am the deputy head of school of architecture.	I am a part time senior architect	I am a full time senior lecturer at school of fashion
Perspective on performance 2	***Depending on what the building is supposed to be for***, **if we take Educational building 1 for instance, there are various parameters such as feeling, as in how the building makes you feel, other parameters can be energy & comfort (heating and cooling), there is also connectivity in terms of how many various people connect through the spaces within the building and** ***there is kind of baseline functionality on whether things work or not & assess the quality of works perhaps***.	***Performance is the way that allows me to deliver my job. I think also that there is aspect of performance, which is the atmosphere that I think it is difficult to be ensured***. **Taking colour for example, different colours give different atmosphere to the building. Also, facilitating social environment like the case in Educational building 1, which again support the atmosphere on the building.**	***It is how it works for me and whether it is suitable or not for what I want it***. **For teaching for example, we need the building to be functioning in the way that it should be functioning.**
Improving performance 3	***Post-occupancy study as it will be really important to learn from people's experiences in the building***. ***There is a new part of the RIBA plan of work, which says post-occupancy, could be incorporated within design and build. I think that there should be space system setup within the building for people to give feedback loop to the project office but that should be proactive***.	**Applied performance such as colours like mentioned, but again this is early rectified when compared to some health and safety issues.** ***Health and safety in some ways can colour the views of performance for people in a building.*** ***In a way, occupants should understand how to use the building.***	***I think that it's about understanding how you can operate within the building***. **In Educational building 1, as you know, we have got many facilities within our school that need to function within a certain way so that students are comfortable when they do their work**. ***I think there should better understanding of how we can report issues and problems and get feasible timing for the time needed to fix them***.
Importance of facilities	**I found out that most of the maintenance and daily running operations people are much more interactive with us**. **Some**	**The spaces should be kept tidy so it doesn't become messy. There are some breakdowns like for instance the photocopiers.**	**I think that the furniture within the open spaces is too big, and some of the sockets do not sit down properly**. **The positioning of some**

4	**problems we have now, some facilities are not fit within their spaces, and we don't necessary have the right furniture**. So, ***it's really complex matrix of interconnected things and you needs users to understand what you are trying to achieve***, ***so designers need to involve users.***		**facilities, for example the projectors, they really need to be thought of carefully**.
Value of the BIM model to achieve effective performance for energy, space and maintenance 5	***It's a potential rich information management tool and it can harness complexity and can involve different people to manage different information***.	***Theoretically, yes, but the danger I would emphasize here is that some buildings may just be designed out by BIM.***	***I don't really know what BIM is, but if it allows better collaboration between occupants and people who design the building, then it should be useful.***
Desire to be involved and provide input for a new building 6	***I think that the involvement students, lectures, administrators, people who clean in helping to understand what makes a good building***.	**Informal atmosphere to work, and more emphasis on the learning spaces**. I think that Educational building 1 provides different alternative accommodation. ***As a teacher, the input will be how teaching is going to be***. ***I also think that there should be a consideration of how spaces have been utilised***.	***I think that we really need to specify the possibility of multi-purpose spaces***. **Currently, we don't have problem within the space in terms of the amount we got, but as we are going through a transitional period, getting used to teach in new teaching spaces.** ***It would be really good if we can also involve the view of students on how their teaching spaces should be, what facilities they think it will help them and what sort of various activities can be carried out within these spaces***. **One of the major concerns I have now, is whether our current spaces provide the right environment to work or lecture within, and that's something, which could be useful to be taken in consideration if I were involved when decisions were made for Educational building 1**.

Office Building Case Study Data

Table 4.5: Extracted responses from the interview conducted with the building client for the Office Building case study

Question focus	Building Client (BC)
Role in the project 1	***I am the head corporate landlord from Birmingham City Council**, **so my duties are management of the buildings, also the logistics side, so we hold the data for the use of the building and how buildings are occupied, the ratios***.
Perspective on building performance 2	For me, ***I think it's about saving money***, ***so what we are looking for is a cost effective building, value for money, deliver what we want for the occupants, and try and reduce as many as issues as possible within the budget planned for it***.
Consideration of performance aspects 3	***So one of the targets was BREEAM excellent***, which we achieved based on a 2006 BREEAM. ***We developed a CAPS policy and standard guidance***, ***so we were targeting 8 m^2/ workstation overall, 85 ft^2/workstation based on what we were looking for***. ***We also planned to have an energy efficient building, so it would operate within the boundaries that we're setting***, **we set the temperature here to operate within the range of 21 – 26 °C, so we got chillers that will kick in if the temperature gets too high and we got sort of solar based radiators (biomass heating),** we are also connected to CHP here from the university. ***In the design of the overall specification, we were looking to deliver as much comfortable building within the budget***.
Achieving performance for users and facilities 4	I mean this is a key one, and ***I wouldn't say in this building that we got everybody happy at the moment, we invested significantly in sort of BEMS-system, so it operates the building***. ***I mean from our point of view, we tried to make this place as comfortable as possible for people, for longer period of time, that was one of the reasons why we went for the sort of furniture we did, we also invested in the chairs, so all the chairs are ergonomic, they got longer support and other things***, **so for most people they can adjust the chairs as they like to suit their comfort rather than investing in access to work chairs**, ***but core comfort was a key I think in trying to design the building, and that's why we set all these parameters and the temperatures***. ***We did occupation survey after people moved in, like an initial survey on perceptions and then followed six months after that, then we are going to follow that annually. It was sort of POE***, **I mean 75% of people who responded that this work area was much better than the one they used to work at previously, and that was quite a positive thing for us**.
Space planning	***We did some 3D modelling, but most of the space planning was done in 2D really***, ***we already determined the sort of layout of desking that we were planning to use***. ***We gone through a process to choose the furniture that we were planning to use. We engaged with conceptual workspace***

