On the integration of Building Information Modelling in undergraduate civil engineering programmes in the United Kingdom.

A thesis submitted in fulfillment of the requirements for the degree of Doctor in Philosophy in the Faculty of Engineering and Physical Sciences, The University of Manchester

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Abstract

The management of data, information and knowledge through the project life cycle of buildings and civil infrastructure projects is becoming increasingly complex. In an attempt to drive efficiencies and address this complexity, the United Kingdom (UK) Government has mandated that Building Information Modelling (BIM) methods must be adopted in all public sector construction projects from 2016. Emerging from the US Department of Defence, BIM is an approach to the co-ordination of design and production data using object-oriented principles as described in ISO 29481:1:2010. The underlying philosophy of BIM is to ensure the “provision of a single environment to store shared asset data and information, accessible to all individuals who are required to produce, use and maintain it” (PAS 1192-2:2013). A key aspect of BIM lies in the notion of ‘interoperability’ between various software applications used in the design and construction process and a common data format for the efficient exchange of design information and knowledge. Protagonists of BIM argue that this interoperability provides an effective environment for collaboration between actors in the construction process and creates accurate, reliable, repeatable and high-quality information exchange. This UK Government mandate presents numerous challenges to the architecture, engineering and construction (AEC) professions; in particular, the characteristics of BIM Level 2 remain explicitly undefined and this has created a degree of uncertainty amongst the promoters and those professionals charged with delivering projects. This uncertainty is further reflected in UK higher
education; contemporary undergraduate programmes in civil engineering across the UK are, on the whole, at the bottom of the BIM ‘maturity curve’. UK higher education institutions are increasingly being challenged to embrace BIM through appropriate pedagogies and teaching practices but the supporting guidance is emergent and variable. In the case of civil engineering programmes in the UK, the Joint Board of Moderators (JBM) has issued a ‘good practice guide’ as have the Higher Education Academy (HEA) under the auspices of the ‘BIM Academic Forum’. Nevertheless, a clear demand for further research to explore the technical and pedagogical issues associated with BIM integration into degree programmes remains.

The research described in this thesis casts a critical lens on the current literature in the domains of object-oriented modelling of infrastructure and the associated implications for procurement and project management. A mixed-methods approach using questionnaire analysis, focus groups and secondary case study analysis was used to enact an inductive research approach that captures a range of data on pedagogic issues and considerations associated with the integration of BIM into the design of a new civil engineering curricular.

The findings include recommendations for the ‘up-skilling’ of university teachers and academics, enhancing student employability and the development of suitable learning and learning techniques. A framework for the incorporation of BIM principles, concepts and technologies into civil engineering programmes is proposed. The findings of the research suggest that the first two
years of study in a typical, accredited civil engineering degree programme should focus on the technical concepts relating to design from a modelling and analysis perspective. The latter years of the degree should focus on the development of ‘soft-skills’ required to enable effective teamwork and collaboration within a multidisciplinary project environment. Further studies should seek to test the proposed framework in a ‘live’ environment, particularly in the context of the necessity to balance the demands of summative and formative assessment regimes.
Declaration

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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List of Publications

Book Chapters


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The following reports were published with written contributions from the author:

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Forum, The Higher Education Academy, York, United Kingdom.
ISBN: 978-1-907207-74-7


**Conference Proceedings**


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# List of Common Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>3D</td>
<td>Three-dimensional modeling</td>
</tr>
<tr>
<td>4D</td>
<td>Four-dimensional modelling (i.e. including time schedule data)</td>
</tr>
<tr>
<td>5D</td>
<td>Five-dimensional modelling (i.e. including time and cost data)</td>
</tr>
<tr>
<td>6D</td>
<td>Six-dimensional modelling (Project Life-Cycle management information)</td>
</tr>
<tr>
<td>AEC</td>
<td>The Architecture, Engineering and Construction Industry</td>
</tr>
<tr>
<td>AIA</td>
<td>American Institute of Architects</td>
</tr>
<tr>
<td>BAF</td>
<td>BIM Academic Forum</td>
</tr>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
</tr>
<tr>
<td>BIMM</td>
<td>Building Information Modelling and Management</td>
</tr>
<tr>
<td>BMS</td>
<td>Building Management System</td>
</tr>
<tr>
<td>BSRIA</td>
<td>The Building Services Research and Information Association</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CE</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>COBie</td>
<td>Construction Operations Building Information Exchange</td>
</tr>
<tr>
<td>JBM</td>
<td>Joint Board Of Moderators</td>
</tr>
<tr>
<td>ICE</td>
<td>The Institution of Civil Engineers</td>
</tr>
<tr>
<td>IFC</td>
<td>Industry Foundation Class</td>
</tr>
<tr>
<td>IMechE</td>
<td>Institution of Mechanical Engineers</td>
</tr>
<tr>
<td>IPD</td>
<td>Integrated Project Delivery</td>
</tr>
<tr>
<td>ISP</td>
<td>The Information Systems Panel</td>
</tr>
<tr>
<td>IStructE</td>
<td>IStructE Institution of Structural Engineers</td>
</tr>
<tr>
<td>QCA</td>
<td>Qualitative Comparative Analysis</td>
</tr>
<tr>
<td>NBS</td>
<td>National Building Specification</td>
</tr>
<tr>
<td>RIBA</td>
<td>Royal Institute of British Architects</td>
</tr>
<tr>
<td>RICS</td>
<td>The Royal Institution of Chartered Surveyors</td>
</tr>
<tr>
<td>WLC</td>
<td>Whole-life cost</td>
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</table>
Chapter 1
Introduction

1.0. Introduction

Building Information Modelling (BIM) is ‘a collaborative way of working, underpinned by the digital technologies, which unlock more efficient methods of designing, creating and maintaining our assets’ (HM Government, 2012). Central to the BIM ‘way of working’ is enhanced co-ordination of the design, construction and operation phases of a project through the intelligent use of data across the value chain. The architecture, engineering and construction (AEC) industry in the UK is currently experiencing a transitional phase in which a number of critical infrastructure programmes such as Crossrail are demonstrating the benefits that BIM offers. Nevertheless, innovation and change introduce new challenges to traditional ways of working and this has implications not just for professional practice, but also for the education of those who will enter the AEC professions in the future. As the UK AEC industry continues to make progress along the BIM ‘maturity curve’, there is an increasing desire to ensure that engineering higher education is keeping pace with this change. Clearly, research is required to establish the current provision of engineering higher education in the UK and its capabilities to deliver graduates that are equipped with the skills and knowledge to work in a BIM-oriented environment. This introductory chapter sets out the justification and rationale for the research, and how it will be achieved.
1.1. Research Overview

Problems associated with communication, fragmented supply chains, varying degrees of risk and uncertainty, technological readiness and capability, coupled with a tendency to seek the lowest capital costs are among the issues that were identified in the influential ‘Construction Task Force Report’ often referred to as the ‘Egan Report’ (1998).

Many of the challenges identified by the Egan Report have been successfully addressed through a range of innovations in project management, procurement and contract – most notably the NEC3 form of contract which has received widespread praise for creating the conditions necessary for successful collaboration in major infrastructure projects. Nevertheless, recent studies such as the AIA Guide (2007) and the UK Government’s National Audit Office (2011) continue to highlight inefficiencies and waste within the industry, indicating that there is 30% waste in modern day construction principally due to cost overruns and production errors. Data gathered by the construction industry research body CIRIA with waste management firms Biffa and Viridis demonstrated that at least 10% of all raw materials delivered to site are wasted through loss, damage and over-ordering; this was due to the lack of ‘lean’ thinking in the industry and failures to keep pace with digital technologies (CIRIA, 2009).

Graphisoft (now known as ArchiCAD) was an early market leader and one of the first to introduce transformational technology systems in the AEC industry
in the form of the ‘Virtual Building’ concept in the early 1980s. At the time, this was the start of the technological shift that enabled designers to create virtual, three-dimensional (3D) designs instead of the standard two-dimensional (2D) drawings that were common. Since then, new technologies and modern software solutions have emerged that enable detailed 3D modelling of architecture, structure and mechanical/electrical design. Virtual building technologies became increasingly commonplace in the design office but rarely was the technology applied to the operational phase of the building or asset. The advent of Building Information Modelling (BIM) changed this; it provided the first opportunity to use digital models to inform the operation, maintenance, refurbishment and decommissioning phases. This insight empowers architects, engineers and construction professionals to work confidently with large, complex datasets, including building geometry and spatial data as well as the properties and quantities of the components used in the design. This ‘object-oriented’ view of the project provides a mechanism to understand building/engineering design from inception through to practical completion and post-occupancy in-use in ways that were previously not possible in conventional 2D methods.

The transition to the implementation of BIM ‘ways of working’ in the UK since the UK government announcement to mandate BIM on all public-sector projects by 2016 has been relatively slow and fragmented; the industry is ‘finding its feet’ and this has created a new demand for improved education, training and continued professional development in BIM. The consequence of
this transition is being increasingly felt in higher education institutions where undergraduate and postgraduate programmes in the built environment disciplines (particularly civil engineering, architecture, construction project management and building services engineering) exist. These institutions are facing increasing pressure from the learned bodies, the government, accreditation agencies and employers to improve students’ competences in BIM. In her conclusions to the American Institute of Architects (AIA) Report on “integrated practice” in 2006, Renée Cheng comments that: “Regardless of the magnitude of BIM’s eventual impact on the profession, its recent rise provides the ideal catalyst for rethinking education. The level of expertise required to intelligently design with BIM is significant, and serious consideration must be given to how it can be taught” (Cheng, 2006).

Anecdotally, UK undergraduate and postgraduate degree programmes in civil engineering appear to be largely passive in addressing the demands that BIM will place on education, training and professional practice (BAF, 2013; Wesley, 2013). Wesley’s sample considered 24 ‘Russell Group’ universities (all accredited by the Joint Board of Moderators). The results indicate that only one university explicitly stated that BIM-related activities were introduced within their civil engineering programmes, with very little evidence to suggest that civil engineering undergraduate students were studying or even being made aware of BIM technologies and principles (Wesley, 2013).
1.2. Research Problem

The research overview highlights the increasingly widespread awareness of BIM and its perceived benefits to the AEC industry and its clients, but this is tempered by concerns that the maturity of undergraduate and postgraduate higher education programmes (from a BIM perspective) is relatively low and potentially misaligned with the requirements of modern professional practice. Proposals by the Joint Board of Moderators (the accreditation body of The Institution of Civil Engineers, The Chartered Institute of Highways and Transportation and The Institution of Structural Engineers), including current ‘good practice’ guides, indicate that the integration of BIM into the teaching of civil engineering is essential in facilitating the wider adoption of BIM across the AEC industry. In response to this, the research described in this thesis explores the desired factors for the integration of BIM in undergraduate civil engineering programmes in the United Kingdom.

1.3. Rationale for the research

There are collective opinions suggesting that essential work is still required to improve the implementation process of BIM within the industry; introducing BIM correctly will have immense benefits and will solve many problems that BIM is proposing to do. Due to the UK Government approach towards BIM, many stakeholders understand the need to change is approaching and
becoming essential. However, there are great misconceptions in what is actually required to evolve from the traditional process to the BIM process.