5	***designers as well, we used square dots, so they came along, looked at the ecstatic's of space and how it would look when choosing a particular colour schemes. Then we looked at the occupants' use of desks ahead before they were used.*** ***So we were looking to utilise the space to try and make it non-demarcated, could simply be used and moved around by anybody, we haven't built cellular offices, we have built some meeting rooms, which seem like cellular offices but nobody has got their own cellular office. We didn't do a lot of 3D modelling, I mean there was some of that done initially, but it was very high-level stuff really.*** ***We had the CAP project team, we already decided our minds that we were going to adopt the AUDIT commission guidelines in the sort of 80s and 90s, 75² ft for a typist, 80 yard² foot for an admin and 160² ft for assistant director, and those are the things that we tried to work into our overall targets in going forward, but what we looked at here particularly was how we reduce space and try to make it as uniform as possible so the people couldn't really argue from building to building.***
Changes and issues with the space 6	***We haven't changed so much space within the building. I don't think that we've changed the space fundamentally really.*** **I mean there is an area on the first floor down there, where we've got to break out top space and storage, but that was to meet the needs for social care workers who were coming in, and that was located in that space, because its above the street, so it can be a little bit noisier, we also discovered when we occupied the building that that we should have done some modelling on the sun in terms of the way it comes around, and the relatively deep plan of the street would actually mean the sun wouldn't penetrate the building and create light issue, because on this front elevation we don't have any blinds or anything, so we had to retrofit internally and you can see up there the blinds are hanging, so that was something we had to introduce.** ***The floor layout has changed a little***, **we have tweet guests, so we have introduced them all workstations in some areas, and took some storage out to meet staff group needs of coming, so up on the third floor we brought a 100 or so contact centre staff from the corporate contact centre, they have slightly different needs to most people, I mean they are a call centre. If we move stuff around, then it's relatively easy, so people just pick up their belonging to move, so it's not like the old days, we as a corporate centre brought all the furniture, so in the older statue if you like, directorates hold their own furniture when they move, so if they say move from the ground floor to the third floor, they will take their furniture with them.**
Value of BIM to achieve building performance 7	***I think what we would have probably want to look at is the maintenance regimes, like command board, we were involved from the FM sort side, in the early part of the design***, **if you look around now, some of the features are very nice, provide the lighting, other than some of these down lighters, you see the ones that are not working currently, I mean we want to replace them, so you have got the cost of that as a maintenance issues in going up to those and replacing them, which is on-going.**

	I think the benefits coming from BIM approach would be around how its going to be maintained in the future**, **most architects don't have this as one of the top things in their list, they more look at the design, just how things will operate. **<u>I suppose if you look at some areas, I mean a lot of people will use the stairs, these stairs, the floating staircases you know, are fine for moving between the floors, but the main staircases almost tucked away a little bit, I mean you've got one at the main reception area, one on the very back, but they're not used much for circulation, a lot of people will take the lifts to be honest, because that's very easy to a certain extent.</u>**

Table 4.6: Extracted responses from the interview conducted with the facility manager for the Office Building case study

Question focus	Facility Manager (FM)
Role in the building 1	***I am the operations manager for two buildings, Office building and Lancaster one.***
Perspective on performance 2	***Building performance is the structures ability to best meet the needs of the building users as well as meeting legal and environmental standards. To elaborate a building can be constructed to meet the most stringent of environmental and construction standards, however, if it fails in supporting the needs of the building user then it has not performed as required.***
Improving building performance 3	***Designers really need to engage fully at the initial stages when conceptualising and designing a building with the client and the end user, particularly if there is a specific function that needs to be incorporated within the initial concept before any detailed design begins*. *This is the concept behind Soft Landings to ensure client satisfaction and for the design team to remain engaged with the building when it enters its operational stage until any after occupation problems are resolved*. *Likewise, the FM operator needs to have been engaged right from initial design if they are to maintain the building efficiently without disruption to the function or excessive ongoing revenue costs associated with impractical maintenance plans.* **However, there are many examples of generic buildings constructed which have to be adapted to client needs prior to occupation. These reverse engineered buildings very often do not fully meet the client's true needs and as such the building will never fully perform**. ***It has been my experience that generic buildings never perform as well as designs specifically developed to meet the users' requirements.*** ***Likewise, the internal environmental conditions need to be considered which leads into full environmental management systems (BEMS) being incorporated to maximise occupant satisfaction. Please remember though that no BEMS will ever satisfy the perceptions of all occupants all the time. This is typical of the complaints at the Office Building St Offices.***
Perspective on space performance 4	***To me, it's about operational efficiency*** because ***I am coming from a facilities management viewpoint***, ***so for me, the space needs to be well-defined, well-met, well-serviced and not break down, so to me that's the space performance, it's versatile so that people can adapt whatever task they want to do within that space within reason, so space utilization is getting the most versatility from the least amount of space and cost effective use of the space so you can reduce the amount of physical space that you have to manage, maintain and pay for, in other words, maximize its use.***
Perspective on good public,	***A good public space to me is a place where people want to be, not because they have to be, but they want to be***, so **if we take this area here at the front, people will meet people like yourself there for the business use, but if I needed to meet you after work for some reason**.

community and private spaces 5	***If we take this community space here, again it is not formal, it can be adaptable***, **in this case (referring to the Office building), it is a business community, its adaption tends to be for the formal things, not things where you are discussing personal issues or major strategic issues, but most everyday work can sit down in here and you can resolve them through discussions quite comfortably**, ***so the community space is multi-faceted, it can be for anything, but in this kind of environment, it needs to be sort of a channel towards its business focus like what happens in here. It needs to be flexible, so nothing is fixed, nothing rigid***, **if you need to think about lighting and power, lighting needs to be generic, it needs to be good overall even, so that you can adapt the space, power needs to be softly installed in locations where it is not intensive but its available, like floor sockets, setting to the raised floor, the carpet is over the top, it's not affecting or causing an inconvenience, not like the days of power pulse stuck in the middle of everywhere and desks have to go around it**, ***so to make it versatile, and it can be multi-faceted***. ***My main issues with the community space is the ongoing maintainability issues from an FM point of view***, **I can't repair the lights easily because the designers never thought about access arrangements, so when I do have to repair the lights, I either have to do it out of hours, which costs me more, or take the area out of public use, which has a business impact**. ***Simple design criteria could have been applied, which would make it easier to maintain, so this is where it's going on in the future, forward thinking, where it's sort of getting people out of silos, get them to work together, the architect gets the concept***, ***so it's all about versatility, maintainability, from an FM operational point of view it will be about serviceability***, **is it easy to clean? Are the surfaces a brush clean, or do I need to clean them by the end of every day? Is it carpeted, I mean that's selling food, so it's going to get trod in the carpet, or is it a hard surface that I can clean easily, but then you think, it's a hard surface, so am I going to get sound problems, am I going to get reverberation of the floors and the walls, so there has to be compromise like the ceilings got acoustic pad in it because it's a hard seat floor, so you get sound vibration so that sort of negates it and cause a reverberation tie**, ***so it's all about thinking together, not thinking in isolation, obviously you as an architect, you build the building, it's not ideal, well you are here for three years, you will find out what you've designed, and now It's affecting in because you've talked to him/her and you've designed it with them, so there shouldn't be a problem, but if you've done it in isolation, then you'll hear all about the bad stories, and you are going to have to put it right***. ***So community space is like value for me for real estate, real estate cost money to operate, real estate cost money to own***, **if I build another 1000 meters space on this and that was wastage space, I have got to heat it, light it, pay rates on it, clean it and service it**, ***it's all about making sure that client has the space they need for the foreseeable end-user of the building, make sure it is economic to operate, economic to use, but is of sufficient magnitude***. ***It really depends whether you need a private space or not? In a work environment, do you really need a private space?*** ***the private space comes then when you need the private space, it brings people as well by not giving people private office that they can lock themselves in, like being in an ivory tower, but engages people***. ***Your private space, you obviously need a little bit of space where you got sufficient room to move, sufficient room to put your cup of tea down, your IT and the stuff that you immediately needing without the person next to you elbowing you or someone behind you when they move their chair they are knocking you, it is that space ratio***, ***but your private space in the building is not totally private***