Bataw et al. (2014) consider a range of issues that universities should contemplate in assessing the opportunities and challenges associated with the integration of BIM into higher education teaching and learning strategies; these include, inter alia:

- How research activity related to BIM (within the institution) can guide curriculum development.
- How can BIM potentially challenge traditional teaching and learning strategies?
- What opportunities exist to expose undergraduate students to BIM, from both intra- and extra-curricular perspectives?
- Is BIM of relevance to civil engineering students?
- How can BIM tools and principles be introduced to students on engineering programmes within a multi-disciplinary environment?

Arayici et al. (2009), in their work on the implementation of BIM, focused on determining the challenges and barriers to implementation in the UK; using surveys and interviews carried out with AEC stakeholders and academics in the UK and Finland, the findings suggest that a clear framework is required to guide educators in seeking appropriate solutions: “a growing need for such
educational programmes to be hosted by academic organisations has been a requirement" (Arayici et al., 2009).

1.4. Aim and Objectives

The aim of this research is to propose a framework to support the integration of Building Information Modelling (BIM) principles into undergraduate civil engineering programmes in the United Kingdom. To achieve this aim, the objectives are to:

- Critically examine the literature on Building Information Modelling (BIM), both from a UK and international perspective. The review will explore the origins of object-oriented modelling of buildings, the varying definitions and interpretations on BIM and the standards and guidance currently used in industry to harness the benefits of increased knowledge sharing, collaboration and common data platform.

- Explore the nature of the construction industry in the UK, and elsewhere, to understand the challenges and opportunities that lie in BIM-oriented ‘ways of working’ and the constraints that the characteristics of the industry place on the desire to implement BIM.

- Evaluate, through a set of series of case studies, current practices in the integration of BIM in teaching of civil engineering and generate a greater
understanding of the current position taken by universities in terms of curriculum design and implementation.

- Identify the enablers and barriers to implementing BIM principles and concepts into civil engineering courses in the UK.

- Provide recommendations on how to effectively transfer lessons learned to real-life practice.

- Design a framework to facilitate the most appropriate approach to curriculum evaluation, re-design and operation.

- Validate the proposed framework using an appropriate methodology.

- Make recommendations for further research based on the outcomes of the investigation and subsequent analysis.
1.5. Research Methodology

The research methodology adopted in this research is described in more detail in Chapter 5 but can be usefully summarised here as a mixed-methods approach using questionnaire analysis, focus groups and secondary case study analysis as components of an inductive research approach. The research seeks to capture a range of data on pedagogic issues and considerations associated with the integration of BIM into the design of a modern civil engineering curricular in the UK. The literature review described in the thesis concentrates on a critical evaluation of the current problems associated with data management in the AEC industry, verifying the importance of digital technology to the BIM agenda, pedagogic issues in the delivery of civil engineering degree programmes and the techniques adopted in curriculums around the world. These themes emerged during the preliminary literature search and through conversations with researchers and practitioners working in the AEC industry. A systematic review of the literature was undertaken to ensure that only the most relevant and reliable evidence was drawn from books, journals, articles and discussions with professionals. In addition, the researcher attended numerous workshops and conferences organised by professional bodies and government personals.

Primary research methods were also used to generate effective conclusions. The following list shows the main methods by which the data was collected and analysed for the purpose of this research:
- Case studies
- Qualitative Comparative Analysis
- Focus Groups
- Questionnaire Surveys

Each of these methods is discussed and justified in more detail in Chapter 5 in general and section 5.4 in particular.

**Figure 1.1.** Research methodology
1.6. Research Scope

The research described in this thesis explores the concepts of BIM, its impact upon the AEC and the broader pedagogical considerations of embedding BIM principles into higher education programmes in the UK. This provides the data required to understand the ‘What’? ‘Why’? ‘When’? and ‘How’? questions related to the integration of BIM into civil engineering programmes. As stated above, the research information was generated from existing information and supported by recent studies from the evaluation of real-life cases along with focus group interviews, surveys and feedback.

This research study began in April 2012, covering more than 360 articles in English that referred primarily to ‘BIM’ ‘building information modelling’ ‘UK AEC Industry’ ‘use of technology’ ‘BIM in academia’ ‘pedagogy of civil engineering’ ‘civil engineering programmes’ and ‘BIM education’, sourced from a range of research repositories including Google Scholar, Harvard Business Review, Science Direct, and EBSCO. Records are included in the bibliography. The focus groups were conducted with a range of different professionals from across the discipline spectrum, such as academic professionals and industry.

During this period the researcher undertook to engage with a range of stakeholder groups by attending and participating in a number of BIM-related conferences, workshops and seminars in the UK, Europe and the Middle East.

During the period of research reported in this thesis, the researcher
contributed to the drafting and subsequent publication of the first UK publications on “Embedding Building Information Modelling (BIM) within the Taught Curriculum” by the Higher Education Academy (see APPENDIX B) and represented the University of Manchester in the BIM Academic Forum (BAF) meetings and BIM HUB meetings in different regions of the UK. These activities enhanced the researcher's abilities and confidence to access reliable data and knowledge of BIM and surrounding issues.

Through a systematic review of the literature and constant comparative analysis, themes emerged that were used to inform a series of research questions. These themes and research questions were tested and developed via a ‘mixed-methods’ approach utilising focus groups and questionnaire surveys in order to generate an operational model to integrate BIM into civil engineering programmes. The operational model reflects effective and successful aspects of introducing BIM within the existing civil engineering courses in the UK that educators would keep in mind when approaching teaching BIM to civil engineering students at university level. These elements were developed from industry and academic staff expertise in collaboration with students’ requirements focusing on introducing BIM best practices within civil engineering courses, while not changing the underlying principles of civil engineering.

To finalise and validate the proposed framework and the recommendations of this research, the conceptual validation approach was used. This approach was adopted to approve whether the model accurately represents the true
understanding of the feedback received from the focus groups project and to simplify the underlying process of the framework and recommendations to realistic approaches, i.e. were the framework and recommendations credible and realistic.

1.7. A review of recently published PhD theses on the theme of Building Information Modelling

1.7.1 A Sociotechnical Systems Analysis of Building Information Modelling (STSaBIM) Implementation in Construction Organisations

    **Author:** Sackey, Enoch
    **Awarding Body:** Loughborough University
    **Year of Award:** 2014

This thesis discusses the problem of technology utilisation in general, and the specific issues facing the AEC industry in seeking to exploit BIM. The research emphasises the value that capability maturity models play in shaping organisational attitudes to BIM. The researcher adopts a two-stage process comprising of an initial exploratory study to help establish the framework for analysing BIM implementation in the construction context; this is followed by a series of case studies to provide a context for formulating a novel understanding and validation of theory regarding BIM implementation in construction organisations. The research is relevant to this thesis as it is based
on the need to strengthen BIM implementation theories and creating a practical approach to adopting BIM within the current practices.

17.2. The development of generic competences in Malaysian universities, specifically civil engineering programmes: a case study

Author: Yusof, Yusmarwati

Awarding Body: University of East London

Year of Award: 2013

The study focused on generic competences that have been considered to be lacking in graduates from Malaysian universities, specifically their problem solving, critical thinking, communication skills, and team building. The argument concerning generic competences has focused upon teachers' pedagogical approaches and their relation to student learning. The creation of a hybrid teaching approach was proposed in order to consider whether this would enhance students' generic competences, as well as to enhance their academic achievements. The study is significant to this research in that it aimed to establish an alternative pedagogical approach in teaching undergraduate civil engineering subjects. Similar to this research, the study used both quantitative and qualitative approaches, and questionnaires distributed to students followed by semi-structured interviews with lecturers.
1.7.3 The integration of hypermedia based learning applications into undergraduate engineering degree courses

Author: Bailey, Julian Donald

Awarding Body: University of Southampton

Year of Award: 1996

This thesis investigates the integration of computer based learning elements into classically taught undergraduate engineering degree courses. The implementation of three separate computer applications was discussed. Focusing on the teaching of both knowledge and understanding of the civil engineering subjects, the applications create an environment to allow the students to develop skills in engineering design and encourage academics to create their own applications.

1.7.4 BIM implementation strategy framework for small architectural practices

Author: Coates, S. P.

Awarding Body: University of Edinburgh

Year of Award: 2013

This thesis considers the domain of small architectural practices and how BIM can be implemented to address the problems both of operational and product efficiency and effectiveness. To develop a BIM implementation strategy framework for small architectural practices the researcher instigated and
observed the minimum BIM requirements using an action research approach. It considered both the internal and external benefits to the architectural practice. The thesis was based on a Knowledge Transfer Partnership (KTP) research project.

1.7.5 A detailed investigation of the applicability and utility of simulation and gaming in the teaching of civil engineering students

Author: Long, Gavin

Awarding Body: University of Nottingham

Year of Award: 2010

This thesis describes research carried out into the use of computer-based simulations and games in learning and with particular regard to the education of engineering students. A number of simulation games were developed during the research, which ranged in complexity, functionality and subject domain. Two complex simulation games for the teaching of construction project management were developed and extended for implementation within a teaching module. The research provides useful insights into the learning styles of civil engineering students and how they interact and engage with new methods of learning technology.
1.8. Structure of the thesis

As shown in Figure 1.2, the research described in this thesis is organised into eight chapters, following a traditional format of Introduction, Literature Review, Research Methodology, Data Collection and Analysis, Discussion and Conclusions:

![Diagram of thesis structure]

**Figure 1.2. Structure of the thesis**

**Chapter 1 – Research Introduction:** This chapter presents the research overview, research questions, research aim and objectives. It also briefly highlights the research methodology and details the structure of this thesis.
Chapter 2 – The drivers for change in the architecture, engineering and construction industry: This chapter presents the literature review focusing on the current state of the industry. Outlining the known complications within the industry such as the fragmented nature, low productivity rate, quality, and time and cost overruns followed by an appraisal of how Information & Communication Technology can provide solutions to address these problems, involving a wide literature research on existing data. This chapter essentially draws out overall conclusions from many sources in order to fulfil the aim and objectives of the research. All sources were critically assessed while highlighting similarities, commonalities and differences between them.

Chapter 3 – Overview of BIM: This chapter presents, explores, appraises, and synthesises the literature review on the main aspect of this research, namely BIM. Identifying the different meanings and definitions of BIM from the views of various researchers from around the world, focusing on the concept, usage, evolution, implementation requirement, success factors and the implications of adopting BIM.

Chapter 4 – BIM in Civil engineering education: This chapter presents an in-depth study on the evolution of education in Civil Engineering, followed by justifications and clarifications of why teaching BIM is required within higher education. It includes an extensive analysis of comparing BIM teaching techniques and approaches around the world.
Chapter 5 – Research Methods and Methodology: This chapter is divided into two parts. The first part outlines the existing methodologies typically used within research projects. The second part illustrates and justifies the selection of methods used during this research.

Chapter 6 – Focus Groups: This chapter addresses the purpose of the focus groups, the planning that was done prior to running the focus groups, how the focus groups were conducted and analysed, with more emphasis on the technical procedures, and finally followed by the report of the analysis and findings. The framework for this chapter is based on Kirk and Miller's (1986) general description of the four phases of focus groups: planning, observation, analysis, and reporting.

Chapter 7 – Data collection and analysis: This chapter describes the design, purpose and results of the questionnaire survey, the planning that was considered prior to executing the survey, how it was conducted and analysed and an emphasis on the technical procedures adopted.

Chapter 8 – A framework for the implementation of BIM into higher education civil engineering degree programmes: The following core recommendations are the key findings from this research to outline the requirements for creating BIM-enabled civil engineering programmes in the UK. The findings included recommendations for the up-skilling of teaching staff members, enhancing student employability and developing suitable learning techniques. All of these competences and factors were used as
benchmarks while designing the BIM teaching framework to assist with the incorporation of BIM within the current civil engineering programmes.

Chapter 9 – Discussion, conclusions and recommendations: The final chapter of this thesis presents a discussion of the results obtained during the course of the research and the subsequent analysis that was performed; the narrative draws upon the original aim and objectives of the research and considers the likely implications, limitations and original contributions to knowledge. Recommendations for further research are presented, the emphasis of which lies predominantly on the pedagogical design considerations that are essential to the successful integration of BIM in civil engineering undergraduate programmes.
Chapter 2

The drivers for change in the architecture, engineering and construction industry

2.0. Introduction

This chapter examines the current drivers for change in the architecture, engineering and construction (AEC) industry with the aim of identifying the potential benefits to the adoption of Building Information Modelling (and in particular BIM Level 2 in the UK). The chapter will identify how and why digital solutions have increasingly dominated the BIM agenda, and identify the potential challenges that may arise from the highly fragmented nature of the industry. Whilst this thesis intends to provide useful insights into the broader AEC industry, Morton and Ross (2007) provide useful further reading – their work provides a detailed overview of the industry

2.1. Overview

The Architecture, Engineering and Construction (AEC) industry is arguably one of the most challenging commercial environments. It is inherently complex, a consequence of highly fragmented, global value chains that, by their very nature, introduce varying degrees of risk and uncertainty into programmes and projects. This complexity often results in problems with communication, coordination and management; this includes issues associated with leadership, management skills, human resources and skills availability that together have
implications for schedule and budget (Kestle and London, 2003). The following sections of this chapter will consider some of the contributory factors to this complexity including risk (and risk management), health and safety, communication, sustainability, design efficiency and productivity shown in figure 1.2a as the drivers for change.

Fig 1.2a The drivers for change in the architecture, engineering and construction industry
2.1.1. Risk management

Risk surrounds every human activity and influences everything that people do (Actuarial Profession and Institution of Civil Engineers, 2005). Political events, climate and weather, design quality, geotechnical conditions, the economic and legislative landscape, industrial relations and unethical/criminal actions are all possible risks that might have an impact on the project. It is therefore important to ensure that identification and assessment of risks is an on-going activity throughout the project life-cycle (ISO31000, 2009).

Not every party to a project will have the same view of a risk and how it should be managed. This has been the focus of many debates in academia and is usefully summarised in the work of Perminova et al. (2008), Ward and Chapman (2003), and Dowie (1999).

To manage risks in a project, a comprehensive risk register should be developed, managed and maintained throughout the life of the project. Various software packages are available that provide tools for calculating/assessing the probability of events occurring and the likely consequence on cost into a consolidated risk profile. In common use are ‘@Risk’ and Active Risk Manager, although most simple spreadsheet applications are capable of coping with statistical methods and simulation to provide guidance on risk management decision making.
The common assumption in modern forms of contract and procurement is that risks should be ‘owned’ by the party or parties best equipped to bear the risk; however, due to varying perceptions of the concept of risk (see Perminova et al., 2008; Ward and Chapman, 2003; and Dowie, 1999), some clients prefer and actively pursue a policy of total risk transfer. However, analysis of such procurement routes by the National Audit Office and others shows that this latter attitude is unlikely to provide the most cost effective outcome for the client.

Numerous models and frameworks exist to guide the implementation of risk management in AEC projects. ISO3100 (ISO, 2009) sets out some generic guidance and RAMP (Actuarial Profession and Institution of Civil Engineers, 2005) provides a civil engineering specific approach. Most frameworks share a common sequential process of identification, analysis, response and feedback as described below (Kirkham, 2015):

- Risk Identification - Research, experience and checklists can be used to identify the sources of possible risks to the project, including physical, environmental, societal, commercial, political, legal, financial, operational, technical, resourcing and logistical risks. Risk workshops are a useful forum for developing the initial risk register and should draw on a ‘broad-church’ of stakeholders to ensure that the intended beneficiaries and those negatively affected by the project are represented in the risk register.
• Risk Analysis - The probability and potential effects of each risk are assessed, using, amongst other methods, the product of likelihood and consequence. Risks are ordinarily rated on a simple integer scale of 1-5 where 1 = insignificant/very low likelihood/consequence and 5 = very high likelihood/consequence. Other methods may also be used such as sensitivity analysis, decision trees, probabilistic analysis and simulation. For risk analysis to remain effective, regular risk reviews should be undertaken and the outcomes of that process disseminated accordingly.

• Risk Response - For each risk, decisions are made as to whether to:
  
  o Take no action, if it is too unlikely or its potential is likely to be trivial;
  
  o Eliminate it, by modifying some aspects of the project or revising the proposed project scope;
  
  o Transfer it, usually to an insurer or a construction contractor; or

  o Bear it, allow for its possible cost and other effects and manage it.

• Risk Feedback - The impact of the decisions taken at the risk response stage should be reviewed. The ‘lessons-learned’ or ‘after-action review’ process is the usual mechanism.
2.1.2. Health and safety

Compliance with health and safety legislation is a professional and legal duty placed on each and every person involved with the procurement, construction and subsequent operation of a civil engineering project. The nature of civil engineering is such that projects can present a dangerous working environment in the absence of adequate planning, management and supervision safeguards. There are a number of characteristics of civil engineering projects, which potentially give rise to health, safety and welfare issues including:

- Varying degrees of uncertainty
- Innovative and novel working methods (including plant and equipment)
- Unexpected geotechnical issues
- Impact of weather and the outdoor environment
- Multi-organisation interfaces with complex channels of communication
- Complex operations and plant/equipment
- Foreign workforces with limited local language skills

There has been a substantial reduction in the number of fatal injuries in construction in the last 40 years; nevertheless, the construction industry accounts for a significant proportion of all workplace-related fatalities and injuries in the United Kingdom. At the time of writing, statistics available from the Health and Safety Executive (HSE) for the reporting year 2013/14 indicate that:
• There were 42 fatal injuries to construction workers; 14 of these fatalities were to the self-employed. This compares with an average of 46 over the previous five years, including an average of 17 to the self-employed.

• There were an estimated 76,000 total cases of work-related ill health, of which 31,000 were new cases.

• An estimated 2.3 million working days were lost in 2013/14, 1.7 million due to ill health and 592,000 due to workplace injury, making a total of 1.1 days lost per worker;

• Injuries and new cases of ill health resulting largely from current working conditions in workers in construction cost society over £1.1 billion a year.

However, since first publication of the Construction, (Design and Management) Regulations in 1995, legislation has evolved to promote the importance of a safety centric approach to the execution of civil engineering projects - further revisions of the regulations occurred in 2007 and 2015. The most noticeable changes have centered on the role of the professional (or organisation) responsible for co-ordination of health and safety information; in the 1995 regulations that was the duty of the ‘planning supervisor’ and then, in 2007, the role was changed to that of the ‘CDM co-ordinator’. The common
feature in both roles was the tendency for the role to be undertaken by a third party consultant or organisation. With the advent of The Construction (Design and Management) Regulations 2015 (CDM, 2015), came the new role of the ‘Principle Designer’ to replace the ‘CDM coordinator’. The other duty-holders remain: the client, the principal contractor, designers and contractors.

In the regulations, a designer is ‘an organisation or individual that prepares or modifies a design for a construction project, including the design of temporary works, or arranges for or instructs someone else to do so.’

CDM (2015) requires the Principal Designer to:

- Identify, eliminate or control foreseeable risks;
- Prepare the health and safety file;
- Ensure designers carry out their duties;
- Liaise with the principal contractor to help in the planning, management and monitoring of the construction phase; and
- Prepare and provide relevant information to other duty-holders

The Principal designer is responsible for coordinating the pre-construction phase health and safety information; this is most likely to be the lead engineer (or lead architect as appropriate). At the stage where the project moves to site and initial operations commence, the responsibility transfers to the Principal Contractor/Contractor. The role of the principle designer will remain, in most projects, during phases of the construction process – the appointment ceases
when design work is no longer undertaken. Where the appointment of the principal designer occurs before practical completion, because all design work is complete, the Principal Designer must ensure that the Principal Contractor has comprehensive information on hazards that have not been eliminated in the designs, the means employed to reduce or control those hazards and the implications for implementing the design work during the remainder of the project. The Principal Designer should also hand over the Health and Safety file (this is a document that contains ‘information necessary for future construction, maintenance, refurbishment or demolition to be carried out safely, and is retained by the promoter or any future owner of the asset’).

As the complexity of projects increases, it brings challenges to the client, design team, construction teams and asset owners in achieving effective systems of data capture and coordination to ensure the optimal balance of time, cost, quality and health and safety. This requires effective co-ordination and communication. The next section will consider the reasons as to why communication can often be problematic in construction projects. Whilst extensive research on the utilization of BIM technologies for project scheduling/planning, design, construction and post occupancy phases continues, the emphasis on the communications and ‘soft’ aspects remains weaker (Azhar, 2011).
2.1.3. Communication

The AEC Industry is often regarded as being inefficient, relying heavily on traditional means of communication (Sommerville *et al.*, 2004). Whilst the historically more common practice of paper-based communication is in decline, there remains a degree of reliance on traditional approaches to information sharing within the industry. Poor communication channels are often symptoms of fragmented workflows; this can lead to the generation of errors and omissions that lead to unexpected costs and delays and conflicts between the different parties to the contract.

Studies by the American National Institute of Standards and Technology (NIST) indicated that the costs of new build construction in 2004 increased by $6.12 per square foot due, in part, to the use of traditional means of communication (Gallaher *et al.*, 2004). This fragmentation is noticeable during data transfer between different organisations at key stages of the project life cycle due to the different techniques used by each organisation and the form of communication used to pass on the project data from one team to another. The problems of poor communication are particularly noticeable in the arena of sustainability; the coordination of data across the disciplines to ensure that opportunities for carbon savings, supply-chain efficiencies and improved constructability requires a good degree of communication maturity (Jalaei and Jrade, 2015).
2.1.4. Sustainability

Sustainability continues to dominate the political and regulatory landscape in the AEC sector; the impact of construction on the environment, both in terms of resource consumption and waste production, remains a key concern for policy makers in particular. The construction industry uses a wide variety of different resources and produces a huge amount of diverse on-site wastes due to lack of planning, unexpected design changes, lack of use of sustainable tools, lack of sustainable materials and ignorance to sustainability (CIRIA, 1999).