	space, it's your working space, there is no such thing as a private space in a communal open plan office, you only go private when you go into a with four walls and a door and a ceiling, it's your personal space more than private space I think.
Major problems with relation to space 6	***One of the main issues in the office accommodation is that an insufficient design time is given at the design stage for ease of maintenance that's all. This building costs twice as much per square meter to maintain when compared to the one over the road, purely and simply because I need to hire things, towers, scaffolding during weekends because I can't do the work during the normal day.*** **If the lights are out in this atria, I got to close the atria or come on Saturday and do it with a scaffolding because simple things could have been done, so the only issues I have with the space here is the maintenance issues.** ***The building users on the other hand are different set of issues, they have issues about the environment***, **some of the building users find its too noisy in the atria, some of the building users find that for some reason every time somebody comes to the revolving doors, a draft goes through there, blows around the land course, and that door is in use all the time.** ***There needs to be more and more computer modelling about the internal effects by the environment for the building users more than just the standards. You can design what you think is perfect, but you must do the follow up testing after and you will find that you will need to adapt whatever you find to suit the environment because there is no one size fits all, but via building operational point of view, you cannot allow the minority to dictate over the majority.***
Involvement in the design of space 7	***In my opinion as an FM operator, I have never been involved during the initial design stage; In the case of this building, I was asked after the roof would come on to cast my eye over it before we completed it and that's when I said I have seen now so many maintenance issues that you could have designed out and inherited, with this particular space, there are simple things that I could have done, far too many to mention, that wouldn't affect the overall ecstatic, but would have made the on-going revenue costs for this building a lot less*****. For example, the atria lighting, they all come from a flat roof on the top, put a chandelier wench on the top, you can get on the top, open the box and drop it down**. ***So you should come across CDM regulations, if you want to look out this building, CDM went out the window at the design stage, they haven't designed at safe methods of working, they have designed methods of working after the event to try and make it maintainable. Mobile elevated working platform great on an empty office, that's what they design for, people use the space, you can't get in, and you can't do the maintenance because it wasn't thought of.***
Value of BIM to support space design and management 8	***I think BIM can help you manage the space, and I think you need to look at it with an open mind when you do the designs. I would tend to focus on operational issues, the client would tend to focus on operational issues of a different sort, they would look at the people issues, the soft FM, I would look at the hard FM issues, because that's my specialism, that's why I am coming here for***. The designer would look at the overall ecstatic, but all that together, and ***I think using BIM has the potential to bring common sense to people, it has the potential to break down silos, break down barriers, and make people appreciate the importance of each others role. I would be looking at BIM model, with my hard FM hat on; I will be looking at space, looking at service clashes and all the stuff that goes behind the scene, but that tends to be the design stage, I think BIM is not just a 3D model and that's where many people think its only 3D and I think this is where it falls down, I think that BIM is a building***

	information management system and you got to get the physical information, but you have to think about the operational information that it requires. **<u>If I want to change all those desks at that level, and the building is occupied, how do I get it out? Do I put them all into those ting passenger lift, or do I throw them over the balcony. If we have got a good bigger lift at the back end, it would have no problem getting your supplies in and out, the porters with their trollies wouldn't be damaging the surfaces of the passenger lifts, because they will be bigger, stuff in and out into the loading bay, it would have been a capital cost, but there is a lift from the loading bay, it would have just making the shaft a 50% bigger.</u>** ***So to me actually, BIM isn't really necessary, it should have already been happening from the concept point of view where BIM does come in if people use it properly it lives the life of the building, once the building is constructed and the people are in it, if something changes, it goes into the manuals, it goes into the building information***. ***So BIM should be a life living model of the building, and it's also a lessons learnt for future projects, so you can use that information where if you use it properly, but involves engagement from the original client concept to the day the last building user walks out and then when somebody comes to knock it down in 100 years time, he knows what he is knocking down and manages to get the replacement.***

Table 4.7: Extracted responses from the interview conducted with the building occupants for the Office Building case study

Question focus	Occupant 1 (O1)	Occupant (O2)	Occupant (O3)
Role in the building 1	***I am the logistic manager for the corporate landlord service***.	***I am a business change manager within the corporate landlord, so I work alongside the logistics manager in helping if you like analyse and design and work out the best optimum use of the building in terms of its occupants.***	***I just work within Birmingham energy savers team***.
Perspective on building performance 2	***Me personally, because I haven't got technical background into building management, is very much about a building to have maximum utilisation, so you are getting the best out of the building in terms of its use and I suppose running an efficient building, so cost wise, maximizing saving potentials I suppose***.	***It means how the building itself performs from a cost perspective in terms of you know the overheads, the resources required to run it, you know the out running costs such as electricity etc., but I think the performance also means what the building can actually deliver, you know the actual solution it can provide, and what that optimum solution is or should be.***	***I think for me, it means how comfortable an environment is, so you know, temperature, fresh air, lighting, and so forth.***
Improving building performance 3	***Through constant monitoring, so I don't think ever you should sit still, you have to work to understand your customers and the people who use the building and what their needs are, which is constantly changing in our case, so making sure that you keep an up to date view and knowledge of that, but also keep data on who occupies your building at what they are, what their numbers are, so again if there is an opportunity to restack that you can free up space and bring in more people and increase utilisation.***	***Well I think it constantly be improved, I think there is no common point when you can only get the energy bill down to a certain level, I think that's a finite performance to measure, but in terms how well the building can be used by its occupants, and by the mix of its occupants, I think we can simply review that, analyse and adjust that to make more effective solutions for the building.***	<u>**I quite like this building, as it got a lot of natural light, so that makes feel much more comfortable, it regulates its temperature from better than MP.**</u> ***There isn't much scope for improvement I think, apart from perhaps the noise, which is one of the difficulties you get in an open plan offices, but the nature of the work that I do here.***
Importance of facilities	***Extremely important, and alongside what we do its crucial, so I guess it's the oil that helps turn the cogs really, that is going in the***	***yea, very important, I think that it is the oil that helps to work the core of the building, and we need to work very closely hand in hand with***	***Again, no real problems,*** <u>**we have quite nice kitchen facilities in here, they work, in terms of cleanness, I don't think that our**</u>