According to the UK Green Building Council, the construction and demolition sector in 2012 and 2013 was the largest producer of waste in the UK; it was responsible for producing 120 million tons of waste every year – around one third of all waste in the UK. At least 10% of all raw materials delivered to site are wasted through loss, damage and over-ordering (CIRIA, 1999).

However, promoters are increasingly demonstrating a commitment to sustainability and the low carbon economy; this is largely due to the short-term and long-term impacts that civil engineering projects can often create. Sustainability is a broad concept and encapsulates a number of considerations; however, a number of methodologies exist to guide designers with the most common being CEEQUAL. CEEQUAL began life as an environmental impact assessment tool but has recently evolved to consider a broader, more holistic approach. The methodology considers 9 aspects of a civil engineering project.
1. Project / Contract Strategy (optional)

2. Project / Contract Management

3. People & Communities

4. Land Use (above & below water) and Landscape

5. The Historic Environment

6. Ecology & Biodiversity

7. Water Environment (Fresh & Marine)

8. Physical Resources Use & Management

9. Transport

Waste reduction is an important strategic objective in design; the costs and environmental impacts of landfill are increasingly requiring promoters and designers to consider innovative solutions. WRAP (The Waste & Resources Action Programme) has published a ‘design team guide for civil engineering’ that provides a practical approach to designing out waste in civil engineering projects. The two-part approach provides the case for action and details the principles of designing out waste through a structured approach to implementation in civil engineering projects. Designers can use a ‘Technical Solutions’ guide that provides summary sheets on a range of design solutions to support design development.
2.1.5. Design Efficiency

The demands, both in regulation and policy, to achieve high levels of energy efficiency and performance continue to increase apace. The main drivers at a political level exist around the climate change agenda. Architects and engineers are charged with delivering design solutions that must balance energy efficiency compliance with budget, time and quality constraints set by the client.

A series of case studies carried out by D'Arcy in 1995 concluded that over-specification adds approximately 15% to the cost of construction work; most of this over-specification is due to problems with design inefficiency. As reported in Atkinson (1995), 60% of offices in the UK at that time were designed to cope with only 6% more staff than actually occupy the building. In addition, many buildings appear to have an unnecessary number of lifts, toilets and escape routes for the number of people that occupy it; lighting, small power and heating, and ventilating systems are also over-specified. A comparative study between UK and US building costs in 1993 (Atkinson, 1995) found that lower specification, more prefabrication, and greater reliance on standard components could lead to spectacular savings in the cost of construction.

Design over-specification has always been an issue to clients as well as the design team, particularly during the current economic crises. Due to the complicated methods that are often adopted, designers spend a lot of time
seeking different design solutions manually to satisfy all stakeholders (Atkinson, 1995). Revisions to the RIBA Plan of Work in 2013 provided a response to this problem. A new ‘Stage Zero’ (Strategic Definition) requires that a project is ‘strategically appraised and defined before a detailed brief is created’. The sustainability implications are made clear in the plan, which states that ‘this is particularly relevant in the context of sustainability, when a refurbishment or extension, or indeed a rationalised space plan, may be more appropriate than a new building’ (RIBA, 2013).

2.1.6. Productivity

A continued concern with the productivity of the UK Construction Industry is reflected in modern and historical literature. In 1989, Gray and Flanagan reported that poor productivity within the UK construction industry was a consequence of numerous factors including poor management and supervision, disruptions to work, extreme weather conditions, frequent changes in specifications, inefficient construction methods, over-manning and lack of planning and task distribution. The fragmented structure of the traditional way of working also contributes towards lower productivity and results in many interfaces and conflicts that ultimately lead to increased cost, and reduced efficiency and productivity. In a recent report published by the Economist entitled ‘Rethinking productivity across the construction industry: The challenge of change’ (Economist, 2015), respondents to a survey ranked access to skilled
labour, procurement methods, government requirements and aggressive project timelines at the key productivity challenges facing the industry today.

2.1.7. Time and cost overrun

Several governmental reports, such as the one by the National Audit Office in 2011, have investigated the problem of construction project cost and time overruns on numerous occasions. Although causes differ from one project to another, these overruns seem to occur in many major projects in the UK such as the classic example of the British Library at St Pancras, Guy's House and Portcullis House. The British Library was delivered at a cost of £511m, three times over the original budget (Harlow and Syal, 1995). Spring (1997) suggests that the project management allowed frequent design changes to occur, fluid project personnel and failed to assign responsibilities to individuals. The same issues played out at The Scottish Parliament Building in Edinburgh, which was the focus of several reports in including that published by The Rt Hon Lord Fraser of Carmyllie (commonly known as ‘The Holyrood Inquiry” (Scottish Parliament 2004) and the Audit Scotland - “The Management of Scottish Parliament Building (Audit Scotland, 2004). The principle findings of the latter were outlined in the executive summary, which stated that ‘There were difficulties associated with the construction of a very complex, densely developed, unusual building against very tight deadlines'.
2.2. The impact of technology

Studies such as Wright (2008), Teich (2008) and Rhodes (2000) indicate that the development of technology is outperforming practical application on projects. The growth in technology usage has come about through developments in wireless communications, nanotechnologies and the increasing computational power in portable electronic devices. Aside from the well-known developments in social media and social networking, the broader digital technologies have the potential to achieve a positive disruptive influence on the civil engineering and construction sector.

2.2.1. Digital technologies and Industry 4.0

The fourth industrial revolution, known as 'Industry 4.0', is a concept that emerged from the German manufacturing sector. At the heart of Industry 4.0 is the ‘Internet of Things (IoT)’ – the idea that everything is connected digitally from factories to the home. The Industry 4.0 ‘technology themes’ span four main characteristics (Deloitte, 2015; Siemens 2015):

1. Vertical integration and networked production systems of smart production systems, such as smart factories and smart products, and the networking of smart logistics, production and marketing and smart services, with a strong needs-oriented, individualised and customer-specific production operation.
2. Horizontal integration through value-creation networks facilitating the integration of business partners and customers, and new global business cooperation models.

3. Through-life-engineering through seamless data sharing across the value chain.

4. Acceleration through exponential technologies that are capable of mass-market production as a consequence of increasing economies of scale.

The current debate on Industry 4.0 is interesting, particularly from a buildings and infrastructure perspective. Industry 4.0 is casting a spotlight on how manufacturing intelligence can emerge from information sources using real-time decision-making software. Whilst the high technology manufacturing sector is a key proponent of Industry 4.0, it is important to recognise that ‘human systems’ remain an important consideration in enabling organisations to move up the maturity curve. The recent Accenture report on the ‘Internet of Things’ emphasises this point elegantly by recommending that, in moving forward with exploiting intelligent technologies such as additive manufacturing, augmented reality and big data analytics, leaders ‘put people at the centre of executing...strategy’. Thus, an important consideration for the UK in embracing Industry 4.0 will be balancing the forecasted reductions in low-
skilled ‘repetitive work’ with the necessity for education, training and professional development in creating a new, highly skilled workforce that is equipped with the skills to facilitate the transformation of manufacturing organisations. Achieving the required shift in the skills profile of the UK industry will require significant long-term thinking. Faller and Feldmüller (2015) highlight the importance of new curricula are to support the interdisciplinary learning that is required by Industry 4.0; one key emphasis lies in supporting small- and medium-sized enterprises (SMEs) who face significant hurdles in implementing and maintaining applications and technologies of Industry 4.0.

Whilst the present focus of Industry 4.0 lies predominantly in manufacturing, the implications for the UK construction market are exciting. The UK Government has set out aspirations for a ‘Northern Powerhouse’ but there are concerns around engineering and manufacturing capability to deliver the transformation change that is required to rebalance the UK economy. In 2014, the construction industry in the UK contributed £103 billion in economic output (6.5% of total output) and accounted for 2.1 million jobs (6.3% of the UK total were in the construction industry in Q3 2014).
2.2.2. Technology solutions to industry problems

Industry has used technology to communicate, store, retrieve, transmit and manipulate complex data within various processes. However, the maturity of certain industries is variable, particularly the contrast between civil engineering and high value manufacturing.

The aerospace sector has been at the vanguard of technology development and integration, from the software used to simulate the aerodynamics of an aircraft, to the networks that enable real-time monitoring and control of engines. This has improved manufacturing capability and output, especially in organisations such as Airbus. Linde and Linderoth (2008) claim that the high involvement of IT reduces the likelihood of human error and inaccuracy and this has led to a large scale research programme across the EU.

One such example is the ARUM project (www.arumproject.eu) - a project aimed at ensuring that high-value manufacturers in the EU retain a competitive advantage. These manufacturers demand ICT solutions and tools that can accelerate the learning curve, allowing a smoother transition from design to production. The mantra of ‘right first time, every time’ is key; the ARUM project aims to contribute to this vision through an intelligent Enterprise Service-Based platform (i-ESB). The platform integrates a service-based architecture with a knowledge-based Multi-Agent System (MAS).

The i-ESB platform gathers information from sources such as sensors and resource management systems, giving decision makers and planners better
insight into and control over the design-to-production process. Also, time, cost and risk analysis will take place within the platform. The i-ESB takes a double approach, making use of both prediction (in the pre-planning phase) and real-time control (in the production phase).

Nevertheless, one of the major problems of data software models in construction is that human intervention is almost withdrawn and professional judgement is left until later stages (Kirkham, 2014). This means that professionals in construction will face an information model generated without considerable investigation and interpolation, which can be a problem when purely relying on computerised models.

The London Ambulance Service (LAS) Computerised Dispatch System (CAD) (1987 - 1992) project remains one of the classic cases of software failure - the project involved replacing the slower and unreliable LAS manual ambulance dispatch system to a more efficient and fully computerized system. However, according to Adamu et al., (2006), LAS staff members failed to receive comprehensive and consistent training leading up to the commissioning of the system, and during the first hours of operation the system collapsed under the strain of ambulance crews sending inaccurate status reports to the control room using the new interfaces. The most recent case involves the £234m C-NOMIS systems; this was an IT project designed to connect the police, prison service and courts and probation agencies through one central database. The project experienced numerous problems from the beginning; many of these problems are illuminated in the parliamentary report into the decision to
ultimately downgrade the project to a new system (P-NOMIS) that now only serves the prison service.

2.2.3. Information Technology and Communications (ITC) in the AEC sector

Information Technology and Communications (ITC) has been firmly embedded into the AEC industry for well over 30 years. Computer-Aided Design (CAD) is perhaps the most commonly known software technology used in the industry. This use of technology has possibly made the design process more efficient and resolved problems facing the design teams and architects including design coordination (Meniru et al., 2003); however, CAD and associated tools have limited impact on some of the broader problems previously mentioned in this chapter.

Nevertheless, the use of technology can advance wider into all the tasks within a construction project in order to resolve the current issues within the industry. Early studies by Mitchell (1977) reported a wide number of applications that software could successfully serve in the AEC industry for tasks as diverse as generating designs, structural analysis, cost estimating, programme planning and work sequence planning. Today, modern software provides enhanced capabilities in these domains in addition to others. The question that remains is one related to collaboration and how ITC can engender closer working relations across the project and the value chain. This has led to the development of ‘Building Information Modelling (BIM)’, which aims to gather
all different applications of construction tasks under one collaborated system within a safe and efficient environment (Söderholm, 2006).