4	***background to ensure that our customers are satisfied and happy in the buildings that we run.***	***facilities management, so if we are the strategic part of how the building should be used, and facility management should be seen as the day to day enforces how the building should best be used.***	**desks are clean as much as I would like, but generally the facilities here are very good, they are well maintained, they are kept relatively clean, and it's a fairly pleasant place to work, and its nice how you understand that every single floor is the same, you know where to find the showers, toilets.**
Perspective on good public, community and private spaces 5	***For public space, it really very much depends on the use of the public space, because each one is different, but public space should be welcoming, light, airy, comfortable, easy to recognise how they can access whatever that they need to access within the building, very friendly, customer service and part of that welcoming is having a good front facing staff*. ***For community space, we've got lots of different types of buildings*, *so I think its good to have a combination of different types of furniture, different types of space for people to be in for different purposes, and for it to be easily accessible for everyone, and welcoming I guess.*** As for personal space, ***currently as part of our mission is to depersonalise office space so it's not somebody's desk***, ***so having the ICT to support you in whatever work that you are doing***. ***For private space, I think it's important to have a designated team area***, **so somewhere for a team to gravitate to where**	***A public space, depending on which building you go to within that estate, there are limited, variant degrees of public space within them***. **To be honest, this building isn't particularly a public facing building, it's primarily an office building for that use**, ***its about having the appropriate space for that public interaction to take place in, while still keeping a defined, if you like private office element within them***. ***For a community/social space, I think lights, airy, welcoming and multi use really and also adapt the space into variety of uses really***, **such as this here at the Office Building street, as we are now, sitting within it, holding a meeting or an interview, there is large enough space within the area to hold quite sizable team meeting on an informal basis,** ***so I think its about adapting that space into variety of uses***. ***For private/personal space***, **I am going to take it as mainly the actual office estate of the building**, ***I think its important to depersonalise that space, I think attached to that is how we***	***A public like the reception point of view, well, I always think that natural light is an important thing, but generally I would say, seating areas, friendly reception and welcoming staff, clean and open environment.*** ***In terms of community space, I like places like that within the workplace where it can take you completely out of work, so you can sit, have chat, may or may not be about work, but it's important that it makes you feel like offline***. **I guess people would think that they need additional requirements such as charging points, etc.** ***Well, I wouldn't call the space where I work is private, which I don't think it's a problem, its friendly, its communal***. **One of the bad things I would say is sometimes the staff come between our desks and there are no signs that say don't do that, so you might run somebody's foot with your**

	they know it's their base where they can communicate with their line management, team members, so I think it's just having an area with less of the personalisation of desks.	***treat things such as storage and making that a consistent approach across the building, and also you know, clear desk policies, to keep that space usable by multitude of users.***	**chair when you suddenly move your chair to the back, but you know, people will always prefer taking the short routes.**
Major problems with relation to space 6	***The desk ownership**, **the people naturally wanting to have their own space that belongs to them and marking it with their personal belonging, so that's probably one of the biggest challenges.*** **I don't know if you are interested in the meeting rooms, because obviously that's still an area, the challenge with that it is people who want to book those spaces and who will want to book those spaces but then not informing when they don't need**.	***Yea one of the problems we've possibly had previously and may have again, is the start to increase occupancy of the building**, **is about storage, there is going to come a point when the storage provision within the building can only really cater for certain amount of occupants, you increase the occupancy of the building, and naturally there is an increase in occupants' belongings**, **and whilst we have undertaken quite a hard line around the storage in allocating a set amount of linear meet to the storage they can hold, but there come a point when there is so much space within the building for storage provision and occupants and there is going to come a point when they meet.***	***I think as a team we don't really have enough space to perhaps store some of the things that we need***, **so we have like a lot of pop ups display stands kind of things, or boards that we can display things on, actually that kind of, so its very difficult because we've only got like one draw if you know what I mean to put all that stuff in and we can got also stationary, so you know things will be put on top of each other like my safety boots I keep them at the back of my desk,** ***so we have a massive problem in relation to storage in this building***.
The use of 3D models to represent the space 7	***Probably if I have seen the model, I might have thought that it would look boring**, **but actually being in the space, what you can't get from looking at the model is the amount of natural light you receive within the building*** **for example and how it feels so for me its very spacious, it's very light and comfortable, so probably it would had a detrimental effect on my thoughts about the building before seeing it in real life.**	***It's an interesting one**, **because what we did have the benefit of prior to the move of this building, we've got other buildings within the … that we've already designed and refurbished to the plan of its design, so we were able to see those buildings in operation, and indeed some of our staff would have worked at one of those buildings and would have been familiar with the concepts that we had in place, the branding, etc. So I am not sure how useful a model would have been, when it certainly haven't got any of that***, **on contextual feel from and on the other side,**	***Well, that would be dependent on the way that I was asked***, **like asking for my feedback, I think it would help perhaps things like movement of people within the space like the moving between the staff members, say that if I am trying to take my cup of tea full from the back of the kitchen to my desk, where are the danger points when someone could come whizzing around the corner, and knock it everywhere.** ***its about getting the feeling and you know that this is different from one***

		this building behaves a lot differently when there are so many people within it, than it did when there was hardly anybody in it.	***person to another, and some of these issues might get addressed when using a model at the design stage to communicate with future occupants I think.***

Educational Building 2 Case Study Data

Table 4.8: Extracted responses from the interview conducted with the building designer for Educational Building 2 case study

Question focus	Building designer (BD)
Role in the project 1	For both projects, ***I was the project director***.
Perspective on building performance 2	***Building performance for me covers lots of areas, you know, did it performance a capital construction project, so did you bring it on budget, time, does it perform as a financial asset, so if you are talking about a commercial buildings, does it give good yields, does it attract the right sort of tenants, is it commercially viable. From a user perspective, does it perform? The space is right for what they want to do?*** ***I suppose that performance for what the building is for is the higher answer***, but when I say building performance as a building designer, written on a piece of paper, ***usually it means the sort of metrics to do with energy performance really, probably orientated a bit more about that, so how much heat does it lose, how much heat is gained in the spaces, how much energy spend on cooling, how much spend on lighting, those sort of metrics, typically in terms of performance, the bits that are more readily associated with that phrase.***
Improving building performance 3	***So a bit more orientated towards energy and sustainability mean***. ***Number of angles on that I suppose, so there is user behaviour, but there is sort of design optimisation is the one that we probably more interested in***. ***So design optimisation is understanding how energy is being used in different areas in the building, different systems, all those sort of things and then make it better. We also do a number of passive house design buildings***, ***so the thermal and energy modelling allows to play with variables to get you to find the optimum balance to reduce energy overall***. ***The operation stage is incredibly important, so that goes to things like user training, so they know how the building is designed to be operated so they can operate it in that way***. **Obviously sitting in a hot room and then thinking how bad the design of this building is because he/she fundamentally didn't know how to use the building, so that works at the end-user level**. ***So how do you improve building performance once the building is occupied is things like maintenance, so you need to know people who maintain the building***, **you need to know how often they need to service a boiler so it remains sufficient for example**.

	BIM has supported my view on performance in a sense that it is much easier to collaborate with engineers who have much better grasp of the metrics used to measure building performance, **so for example, they can run a set of overheating calculations for the building and they attach that information into space units within the model so we move a room, then all that data moves with it, so this better collaboration**, ***which means you get a better result in terms of trying to optimise a design of a building to perform better.***
Achieving building performance for users, facilities and clients 4	***With buildings you have few problems to start with and less problems in the future***, ***as people understand how they work and they manage, it's important for lots of reasons I suppose***. Again, thinking not only about university building, ***energy performance is important for lots of reasons you know, they need to do what they suppose to do, because otherwise productivity might be affected***, **you know if the building performance isn't right in a supermarket, it can affect sales and profitability, so it's important, you want a happy positive work force with really good environmental conditions.**
Perspective on space performance 5	***Comfort criteria covers off all the things like does it have the right temperature, does it have the right level of lighting, acoustically is it ok***, ***I suppose there is a metric that you can define. So in terms of those metrics you can apply for space, it depends on the brief, but if the client doesn't have specific requirements then there is guidance about what typically is a good temperature for a room to be, what is good acoustic performance, how to avoid glare, how to avoid too little light in the space.*** ***So Building regulations is minimum statuary requirement that we need to achieve***, ***there are British standards, which define lots of things, for different types of buildings there are different guided piece of guidance, CIBSE guides define a lot of sort of energy, M & E systems, services design criteria, and then any specific user briefing requirements***, ***but I am always drawn to things that are intangible as well***, **so there are sort of metrics that you can measure, you get thermometer you can measure the temperature, you get a microphone you can test the acoustics**, ***but there is a lot of immeasurable things that are equally important like well-being***. **The best way of thinking about that is the British council for offices award criteria, I think it really has holistic list of standards, it talks about how much did it cost, how big it is, how sustainable is it, what's the energy consumption. It deals with metrics, but last category is called 'lifting the spirits', so it is the intangible, does it feel like a good place to be to work, does it have good atmosphere, and that covers lots of things you know, what's the colour scheme like, is it like neutral, is it monochrome, is it very vibrant, does it have a cause of history**, ***I think it is valuable element in the performance of a space***.
Perspective on public, community, private and personal spaces 6	***For a public space, it's sort of accessibility, are there barriers that prevent you to enter that space, so when you see these spaces from outside, you can move into them, when you are in them, it is easy to move around them, is it clear, is there a clarity of signage if you need signage, eligibility I suppose for the space, so if it's a long space can you see the end of the space, can you see the exit, all that sort of things***. **So for Educational building 2, when you came into the publicly susplarious, the first thing we wanted was a view straight back out the building to the courtyard space into the canal at the back of the building, so that is a really strong asset of the site when you have to come into the public space, but having very visual communication to the outside was important because there was some great external public spaces around the building. Although we want the building to be secured, we don't want to perceive barriers into the building so how do you design security turn styles with a low visual impact, where do you place the reception desk for example. Then**

	there are other things like quality, so the materials we use on the floor and the furniture we use in the reception area is very important that they are the highest quality because its your first experience, so the tiles are high specification, the carpets in the nasal area are high specification, and then there are things like TV screens, so the information is accessible on a rolling base, and there are other safety related aspects, so the floor is sufficiently slip resistance, so it's wet free when you come in. ***For a social space, again there are more subjective metrics than hard or fast number metrics really, but they sort of look open, inviting, look comfortable, they're flexible, a lot of them you can arrange pieces of furniture to suit the need, so flexibility was important, ownership was an important idea, so it's the feeling whether you can go and sit there and they are not for other people for you to use, those sorts of ideas, metrics to do with those*. *Yea, I mean these are sort of baseline of metrics, which are applied across large part of the building, which includes social learning, which has to do with standardised demand of light in those areas*. **For example, in Educational building 2, the space (the small booth by the entrance) that you arrive into has a video pod for recording students' comments, then the rest if you go to the cafeteria spaces, all the furniture is loose, so you can move them around, we put in lots of big folding doors, so you can open up spaces, sit with each other into large spaces for conferences, for open days importantly for the university,** ***it depends where it is and what you are trying to do with it really***. **So social learning covers a lot of ground really, so it could be learning spaces, it could be seats outside the classroom corridor really all the way to the big central spaces, like the spaces of Educational building 2 that got sort of shop front to be used on to them, cash points, you know lots of things to activate those spaces and make people use them.** ***For private and personal spaces***, on a building at the scale of Educational Building 2, ***you have to sort of create some benchmarks***, ***because personal space for lots of people is different in different ways***. **Some people like to put pictures on their desks, you know all these sorts of ideas whereas the university can't go and see every single user and spoke for every sort of workspace or personal space for that particular person**, ***so you create some benchmarks***. ***To do with personal space, every member of staff gets a fixed agreed size of desk, fixed type of chair, fixed amount of shelving, a personal storage, so personal spaces is how you to that or how you configure a space to make that as good as you can***, **so you generally don't want a member of staff and their personal space their desk with a back to a glazed screen, so somebody walking in the corridor can lookover their shoulder and what they're doing, you generally want to think how you position people next to each other**, ***so there are sort of privacy elements of personal space, which is quite important, there are lots of strategic objectives***, **so privacy quite often is sacrificed to achieve more collaborations, so there aren't very many individual offices for example, but then you have to deal with privacy issues, how does somebody make a personal call or need to call to deal with HR information, so there small meeting rooms available to do those sort of things.**
Value of BIM for space 7	***I would sort of clarify that by saying, it's a yes and no answer because at the conceptual level, BIM is a really bad tool because it's not quick enough to move through design iterations***. **So if you look at Educational building 2, got something like 400 rooms in it included in the brief, so imagine how long it will take to plot out different iterations for 400 rooms, in BIM it is impossible,** ***so we tend to use 2D tools to get some high level principles fixed, so we only use BIM once we have agreed with the client broadly speaking this isn't the final design, but this is sufficiently agreed that you are not going to change it all and we are going to restart the whole process in BIM***, ***so at a***