Proponents of BIM suggest that it has the potential to be a driving force in the digital revolution within the AEC Industry, principally because it involves the use of digital modelling software and collaborated database software that increasingly makes paper drawings and multiple text documents redundant (Henrik and Linderoth, 2010).

2.3. The potential for BIM

As emphasised in previous paragraphs, the ‘traditional’ way of working within the industry is perhaps one of the root causes of the time, cost and quality issues that the industry currently grapples with. The traditional procurement system, characterised by a high degree of separation between design and construction, created a noticeable fragmentation; the flow of information and data are disorganised and so will lead to ‘downstream’ problems. The traditional system also presents difficulties in adopting design, planning and cost estimates from previous projects to enable impacts and lessons learned on new projects. So, in summary, poor coordination, poor collaboration abilities, ineffective communication and wastage have emerged as common issues with traditional ways of working.
With the advent of design and build, early contractor involvement (ECI) and long-duration public sector construction contracts such as Public Private Partnerships (PPP), new ways of working have evolved to support the very different types of relationships that these forms of contract create. In the late 1990s, technology to support the design phase using 3D principles with other construction and management software tools like GIS, cost estimation and health & safety planning emerged; despite this, there was still the need for a system integration to cover all aspects of a project in a shared and integrated space, connecting the various professionals in a building project in real-time (Bédard and Rivard, 2003).

This demand led to the BIM paradigm, and today there is a take-up of the principles of object-oriented modelling, collaboration and information/knowledge sharing. BIM has caught the attention of many stakeholders within the industry and been applied successfully in many project and project tasks such as the process of 3D design, assisting within quantity bills and take-offs, and scheduling construction programmes and processes within an interactive and collaborative communication system. BIM could present a real opportunity to enable project stakeholders to overcome the problems identified above and deliver greater value and efficiency to clients and end users (Bédard and Rivard, 2003). Fig 2.1 identifies the communication, collaboration and visualization aspects of the BIM process; of note is the emphasis on the operational and eventual decommissioning of assets – the
knowledge generated from these phases being essential for the briefing of new projects and programmes.

A key concept of BIM is that data and information is horizontally and vertically integrated between stakeholders in order to enhance communication, teamwork, risk management, integration of sustainability, collaboration, health & safety, design efficiency and production throughout the project lifecycle (see Fig 2.2). Further studies claim that BIM is capable of resolving the problems of fragmentation by assuring the availability of data in a common format across the value chain (Jordani, 2008).

![Integrated Building Information Model](image)

**Figure 2.1.** Communication, collaboration and visualization with BIM model - Redrawn from NIBS (2008)
2.3.1. Risk management

The integrated software within BIM enables the stakeholders to detect hazards and risks in early stages and act upon it with advanced risk management strategies and techniques whilst all information is shared and notified across all stakeholders and transferred into the ‘cloud’ where it is kept and is accessible for future use. The UK’s BIM Task Group Report (2011) for the Government Construction Client Group illustrated that using BIM within projects could result in safer sites. For example, BIM permits stakeholders to have the necessary control of materials, which can make it easier to arrange for pre-assembled materials/items and products when required or to keep the on-site trades to a minimum, avoid stockpiles on site, reduce fabrication on site and minimise waste.

The use of technology within BIM in the design phase can also enable architects to produce more accurate drawings and in a shorter time than usual; clash detection and real-time design updates enable the team to identify and respond to changes and quickly act on them to reduce risk. A number of case studies have illustrated that leading international design and engineering firms strive to influence health and safety during construction by implementing BIM into their project; since the BIM system utilises a large number of tools it might have the potential for assisting design and management teams with automated hazard recognition and clash detection features (Ku et al., 2008). These features can make it possible for users to identify areas of conflict in early stages and resolve them sooner. Earlier clash detection means shorter time
required to design buildings and thus reduces costs and enhances risk management.

2.3.2. Sustainability

The AEC is one of the UK’s largest polluters after transport and power generation. The government’s sustainability NAO report in 2012 stipulated 50% reduction of construction, demolition and excavation waste to landfill, and 15% reduction in carbon emissions from construction processes by 2016 in comparison to 2012 levels. Correspondingly, the WRAP report (produced by the government in 2012) illustrated how a sustainable design approach embracing BIM could aid the design team sustainability plan. By using tools within BIM, designers can analyse how a building will perform even in the very early stages of design to evaluate design alternatives and make better decisions to enhance a greener design (Zakar, 2008; WRAP, 2012).

With BIM sustainable design approach tools, all the required information to determine which sustainable approach to use (such as options of sustainable design, critical design analysis and code compliance) can be available for each item within the design during all times in a collaborative environment (as shown in the BIM platform in Figure 2.2). This can make it easier for the design team to decide on the most suitable sustainable approach with enhanced efficiency and cost saving.
2.3.3 Communication and Collaboration

The often-disjointed relationships between project participants can lead to time-consuming processes with a significant loss of efficiency, productivity and money. Research in the US illustrates how stakeholders suffer from the lack of effective collaboration as a consequence of manual data transfers and re-handling of data with losses costing up to $15.8 billion a year (Penttilä, 2007; Baldwin et al., 1998). BIM is often publicised as a solution to the problem of overcoming adversarial relationships in project teams by providing a framework to reshape the way individuals and organisations work together in order to increase productivity and improve the final project outcomes for all stakeholders – this requires cooperative control features, structures and
analysis tools that enable real time data exchange and knowledge sharing across platforms (Penttilä 2007; Baldwin et al., 1998).

BIM technologies such as ‘buildingSMART’, aim to introduce digital collaboration into the way of working; this can arguably help the users to overcome interoperability (see 2.3.3.1) issues. buildingSMART can be used to combine the owner’s requirements and the initial design, which allows seamless exchange of core data via open standards and provides potential solutions to avoid manual handling and mistakes; this can save significant project time and result in a positive return on investment (Christensen and Severin, 2009).

Other technology systems used within BIM attempt to maintain a collaborative atmosphere through regular data exchange processes, reflecting the desire to make sure as many data formats as possible are accommodated across the project. These software applications also aim to recognise and translate data changes to and from all building elements. This means, for example, whenever there is a change in a floor plan design, the whole building and attached data will adapt to it and be available to all related users in order to collaborate and to respond when needed. Therefore, the data is consistently circulated and communicated throughout the BIM model for the entire life cycle of the building (as shown in figure 2.3); the data is simultaneously transferred to the ‘Cloud’ in order to be retrieved in future projects.
BIM aims to enhance communication and collaboration, increase efficiency and reduce errors, which in turn can reduce resources, energy, materials and waste within the project (Grilo and Jardim-Goncalves, 2010; Europe INNOVA, 2008).

A study by Manning and Messner (2008) reviewed two similar projects; one was undertaken using BIM while the other adopted a more traditional method of working. The study established that using BIM tools to collaborate in a real-life project saved $9 million and 6 months in comparison with using the traditional process. The reason was that all stakeholders had the ability to be involved sooner and resolved issues in earlier stages in advanced efficient methods. BIM
platform was used to communicate data into one fully integrated way of working throughout the construction phase. Following construction, this data was collaborated and used to gather usage data, prepare maintenance schedules and manage daily operations.

2.3.3.1 Interoperability

At the heart of BIM is the necessity for multiple pieces of software (on different platforms) to be able to exchange and use the same data. This is known as interoperability and creates efficiencies by removing the requirement for the copying of data between different design software applications on a manual basis. One of the key benefits of this is that errors that are often introduced during design iteration are reduced; this is crucial in enabling designers to achieve the optimum solution in the most efficient time period.

In BIM, the interoperability is achieved through the use of an impartial exchange format called Industry Foundation Classes (IFC) (Eastman et al., 2014).

2.3.3.2 Industry Foundation Class (IFC)

IFC allows for interoperability between software applications by providing a means of transferring building information from one system to another without any loss of data quality or integrity. IFCs were developed as an ‘open-source’
system (Mordue and Finch, 2014) but the schema is still under development. Eastman et al. (2011) identify some of these including problems with the exchange of geometries, rules and constraints, and object classes are not defined to the same level of detail for architectural/building purposes as these would be in manufacturing.

2.3.3.3 Construction Operations Building Information Exchange (COBie)

The Construction Operations Building Information Exchange emerged from the United States and is the UK standard exchange format for non-graphical information. COBie provides a standardised approach to the collation of construction data across the project life cycle and is structured and categorised in a logical fashion.

It is often noted by practitioners that COBie benefits from simple IT requirements; it can be enacted through spreadsheets although this can be cumbersome with large, complex building projects. As COBie is essentially a system-to-system information exchange protocol, its purpose is to enable the technology for the use of BIM rather than an interface that users interact with.

The intention is that asset information is transferred to the client at the handover stage, in a highly structured and systematic fashion – it is often the case that this information is presented to clients in a range of formats that do not lend themselves to reuse in other applications.
2.3.3.3 Information Delivery Manual (IDM)

Whilst IFCs and COBie provide data structures and classification for interoperability, there is a requirement for a protocol or system to link this with the construction process; the information communicated needs to be of the right quality and supplied at the right time. This is achieved through the Information Delivery Manual (IDM) using a 3-step process:

1. Identify the construction action sequences
2. Establish the methods and processes required
3. Assess the result of the processes being carried out

This will act as a catalyst for BIM implementation as it will give stakeholders access to easily-understandable information about the processes involved, the information involved and the outcomes.

2.3.4. Health and safety

Proponents of BIM claim that it enables project teams to produce advanced drawings more quickly and easily, offering increased support to health and safety strategies during early stages of design development and production of construction documents; however, this technology does not currently cover all health and safety requirements and legislations (Mordue and Finch, 2014).
Furthermore, leading international designers and research teams in universities are conducting researches and case studies to identify further solutions to implement tools within BIM to help conduct all the required health and safety procedures. These studies can provide a crucial improvement to the industry by implementing a virtual checking/detection system that complies with UK health and safety procedures and regulations. This system can aim to detect possible hazards and inadequate methods, find and introduce potential solutions and methods, and generate and control health and safety schedules. Therefore, BIM can perhaps influence health and safety control during construction by automating health and safety procedures and recognising appropriate solutions (Slaughter, 2005; Nussbaum et al., 2009).

2.3.5. Design Efficiency

As illustrated in Figure 2.4, BIM proposes to provide data management platforms based on the information that the design team and tender team gather from client’s requirements and the broader project environment. Technology features of AutoCAD, ArchiCAD and COBie within BIM’s platform can perhaps assist in integrating different design solutions, handling and controlling design efficiency, managing information, displaying product information, and providing environmental solutions and effective technologies.

These design features are designed to constantly stay active in a form of electronic demonstrative visual conflict resolution, available to every item
within the building in a managed platform for all users from different departments, such as architects, energy saving engineers, structural engineers and HVAC engineers throughout the entire life cycle of projects.