	conceptual level, BIM is not a very flexible tool, but yes, when it comes to these are the right sort of number of rooms and broadly speaking, this is the arrangement we want, we can move things*, *BIM becomes more powerful and I think it becomes powerful is because you can automate lots of things, so if you need to measure a room, it's very easy or it knows how big that room is at any given time, so you can check that it meets the requirements of the brief, so it's the data you can add to that, and the further down the design process the more data you need **and then you can say this room is designed for three people, and then the model shows you for how many people the building is designed for, all these positive things,** ***so it's the addition of data for space that actually BIM is really good at*****, and the other big benefit for us the designers is that you can show people a room and put them in a room rather than just having to look at the plan, which is good for understanding, so there is a time and place for BIM, it doesn't start at day one for us, it starts somewhere in the middle of the design process, so specifically for space planning BIM is really a bad tool.**
Shortcomings of BIM when designing the space 8	***Well is better at the design delivery, so you've planned your space and now you want to build up the information, get to a construction stage, it's a very strong tool,*** but ***for planning is a very bad tool***.

Table 4.9: Extracted feedback gathered from the facility management team for Educational Building 2 case study

School/Role		Building services supervisor	Facility manager
Experience of looking at building designs, if yes, how?		No	Yes, I have been a requirements manager, it is critiquing after the design happened
Problems with buildings		Space allocation, fixtures and fittings	They don't seem to help to make the job easy, layout issues, for example, deliveries cannot be taken from the ground floor in Educational building 2. Many operational challenges-cleaning (e.g. how paint can hold up)-movement within the building.
Issues in the following aspects	Temperature	Too cold or too hot, inability to regulate temperature	Can't open windows
	Ventilation	Adequacy, blocking air vents	Issues within the internal rooms
	Space Comfort	Inefficiency of the space usage	Depends on the department
	Noise		
	Facilities	Are they what the user wants, aesthetically pleasing	Heating and Cooling-roof leaks-Housekeeping operationally (no current FM policy for that)
	Maintenance	Constant constraints on managing	Time scale-budget (priorities)-very ad hoc-No planned preventive maintenance (PPM)
Familiarity with the building plans	Not familiar at all		
	Quite familiar	We use building plans to aid our services	
	Very familiar		Very familiar
Access	What is important?	Open, airy, welcoming, well sign posted	Welcoming, open, clearly sign post
	Information from 2D	The view itself is explanatory, well informed of different areas on that level	Layout, no enough information, access routes, reception, speed gates, access for disabled

	Information from 3D	Speed gates, reception, missing information on free space, missing signage by the reception, missing seats, vending machines and information about the building	Better idea of the layout, can't figure out what the shelves nearby reception are? Fixing lights above the reception
	Concerns	Information to be available for the customer, maintenance, accessibility, usability (e.g. hanging artwork or ads. On the wall)	The shelf by the reception going to be dirty, how the flooring is going to be? The entrance is not very welcoming
Social-learning space	What is important?	Connectivity (e.g. floor boxes), versatile correct furniture (fixed/removable)	Safe, fixed furniture, loose furniture, no eating
	Worries	How the users use it, cleaning access, maintenance	Ownership (FM policy), needs to be bookable, reporting issues
	Information from 2D	Seats, tables, not clear facilities, projects limited use	Sort of layout, don't know what's the dotted line by the space
	Information from 3D	Book shelves, seats, tables, no electric boxes, not sure where the lights are, unclear facilities	Are the shelves for books, acoustic considerations? Furniture (fixed/removable)?
	Concerns with temperature	Could be too hot, too cold, Glare	No problem
	Concerns with ventilation	Access to fresh air	No problem
	Facilities needed	Printers, nearby café	The space is in the library so you need compromises. Culture in the library
Teaching Room	What is important?	Projectors, white boards, occupancy level, lighting, location of logistics sources	Functionality, flexibility
	Worries	Facilities, everything in working order, students to move furniture in & out, are they designed for only teaching	Heavy furniture, complicated AV systems
	Information from 2D	No clarity about the flexibility of the teaching space, seats, tables, access points, no clarity about the walls are movable, less clarity about available facilities	No information about the folding wall, layout, would like to see which one is glass and which is solid for cleaning, which is hard and soft floors
	Information from 3D	Projector, where does the projector projects at? Lighting system? Are chairs stackable when used for events; are	Glass walls, feel of the space, flooring?

		there any floor vents? Can't see floor (electricity) boxes? Are they lockable?	
	Concerns with temperature	Occupancy rate, comfort	[redacted]
	Concerns with ventilation	Floor ventilation, access to fresh air	
	Facilities needed	Tables, bins	Store cupboard for the furniture, heavy? If moving, where?
Academic office	What is important?	Storage, number of desks per room to determine the available space	Sufficient space to store their essentials, housekeeping
	Worries	Additional furniture, change of configuration, users to know how to operate the space in terms of lighting systems, floor boxes, and avoiding as much as possible to prevent the staff from turning the space into kitchen	Extra power supply for the staff, clear desk policy? Security issues?
	Information from 2D	Natural light access, layout, furniture, everything looks even, missing facilities (e.g. printer)	Layout, looks tight, what sort of accessibility?
	Information from 3D	Are the doors represent storage cupboards or are they risers? Shelves, no clarity about some facilities, seats, tables, maximum occupancy	Shelves, desk, don't look spacious
	Concerns with temperature	Controls (manual or BMS)	[redacted]
	Concerns with ventilation	Blocking air vents on the floor, manual control of vents	
	Facilities needed	Copy machine, white boards	The coffee maker facility
Additional comments		[redacted]	

Table 4.10: Extracted feedback gathered from the building occupants for Educational Building 2 case study

		Participant 1	Participant 2	Participant 3	Participant 4
School/Role		ELSS / PhD student	ELSS / Visiting lecturer	ELSS / Senior Research office	ELSS
Experience of looking at building designs, if yes, how?		Yes, consultation with Associated Architects about Educational building 1 by looking at layout	No	Yes, phase 2 designs in the faculty	Yes, phase 2 briefing
Problems with buildings		Location of scanners in MP, café location at city north, Attwood far from library	Temperature, over occupied, confusing access	Poor navigation in the building, limited access, poor lighting, all staff in individual offices	Too hot sometimes
Issues in the following aspects	Temperature	Too cold	Usually too hot	Can’t control locally	Uncontrollable temperature
	Ventilation	[redacted]	There is often no ventilation	Windows can’t open	Opening windows
	Space Comfort	Rooms are too large	Space isn’t an issue	[redacted]	
	Noise	Trains near Perry Barr very noisy, also people like catering wheeling trolleys around on parking outside	Noise not an issue	Thin walls – can hear classes and sometimes music	Noisy when classes are nearby
	Facilities	Slow computers	[redacted]		Quite good
	Maintenance	Air conditioning breakdowns	Only one PC for 5 people to use	Repairs take long time	Quite good
Familiarity with the building plans	Not familiar at all	[redacted]		Not familiar at all	[redacted]
	Quite familiar	Looked at plans with associated architects	Seen some plans	[redacted]	Information from the briefing

	Very familiar	Viewing still 3D images		[redacted]	
Access	What is important?	- Welcome point - Warmth	- Accessible entrance for everyone - Welcome point - Signage	- Manned reception desk - Open, spacious, light, information point - Signs	- Reception - Signs - Map
	Information from 2D	Hard to get a real feel of size	Only shows layout	Provides some information such as doors, layout	Doesn't show the scale
	Information from 3D	- Doesn't show colour- might change feel if shown - Better than 2D	- Would be helpful to see colours - Better for visualisation	- More accurate shadings - No actual colour - Strange wall in the front	Shows entrance with more perspective
	Concerns	- Hate revolving doors. - Doesn't look very grand.	Random wall in front of card scanners	No revolving doors, access for disabled	Wall at the bottom of the stairs
Social-learning space	What is important?	- Inspiring quotes - Professional looking coffee - Charges	- Computers - Comfy sets - Café nearby	- Quiet space - Charging points	- Area far from noise - Plenty of space - Good facilities
	Worries	Confidentiality when doing mentoring	Noise levels	Social and learning, do they match?	Noise level
	Information from 2D	Layout of furniture	Layout of furniture	- Cannot tell the scale - Location of charging points	Good detail, but not perspective
	Information from 3D	Very good, but would like to see people using the space and actual colours	- No max. Occupancy included	- More colour - Ease to work on tables	- No detail - Capacity of space

			- Only 3 tables – students don't like to share	- Detailed furniture - Disabled access, space share	- Types of furniture - Workers access to work
	Concerns with temperature	Looks cold, but might be because of cold colours	It maybe cold if there's no sunlight	Small space	Hot due to windows
	Concerns with ventilation	Not sure	[redacted]	Not able to open windows	- No open windows - Fresh air
	Facilities needed	More seats needed	Disabled access	[redacted]	Disabled facilities – more desks
Teaching Room	What is important?	Good seating layout	Computer, projector, comfortable temperature	Space, light good acoustics	- Space for number of students being taught - Adequate facilities - Noise free
	Worries	- Glass windows - Walls causing distraction	- Distraction - Ventilation - Glass windows	- Ventilation - Glare from windows - Sockets - Distractions	- Temperature - Lack of quiet space - Not adequate facilities
	Information from 2D	Can't tell how many people will fit in room	- No occupancy measurement - Space identification	- Can't understand the scale - Level of occupancy - Can't see lighting	- Shows outline of rooms and areas - Doesn't give perspective of information on capacity
	Information from 3D	- Missing a lectern - Notice boards	- Desk - Chair - Layout	- Rendering – colour could be improved - Lectern missing	Spaces don't look comfortable

		- Can’t tell which walls move	- Projector	- Can’t tell walls are movable	
	Concerns with temperature	Lots of windows	Maybe cold if walls are removable	- Movable walls – change temperature - Do the windows open?	Depending on walls/ windows/ air condition
	Concerns with ventilation	Not sure	Lots of windows	Opening windows	No fresh air
	Facilities needed	Would love to see a raked mini lecture theatre	Notice boards	- No autonomy over space - Ventilation - Temperature	Comfortable facilities
Academic office	What is important?	Storage space	- Access to computers - Storage space	- Privacy - Storage - Appropriate space	- Space - Ventilation - Required facilities (PC, phone, printer, scanner)
	Worries	Messiness in a group office	Privacy for student meetings	Privacy to discuss problems with students	- Confidentiality - Noise - Lack of desks - Lockable drawers
	Information from 2D	Number of desks	Furniture layout	Cannot tell the space, ventilation, light	Overview
	Information from 3D	- Room access is difficult to tell whether it is scan/lock or other - Number of desks	Better visualisation, but you can’t visualise how much space your computer will take up	- Can’t see how many doors - Desks look small – need to see what it looks like with the PC on it.	- Shows better information, but lack of details - Space on desks?

	Concerns with temperature	Not sure	Too much furniture – hotter	Can you control temperature	Too hot/cold
	Concerns with ventilation	- Probably stuffy - Small - Shared space	Ability to open windows	[redacted]	Lack of fresh air
	Facilities needed	More book shelves	Personal space for valuables such as handbag, more storage space, book shelves	Computers Book shelves Accessibility	PCs, lockable drawers, book shelves, kitchen area
Additional comments		Where is the staff kitchen?	Accessibility to kitchen area	Lighting will be a problem Access to kitchen area	[redacted]

List of published papers

Boyd, D., Mayouf, M. and Cox, S. (2016) 'A Study of Clients and Users Perceptions of Building Information Modelling: A Study in Phenomenology', paper accepted at CIB World Building Congress.

Mayouf, M., Cox, S. and Boyd, D. (2015) 'Using Soft Systems to explore the complexity of space beyond its digital representations', proceedings of the 15th International Conference on Construction Applications of Virtual Reality, 5 – 7 October, Banff, Canada.

Mayouf, M., Cox, S. and Boyd, D. (2014) 'Exploring different information needs in building information modelling (BIM) using soft system methodology (SSM)', *IDIMC Conferences*, Loughborough (17 September), Loughborough University.

Mayouf, M., Boyd, D. and Cox, S. (2014) 'Perceiving Space from multiple perspectives for buildings using BIM', *Proceedings of 30th Annual Conference*, Portsmouth (1 – 3 September), Portsmouth University, pp. 697 – 775.