![Diagram: BIM Platform](image)

**Figure 2.4.** Data management on BIM platform

### 2.3.6. Case study; The Leadenhall Building, London

The Leadenhall Building (a new landmark in the heart of the city of London); was under construction in 2012 and used BIM during the design and construction stages. The architect working with Roger Stirk Harbour & Partners on the design of the Leadenhall Building, has demonstrated that using BIM on this project has enhanced both design sustainability and geometry control, and assisted the construction planning, scheduling, and estimating.
The contractor has suggested that BIM provided full control to the design team and enhanced their working-flows during the complex process of designing the complex architectural features of steel and glass within a distinctive mega frame every seven floors. Similarly, it enabled the construction teams to thoroughly examine the construction methodology in the early stages to identify potential opportunities for engineering approaches to the erection of the symmetric steel superstructure, the frame, the backbone structure and the claddings with smart creative strategies, careful planning and execution while maintaining the quality and the timeframe of the project.

BIM has also provided enhanced site possession within the busy road of Leadenhall. BIM enabled early arrangements of suitable crane positions, mechanical access platforms, pedestrian walkways, access platforms, required machineries, site welfare offices, monorails, site access and egress, working platforms and material hoists throughout all stages of work; this guaranteed a smooth project and provided:

- Client with lower net costs and contractors requiring less time.
- Reduction of subcontractor costs and risks.
- Safer and greener buildings.
- Enhanced decisions through the improved visualization of 5D Models.
- Inclusive decrease in RFI.
• Easy recovery of information.
• Increased coordination of construction documents with better understanding and appreciation between professionals.
• Increased speed of product delivery.

2.4 Summary

This chapter has explored the main drivers behind changes in the AEC industry and highlighted how the potential for BIM might enable improvements in the way engineering projects are delivered. In the next chapter, the current literature on BIM will be explored in greater depth in order to evaluate the opportunities and challenges that might exist.
Chapter 3
An overview of Building Information Modelling

3.0 Introduction

This chapter explores the contemporary literature on Building Information Modelling and aims to illustrate the diversity of meaning and understanding across various industry stakeholder perspectives. This analysis is grounded in a historical perspective and considers the impact of IS/IT developments in the United States as a driver for improved design co-ordination and collaborative working. The chapter concludes with an investigation into the principle challenges surrounding adoption and integration of BIM in educational settings.

3.1. First principles

BIM technology has been in existence, in some form or other, for almost half a century. Within the AEC industry, the first introduction to the theory of BIM was in the late 1970s by scholars at Georgia Institute of Technology. Their research made significant contributions to technology development within the industry, and is perhaps best illustrated by Autodesk under the CAD concept (AutoCAD) in the early 1980s. Graphisoft, who introduced their initial “Virtual Building Solution” in 1986, now known as ArchiCAD, followed this. This was the start of the software ‘revolution’ that allowed architects to create virtual, 3D designs of their project instead of the standard 2D drawings.
However, this technology was only limited to designing within the architectural practices; it was mainly used to illustrate building materials in order to show clients and stakeholders the design of the building in the early stages. This technology allowed the design team to reduce time and increase the quality of design but was also known to be expensive, fragile and complex (Puckett, 2012); designers using 3D software still had to go through the process of producing countless specification sheets in order to express all the required information to the rest of the team.

Since the early 1990s many other software tools have been developed to assist the roles of other professionals and stakeholders within the industry, such as project management software, programming software, planning software, and developed excel software for pricing. These software tools have given the industry an enhanced control of time, cost and quality but it was still a fragmented way of working as each member of the team was working on separate software. Therefore the creation of a collaborative constructed virtual building model such as BIM was required to complete the missing part of the jigsaw of the virtual design concept as demonstrated in Figure 3.1.
The term ‘Building Information Modelling’ was first used in 2002 to achieve the virtual design concept. BIM has progressed quickly since then, with many construction teams having observed value in using BIM within the construction industry; it has become more attractive with the continuous development of BIM tools. Today BIM is a moving target with a wide progress, becoming increasingly popular within the AEC industry, throughout conferences, government strategies, company strategies, awareness campaigns, and a wide range of journals and researches.

3.2. Definitions of BIM
As a starting point, it is useful to consider some of the definitions of BIM that have recently emerged. The professional institutions (RIBA, RICS, ICE etc.) have all developed strategies to respond to the BIM agenda and it would be wise to consult the various institutional special interests groups for up-to-date information but, as a starting point, the current definition of a ‘building construction information model’ (AKA BIM) adopted in BS ISO 29481-1:2010 is;

‘shared digital representation of physical and functional characteristics of any built object (including buildings, bridges, roads, etc.) which forms a reliable basis for decisions’

The emphasis of the ISO definition is embedded in the notion that construction project data lies at the heart of the representation of a model that may be used by the collaborative team to enact a series of decisions that ultimately lead to the successful completion of the project. The RICS recently published a note to members that emphasizes this point;

‘A BIM model contains representations of the actual parts and pieces being used to construct a building along with geometry, spatial relationships, geographic information, quantities and properties of building components (for example manufacturers’ details). BIM can be used to demonstrate the entire building lifecycle from construction through to facility operation’
It can be inferred from these definitions that BIM is a contemporary industrial transition from the traditional two-dimensional (2D) standard drawing format to one that provides a rich information model consisting of multiple data sources, elements of which can be shared between all project participants and be maintained throughout the life of a building from inception to demolition/recycling. Advocates of BIM are keen to emphasise that the concept is not simply concerned with software tools and data classification systems; it also advocates a collaborative working process characterised by well-managed information interfaces that provide a ‘joined-up’ decision-making process in a real-time format. It seems obvious, therefore, that a key facet of BIM is good project management coordination.

Adopting a BIM strategy in the early stages of a project should allow project participants to contribute to building a model that represents the whole building’s components, interactions and performance (structurally and thermally say) before construction, therefore resulting in potentially significant improvements in safety, cost, value, and carbon performance. BIM could have benefits for clients too, assisting the multi-disciplinary team in communicating design concepts in formats that are readily envisaged.

There are numerous lenses through which one can understand BIM; Aranda-Mena et al. (2009) highlight this as ‘an ambiguous term that has different definitions for different professionals’. BIM is sometimes confused with being just software rather than a way of working; no doubt this way of working is
concentrated around creating and using a computable information model to build and control a project but there is a lot more to it, as Figure 3.2 illustrates. BIM is a contemporary industrial transition from the traditional 2D standard drawings to providing a rich information model consisting of multiple data sources, elements of which can be shared across all stakeholders and be maintained across the life of a building from inception to demolition or recycling. However, BIM requires contributions from a variety of parties involved within the project to work collaboratively to provide a well-managed bond of information.

Figure 3.2. The iceberg model of Building Information Modelling (Succar, 2011)
Using BIM in early stages could allow all stakeholders to see and visualise the model, which represents the actual building’s parts and pieces that are used to build the structure virtually before it is actually built. Therefore, it could potentially result in significant improvements in safety, cost, value, and carbon performance.

However BIM was developed to be much more than just a tool to see what the building might look like before it is built; the BIM model is proposed to contain data and information from spaces and geometry, to costs, workforce programming and planning, quantities, specifications, suppliers and other information types.

<table>
<thead>
<tr>
<th>Plan</th>
<th>Build</th>
<th>Operate</th>
</tr>
</thead>
</table>
| **Building Information Modelling (BIM)** | • Conceptual Design  
• Interactive Designs  
• Architectural BIM  
• Structural BIM  
• MEP BIM | • Construction Sequencing  
• 4D Modelling  
• Clash Detection  
• Fabrication BIM  
• Spatial BIM Installation | • As Built Model  
• As Built Equipment.  
• Complete Virtual Blog. |

**Figure 3.3.** BIM Integrated Life Cycle
This information is contained in such a model where it is all related and built on each other to help provide the best solutions, enhance decision making, improve production to a high level of quality, enhance prediction of building performance, save time, and control the budget in a safer environment within an organised collaborative environment throughout the building life cycle as illustrated in Figure 3.3.

### 3.3. BIM maturity levels

The simplest way to understand BIM is by considering the different maturity levels as illustrated in Figure 3.4. It is important to reiterate at this point that, as far as the UK construction industry is concerned, all projects commissioned (on behalf of the government) should be Level 2 compliant by 2016:

- Level 0 BIM involves producing information from 2D CAD files. This process is known as ‘the traditional practice’, which has been used for many years by the multi-disciplinary team.

- Level 1 BIM uses both 2D and 3D tools for object-based modelling. This process tends to be used by architects, usually in early project stages where 3D tends only to be used as a design tool for visualisation and presentation of designs rather than as a tool to control costs (say).
• Level 2 BIM involves producing an information model in a collaborated environment, and could be said to be ‘object-oriented’ in programming parlance. This level of working represents the UK government ideology, where 3D tools are used with 4D construction sequencing and/or 5D cost information by the multi-disciplinary team (including clients) to produce object-oriented models capable of manipulation in an optimal way.

• Level 3 BIM features BIM tools in a network-based integration system where the multi-disciplinary team work in an integrated and federated ‘society’ using 3D design tools, 4D construction sequencing, 5D cost information and 6D project life cycle management information. All of these tools are managed and sequenced by Industry Foundation Class (IFC) web services and standards.
Figure 3.4. BIM Maturity Diagram (based on the original Richards/Bew ‘wedge’, 2008)
While defining the different maturity levels of BIM, the features of 3D, 4D, 5D and 6D are used. Each dimension is characterised as follows:

- **3D (Design tools)** is a common-used terminology within model designing. As mentioned previously, 3D designs were used in the early 1980s when AutoCAD and ArchiCAD were introduced. However, these software tools were only used for model simulation purposes to show the client what the building could look like. The 3D concept is much more than that with BIM. The model walkthrough feature within BIM not only allows clients to visualise the detailed design but also enables the design team to work together with other members to communicate different ideas and contribute towards the model. BIM also provides a clash detection tool that allows users to identify and resolve problems in early stages of the design process. This 3D Model is of great use to the project team, allowing them to visualise what the building looks like as construction progresses in accordance with the schedule, which can enhance the contractor’s understanding of how the building should come together.

- **4D (Construction Sequencing)** is provided by construction planning, programme management and schedule visualisation tools that allow users to input a detailed construction sequence with a visualised work schedule of every element on the model in a form of a critical path chart that is based on multiple information sources; if one element of work is
delayed then all works will change automatically and accordingly on the model where construction sequence clashes are detected. These tools can also be used during the design and construction stages to enhance the on-site health and safety planning and monitoring.

• **5D (Cost Information):** BIM Model can include the cost data of each object to enhance the procedures of cost estimating and cost analysis by using Quantity Take-offs tools and ‘Real Time’ cost estimating tools. Cost estimating experts can use these tools to automatically calculate a rough estimate of material costs, which will minimise errors, provide quicker process in take-offs and guarantee accurate quantity measures in comparison to the traditional manual take-off. All information quantities can be generated directly from the model and estimated information can automatically adjust accordingly if any changes are made within the model.

• **6D (lifecycle management):** the building information model can be created and shared across a collaborated platform throughout the whole life cycle of the project from inception to demolition. During the construction phase, the model is created and updated throughout the construction phase then handed over to the owner once the final stages of the construction phase are complete. At that stage the model can be comprehensive with all the required useful data to manage and maintain the building, such as operation and maintenance manuals and warranty
information for each element of the model, along with data sensor tools that can capture and feedback when and where any future maintenances are required. This feature can give the building owner the ultimate control to manage, maintain, evaluate and control the building until demolition.

3.4. The benefits of BIM

Communication problems (whether intended or unintended) remain as much a problem in engineering projects as elsewhere in business and commerce. Proponents of BIM argue that it provides a ‘bridgehead’ enabling reliable and regular knowledge exchange across the project organisation, with the potential to improve relationships between the architects, engineers, construction professionals, facility managers and building owners; this feature could also enable a multi-disciplinary team to remain synchronised – this should improve accuracy and enable a more informed and knowledgeable approach to decision making, which could in turn reduce waste and help to achieve a successful project.

BIM is also considered to be a positive transition for designers, where they can be supported by new means of technological tools throughout the design processes; this can make their work easier, smoother and faster while enhancing the quality of designs.
Similarly, contractors can create visual data for the costs, materials and construction sequences within a shared collaborative model. Once the information data is placed within the BIM model, it can automatically present itself in floor plans, elevations, specifications, work sequences, and quantity takeoff, etc. All accessible users can view the information and operate on it, instead of working from detached drawings and schedules in the form of many separate paper documents. Information within BIM would also automatically adapt when changes occur to a set of data, together with a clash detection tool if changes are unsuitable. This is different to the traditional fragmented practice of numerous individual sets of drawings, where design and construction teams have to go back to manually change and re-print each set of drawings, elevation, specification, work sequence and quantity takeoff.

Case studies carried out by Kaner et al. (2007) and Eastman et al. (2008) indicated that the use of BIM in projects reduced the number of information requests and order changes; it also improved productivity and efficiency, especially in the early stages of design.

A report commissioned by The Department for Business, Innovation & Skills (BIS) and HM Cabinet Office in 2008 recommended that a BIM approach could account for up to £2.5 billion per annum savings in the construction phase alone (HM Cabinet Office, 2008)
3.5. Challenges towards the implementation of BIM

The co-ordination of activity to promote and embed BIM in the UK is achieved in part by the 'BIM Task Groups’ – and whilst the overall message that has emerged has been one promoting the virtues of BIM, there is an alternative viewpoint that suggests that BIM could introduce problems that hitherto would not otherwise have been evident using more traditional methods of design and construction co-ordination; these are summarised in Migilinskas et. al. (2013), based on four international case studies:

- Predisposition to software tools and methods of working that are familiar to the project participants;

- Focus on ‘difficult’ aspects of the project rather than broader application to the whole;

- Some intelligent approaches such as Virtual Project Development utilised for the first time and some concerns regarding the quality of the data used to construct the model.

- Benefits of BIM are directly correlated to the ability to maximize collaboration in projects. Piecemeal adoption across the project team leads to problems;
• High costs with software purchases and staff upskilling;

• Lack of standardisation and expectations of contract obligations in certain countries or regions (such as European Union, Americas, Asia and others).

In essence BIM is only as good as the people using it. Many clients are still hesitant towards the implementation of BIM because they remain uncertain about the scope, costs and benefits. This is due to the nature of the stakeholders within the industry and the high costs of BIM implementation owing to the required extensive training of the different professionals, cost of technical expertise, costs of organising protocols and managing a network server to store and access the model.

Other issues preventing the implementation of BIM are the legal barriers surrounding liability and uncertainties over Intellectual Property Rights, digital information exchange and ownership of the programme. However, these issues could be resolved in time and with careful consideration.

Although these issues might seem to be great barriers to implementing BIM, reports and studies illustrate that it has been widely used around the world.
3.6. International perspectives on BIM

Despite the above-mentioned implementation barriers, many countries have showed great interest toward implementing BIM across the Architecture, Engineering and Construction industries. However, each country has its own arrangements and progressed differently as explained below.

3.6.1. United States (US)

The USA was the earliest initiator of BIM, particularly within the public sector. In late 2006 the US General Services Administration (GSA) issued a BIM guideline outlining an implementation plan to accompany the integration of BIM use within the US AEC sector in general and the Public Building Service (PBS) in particular. Following this, in 2007 the US GSA issued a mandate to obligate all planners to use BIM while applying for GSA funding schemes (GSA, 2007).

In addition to the widely-recognised benefits of BIM that the public sector appears to be gaining benefits from, the US AEC sector has established BIM policies by addressing the allocation of risks associated with the implementation of BIM, outlining the roles and responsibilities of each participating party while avoiding any conflicts with the existing construction contracts and policies. This in return has encouraged many stakeholders to use BIM as indicated by the American Institute of Architects’ report on the
Business of Architecture (2010), confirming that 60% of US architects were using BIM throughout their projects and still increasing yearly.

3.6.2. Finland

The implementation of BIM within Europe was initiated later than the USA but it has spread more quickly and exposed a wider improvement within the industry, especially in Finland (as shown in Figure 3.5). According to the Finnish ICT Barometer for architects in Finland (2007), 93% of architects were using BIM in projects with 33% of that usage at BIM level 3. In the same survey it was indicated that nearly 60% of Finland’s engineers are using BIM in both the public and private sectors (Kiviniemi, 2007).

This spread of BIM use within Finland is due to increased interest by the AEC and Facilities Management (FM) companies in profiting from the benefits of BIM. Starting from 1st October 2007, the Finnish FM companies focused on using BIM’s modelling technology within common project works. In 2009, they established detailed modelling guidelines to assist with the use of BIM during the design stages. Later in 2009, the governing body of public properties used these guidelines to run several pilot projects; it had a great impact in making decisions for the Senate Properties’ investment processes and enhanced developments within the public sector (VTT, 2007).
BIM has also reached the private sector in Finland, where major companies such as ‘Skanska Oy’ and ‘Tekes’ took the lead of adopting BIM within private projects (Kiviniemi, 2009). Giant private companies have also funded a number of BIM related researches with local universities such as Tampere University of Technology; these researches investigated the benefits and outcomes of BIM practice within the industry to promote the integration process of BIM, developing technical tools and investigating the potential of BIM in providing sustainable solutions within the industry (Leicht et al., 2007; Huovila, 2008).

3.6.3. Singapore

The National Ministry of Singapore first introduced BIM in Singapore in early 1995. This gave organisations such as ‘Development Construction and Real Estate Network’ (CORENET) an early involvement to develop and implement BIM within governmental public projects.

Singapore’s government has been successful in pushing for BIM implementation and BIM standards on various kinds of projects within the public and private sectors with the help of CORENET’s BIM Guideline “Integrated Plan Checking” (Khemlani, 2005). This has noticeably enhanced the number of public-private initiatives to encourage the use of BIM in a large number of pilot projects.
3.6.4. **India**

India’s fast growth of population and economy have provided a boost to the building environment and provided the perfect platform to implement BIM. India has a strong workforce of qualified, trained and experienced BIM specialists who are not only implementing BIM technology in India’s Construction Projects but also assisting on the implementation of BIM in Canada, USA, UK, Singapore and the Middle East regions.

3.6.5. **Canada**

The Institution of BIM in Canada (IBC) has taken the responsibility of leading and facilitating the full implementation of BIM into the Canadian built environment where they maintain a keen interest in focusing on the primary stakeholders, allowing them the right method and pace to understand their roles and responsibilities and to assess their capacity to contribute in this process.

3.6.6. **Continental Europe**

UK, Netherlands, Denmark, Finland and Norway Governments are already demanding the use of BIM for public projects. Consequently, in November 2013 the European Parliament voted to support the utilisation of electronic tools
such as BIM for public works contracts. They have described this convention as an approach to possibly enabling more efficient construction and building projects in Europe and help advance European competitiveness.

Following this decision, leaders from Europe's AEC industries have expressed their support to the European Parliamentary vote on what they described as modernising the European public sector.

This parliamentary vote is perhaps viewed as paving the way for adopting BIM and permitting all 28 EU member states to encourage, specify or mandate the use of BIM for public funded construction and building projects by 2016.

3.6.7. France

In April 2014, the French minister of Housing and Development announced the new "Building 2.0", which primarily uses Building Information Model as the main tool for public projects and outlining that BIM will become obligatory in all state-owned projects by 2017. However, no plan has yet been introduced for these requirements to take place.

3.6.8. United Kingdom

The UK Government has already shown its awareness of BIM's benefits in perhaps controlling costs, time and quality and the advantages it could offer to everyone involved in the construction projects, including clients, designers, contractors, suppliers and facilities managers. On 31st May 2011 the UK
Government showed its interest in BIM by publishing a construction strategy report that announced that it is aiming to adopt BIM’s technologies, processes and collaborative behaviours into all stages of the life cycle of all public projects by 2016. This is expected to advance the use of BIM in the UK, as shown in figure 3.5. However, the UK industry is not yet ready for the implementation of BIM. The following will establish the barriers that stakeholders within the UK industry will face in seeking to implement change. Most of these issues may only appear during the implementation of BIM level 3. Implementing BIM level 2 should not create significant additional risks, but some amendments might be required to smooth the implementation process.

![Figure 3.5. BIM Adoption in Europe](image)
3.7. BIM implementation problems

As mentioned in section 3.3, BIM level 1 only contains the use of the design software features within the design stage; this level is currently used and is widespread within the industry without any major implementation issues. On the other hand, BIM level 2 is an increased method in using software technologies within separate disciplines. Therefore, the following topics should be considered before BIM level 2 could be implemented within projects:

- The necessity for intense awareness campaigns and training courses throughout the industry to cover the doubts and debates surrounding BIM and enhance awareness towards the responsibilities and roles of individuals and organisations throughout the use of BIM level 2.

- Implementation of Level 2 BIM may require amendments to the intellectual property legislation.

- Contractual amendments and software measures might require rearrangements to protect users from data corruption and software tool failures especially when different users operate on the same model.

- Enterprises operating on level 2 BIM might become limited during tenders when level 3 BIM is fully implemented by others.
• A BIM protocol must be outlined and agreed during the procurement stage to address risk sharing, detailed responsibilities of all users, technology level of each model, level of definition, and an exclusion of liability. These protocols must be clearly outlined within the agreements between the client and those responsible for the BIM model (Beale and Company Solicitors LLP, 2013)

Implementation of Level 3 BIM is not just a simple step up from level 2 in terms of using software tools; it is an elevation to a very different style of working. BIM level 3 will require using 3D, 4D, 5D and 6D tools within one collaborative platform; this will require a number of considerations as detailed below:

3.7.1 Barriers to implementing BIM on existing buildings and infrastructure

Attempts have been made to use BIM for old and pre-existing facilities. However, this was only possible when the existing facility was rebuilt visually in BIM or converted into the form of BIM. Converting an existing building into a BIM model would require numerous assumptions such as the standards and codes of the existing building design, the construction methods used, and the materials used at the time of construction.
3.7.2 Barriers to implementing BIM on new buildings and infrastructure:

- **Cost** – BIM level 3 will require significant investment from across the industry. There would be a need to take into account the costs of BIM’s software and hardware as well as other costs, such as the extensive training of the different professionals, cost of technical expertise, cost of organising protocols and organising a network server to store and access the model. These costs raise the concerns of many small/medium enterprises within the industry. Failure of these enterprises in fulfilling the cost requirements will generate a large gap between them and other BIM-using enterprises in terms of recognition, work quality, winning tenders, saving time and money etc.