Mayouf, M., Boyd, D. and Cox, S. (2014) 'Different perspectives on facilities management to incorporate in BIM', *Proceedings of CIB Facilities Management Conference: Using Facilities in an Open World Creating Value for all Stakeholders*, Copenhagen (21 – 23 May), Denmark Technical University, pp. 144 – 153.

Clients' and Users' Perceptions of BIM: a study in Phenomenology

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Abstract

Although Building Information Models (BIM) are declared as singular and correct expressions of buildings, these still are merely representations of designs and complete buildings. The digital model is not the building and is not the design. The digital model does allow visualisations of the buildings allowing stakeholders a new perception of the building through its 3D representation with the ability to choose viewpoints and to travel dynamically, but virtually, through the represented building. This paper explores what is perceived by clients and users in building information models using phenomenology. It emphasises the differences in perception and explores the meaning of this for design and construction. The work has involved interviews and experimental studies with users using models in different forms including static 3D, walk-throughs, 2D and room data sheets. The results show that different people view models with a difference in focus, intent and expectation. This makes models not have a singular and correct expression which means that the engagement with stakeholders still needs to be worked on and actively managed during design and construction. Digital tools then are not finished expressions but examples to be worked with dynamically and used to demonstrate differences proactively to help work on these different perceptions so that a higher performing building can be produced. The future of BIM to deliver value for both the client and users then lies in its ability to provide soft informated representations.

USING SOFT SYSTEMS TO EXPLORE THE COMPLEXITY OF SPACE BEYOND ITS DIGITAL REPRESENTATIONS

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ABSTRACT: *Space is fundamentally considered to be one of the most complex aspects of the built environment. Research and industry continually seek to improve digital representations of space in order to minimize the gap between predicted experience and actual experience of space in a building. However, space is an elusive concept, representing it requires going beyond consideration of its tangible requirements represented in digital forms, to also consider intangible aspects of space. Intangible aspects of space affect the actual lived experience of those who use and manage the space in a building. A more holistic approach to representing space is therefore needed that acknowledges the different perspectives of those who use and experience the space in a building, in order to support the design of better spaces. This paper aims to explore the problematic nature of space, going beyond digital representations of space that mainly focus on tangible requirements, to represent a richer view of space, which acknowledges both tangible and intangible aspects. Soft systems methods will be used to represent the different experiences of space from three stakeholders (building designer, facility management team and building occupants). Data have been attained from interviews with these stakeholders and from feedback on the use of digital models used to communicate building design. The paper concludes by highlighting the information requirements and information categories needed to construct representation of space, which potentially can overcome the current deficiencies in the data used to construct digital models of space. Further work is needed to extend this richer representation of building space so that the designers' view of space becomes explicitly informed by the lived experience of space. This paper provides a richer information-based view of space, which contributes to enhancing digital representations of space that are needed to deliver building performance that satisfies the needs of different stakeholders.*

EXPLORING DIFFERENT INFORMATION NEEDS IN BUILDING INFORMATION MODELLING (BIM) USING SOFT SYSTEMS

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Abstract

Managing information in construction projects is a crucial task and information technology (IT) has been employed to tackle this issue. Building information modelling (BIM) is considered to be the first truly global digital construction technology; it supports a process that aims to inform and communicate project decisions through the creation and use of an intelligent 3D model. BIM is claimed to be an effective tool for information exchange, which involves digitally representing the physical and functional characteristics of a building. However, the involvement of interdisciplinary stakeholders within a construction project implies different data and information requirements that need to be supported in BIM. The complexity of data required to deliver the information needed by different stakeholders in construction projects is an on-going issue, thus an understanding of the nature of this complexity is needed. This paper aims to investigate the different information needs from multiple stakeholder perspectives, and raise awareness of the data requirements that BIM needs to incorporate. CATWOE, one of the modelling tools of soft systems, is used to surface the different information requirements of three groups of stakeholders. The data have been obtained using interviews conducted with the building design team, facility management team and occupants of a newly operated building. The paper concludes with a proposed road map suggesting that different data are required to support the design and operation of the building. Further work is needed to assess BIM capabilities in terms of integrating the data to support the information needs of different stakeholders, and whether interoperability issues mean that additional tools are required to support the BIM process. This paper raises awareness about the information needed from BIM by different stakeholders in order to create a more productive building.

PERCEIVING SPACE FROM MULTIPLE PERSPECTIVES FOR BUILDINGS USING BIM

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The way that space is being perceived during the building design stage affects the way it is delivered. This becomes more complex when considering not only the geometric view of space, but also the building as a whole with all its uses. It is recognised that different users have different needs particularly as regards their use of space. It is proposed that building information modelling (BIM) can accommodate different perspectives on space held by the building design team, facility management team and building occupants. This paper investigates various views on the way that space is perceived from different perspectives. Data have been attained from a university building under construction in the United Kingdom using interviews with the building design team, and questionnaires with the facility management team and building occupants. The collected data demonstrate the complexity of space including the effect of 2D and 3D views on perceptions. The paper concludes with highlighting these different perspectives emphasizing the need for collaboration. Further work is needed to explore different space algorithms, which can accommodate these different perspectives in the BIM model. The paper provides an initial basis towards understanding the problematic nature of space from a holistic approach and its implications of the way it is being perceived.

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DIFFERENT PERSPECTIVES ON FACILITIES MANAGEMENT TO INCORPORATE IN BIM

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ABSTRACT

Purpose: This paper will review the value of Building Information Modelling (BIM) and demonstrate how the early integration of Facilities Management (FM) within BIM can enhance building performance from the perspectives of the building delivery team, facilities management team and building occupants.

Background: It is proposed that involvement of the facility management team at an early design stage can contribute towards enhancing building performance, but this requires a multiple perspective of FM to be adopted. BIM has the potential to be used for managing facilities as it provides extensive information about all physical assets in the building.

Approach: Pilot data has been acquired from a newly built and operated university building in the United Kingdom using interviews to capture information from these different perspectives.

Results: The differences in perspectives are presented based on the responses collected from the interviews. Three parameters are used to compare and analyse them highlighting how these differences are difficult to accommodate in building design

Practical implications: The paper proposes a structure for BIM to accommodate the different perspectives on FM from the building design stage. This leads to the necessity of involving the facility management team during the design and construction process.

Research limitations: The proposed structure is based on the responses from the interviews, and may apply to other educational buildings, but may not be generalised to all buildings.

Originality/value: This paper provides an initial platform towards better understanding of the contribution of facilities management in the design process to improve building performance with the use of BIM.