- **Industry ‘mind-set’** – (Need for teaching and training) The current traditional way of working will not easily adjust to the high-tech collaborative way of working that BIM is introducing to the industry. BIM level 3 will completely change the way that professionals would approach their day-to-day duties, from the fragmented paper method to having to work within an informational collaborative model that requires regular communication between different participants from early stages. Therefore, all existing and new coming professionals must be trained and educated to fully understand their responsibilities and duties. Also, these responsibilities and duties must be considered and drafted within the
contractual documents to ensure services are carried out according to the collaborative nature of BIM.

• **Information control** - BIM level 3 relies considerably on IT and software systems. This reliance raises many concerns as to the need of various control procedures in order to limit and control access and inputs such as data protection with firewall systems, data backup features in case a corruption of data appears, technical support facilities and professionals etc. The BIM model is the core data platform of the project; one error within the model can be both costly and time wasting.

• **Ownership** – The issue of model ownership has been widely debated, with many stakeholders within the industry being concerned with who should obtain the final version of the model and the involved data. These debates are mostly due to the misunderstanding of the concept of BIM; if the model generated by BIM was correctly categorised as a product then by law it should only be retained by the buyer, i.e. the client or the building owner. However, the data contained within the BIM model is a separate issue because it is generated from contributions of various team members; they should be authorised to obtain a copy of their contribution for future records. These issues must be considered and discussed by the government to outline and verify the legal regulations towards ownership of the BIM model and the involved data during and after construction.
• **Liability exposure** - Different professionals from various enterprises contribute towards the BIM model throughout different stages of the product’s life cycle through collaborative software systems; this new way of working might create irregular liability issues. BIM software system is protected by “blanket limitation of liability” clauses that generate the question of who is liable for any errors caused by the software tools. Another concern is who is liable if works were carried out incorrectly due to inaccurate information given by a different professional in the early stages. These risks must be dealt with and clarified in contractual protocols and carried out accordingly to distribute risk and liability evenly.

• **Insurance** - limited insurance companies can currently offer to insure BIM. Due to the limited use of BIM and doubtful impressions that was surrounding its benefits and the risks it may incur, it was incredibly expensive to insure works done with BIM. However, now that BIM has been successfully implemented within different projects, insurance costs have decreased. For the time being, it is important for parties to consider taking out the appropriate insurance to cover their engagement in the BIM process to obtain their usual coverage and protect themselves against liabilities and risks.

• **Contractual documents** – BIM level 3 offers new roles and responsibilities for existing and new professions such as BIM managers and architects and draftsmen. Project contracts should include a detailed brief of these roles.
and outline the duties of each professional role to suit the use of BIM within projects. The same set of BIM privileges and requirements should flow through the different contracts to avoid clashes between the clauses of the principal contract and the legal terms of the BIM protocol.

3.8 Commonly used BIM software tools and vendors

The BIM software market is changing rapidly and consequently a range of products is currently available to the design team, of those currently in use the most common are:

- **Autodesk® Revit®** software is widely marketed as a ‘one-stop-shop solution’ for BIM that includes features for architectural design, MEP and structural engineering, and construction. The software has the benefit of bidirectional associativity (this allows connections between objects to update automatically) and work-sharing so that multiple users can work on the model simultaneously. Autodesk® Revit® 360 is a collaborative tool that provides access to data storage, collaboration workspace, and ‘cloud services’ to improve collaboration. In simple terms, ‘cloud computing’ involves a large number of computers connected through a real-time communication network.

- **Autodesk® Navisworks®** software is widely accepted as a BIM tool, given it performs many of the functions that the spirit of BIM aspires to including coordination, sequencing and construction process
simulation, and project analysis. The tool includes scheduling optimisation algorithms and assists with the identification of clashes and interferences. Up until quite recently, the industry perception of BIM was ‘clash-detection’, probably due to the popularity of tools such as this.

• **Bentley Systems** software functions in a similar way to Revit; it integrates the project model through a family of application modules such as Bentley Architecture (Microstation Triforma), Bentley Structures, Bentley HVAC, etc. The vendors suggest that interoperability is best achieved through the use of the whole family of tools rather than piecemeal adoption.

• **Graphisoft’s ArchiCAD** 17 application is now enabled with BIMx (a graphical tool that enables the design team to present and communicate model data) and BIMserver which is designed to make projects accessible through standard internet connections by optimising data exchange traffic.

• **Nemetschek Vectorworks** is Nemetschek Vectorworks Allplan 2013 is a similar product to Bentley and is commonly used in Germany. It features a number of discrete components that can be utilised to develop a BIM work-stream including Allplan Architecture, Allplan Engineering, Allplan BCM (the software for tendering, billing and construction cost planning) and Allplan Allfa which focuses on hard and soft FM.
3.9 Implications for UK industry and higher education

As established from the literature review, it is arguable that BIM could address, in part, the problems that have emerged from the highly fragmented and in parts, inefficient nature of the AEC industry. Whilst BIM is perceived by some as the mechanism to eliminate the inefficiencies identified in Chapter 2, the literature suggests that BIM is not, in itself, the entire solution to industry’s problems. The emphasis on “the collaborative way of working” will provide the industry with a more productive working environment but it must be recognised that contract and procurement play a significant role in shaping those behaviours too.

A number of high profile civil engineering projects that have deployed BIM are now becoming beacons for improvement, although the UK government’s first BIM pilot study was on a significantly simpler project: HM Young Offender Institution Cookham Wood. The project consisted of a new three-storey block to house 179 young people in single cells, together with an education facility, a new two-storey regime building offering vocational skills training and external works including three new fenced exercise yards, access roads and associated security fencing. Reported benefits of operating with BIM include improved collaboration and design co-ordination; design efficiencies; reduced wastage in design, materials and on-site production; and greater benefits for asset management, custodial operation and on-going maintenance of the facilities as well as a recorded £800,000 saved (MoJ, 2013).
Other examples of recent BIM schemes include:

• **The Panama Canal** - BIM was used to assist the design and construction team with the complex engineering challenges of The Panama Canal, in particular to find major engineering design solutions such as the lock walls seismic design, water consumption and integrated operations and controls. BIM was also integrated into the design delivery phases.

• **Highways Agency/Highways England Projects** – A number of major highways engineering projects have been delivered in the UK as ‘pathfinders’ for BIM. One such example is the A160/A180 Port of Immingham Improvements. The organisation devised a BIM strategy within its project and asset management activities to develop the required systems, software, protocols and capabilities with a target to develop a project strategy aimed at BIM Level 2 compliance, with the potential for some elements of Level 3 being demonstrated too. Specifically, the following activities were implemented across each of the BIM dimensions:

  • **2D Information** - 2D drawings where required generated directly from the 3D model.

  • **3D Design Model** - A fully federated 3D model of the scheme was produced and maintained throughout the duration of the scheme. The model was used for co-ordination, communication and clash management.
• 4D Programme Model - The programme was embedded into elements of the model for construction purposes.

• 5D Cost Model - Budget and forecasts were integrated into the model on a trial basis initially and used to determine earned value, valuing change and optimising visibility of cost.

• 6D Asset Model – the project achieved (for a small section of the works) a fully functioning set of BIM data. The principles of COBIE standards as the transfer mechanism to tie the asset data to the model were observed.

• Crossrail – The use of BIM in Crossrail projects has been instrumental in visualising the complex interplay between the tunnelling work and the existing sub-surface infrastructure.

• Heathrow Airport expansion - BIM was used throughout the design and construction stages of the Heathrow Terminal 2B project and in part on the new Terminal 5 at Heathrow and Gatwick redevelopment works.

During the course of this research, various meetings, workshops and conferences were organised by HM Cabinet Office (hosted by David Philp, Head of BIM Implementation) and supported by executive members of the BIM task group. The researcher was able to contribute to a number of these events.
and observations that emerged from participants centred on deployment issues such as interoperability, workflow disruption and legal and contractual issues. However, the deployment issue of training and education of BIM remains largely unresolved and this is of increasing concern to employers and clients.

The advent of major programmes like Crossrail has illustrated the valuable role of BIM in large scale infrastructure schemes; indeed it has emphasised the importance of civil engineering as a discipline in its own right. Any research aimed at making recommendations for the integration of BIM into a civil engineering syllabus requires a greater awareness of the specific learning outcomes of the Engineering Council UK-SPEC and the requirements of the JBM – this was something that the BAF report did not address.

Nevertheless, over the last three years, a range of university programmes have started to include BIM in their curriculum (mainly construction management and similar degree programmes) and some are delivering a dedicated BIM higher degree. Progress in civil engineering programmes appears slower and this is complicated by there being no recognised process for teaching/embedding of BIM (Rubenstone, 2007).

Consequently, the BIM Academic Forum (BAF) was commissioned by Aled Williams, Discipline Lead (Built Environment) at the Higher Education Academy (HEA) in late 2012 to initiate the process of guiding HE institutions in embedding BIM within the taught curriculum, with the involvement of over 60 academic staff drawn from 29 different institutions (including the researcher).
The BAF produced a report in June 2013 by conducting a series of workshops and information events. That report considered the impacts that BIM would have on the learning needs of undergraduates and postgraduates studying programmes within the Built Environment and Architectural schools and faculties. The report did not, however, consider the issues and approaches suitable for undergraduate civil engineering courses within universities and educational institutions in the UK.

3.10 Summary

Wesley’s (2013) research on BIM within the civil engineering undergraduate curriculum indicates that many undergraduates appear to lack a basic comprehension of the basic fundamentals. This research involved establishing how (and if) BIM was taught in 24 Russell Group universities in the UK. The results indicated that only one university stated that BIM activities were introduced within their Civil Engineering programme as shown in Figure 3.6.
The research also highlighted that, of 9 universities who indicating that some BIM activities existed, these were mainly related to research and postgraduate study. The study confirms that a large proportion of programmes have yet to address the integration of BIM and this could have implications for student recruitment, accreditation and employability – these issues, and others, will be discussed in the following chapter.

**Figure 3.6.** BIM within the CE Undergraduate programmes (Wesley, 2013)
Chapter 4
Building Information Modelling in Civil Engineering Undergraduate Education

4.0 Introduction

The previous chapter considered some of the issues that the AEC industry is grappling with insofar as BIM is concerned and summarised with some of the implications for higher education degree programmes in the built environment disciplines. This chapter consolidates further by exploring the particular issues of the civil engineering discipline. The chapter opens with a narrative on the evolution of education in civil engineering. This is followed by justifications and clarifications as to why the teaching BIM is required; this includes analysis of teaching and learning techniques and approaches elsewhere in the world.

4.1. Evolution of Civil Engineering Education

The practice of civil engineering is strongly related to education; its nature is a reflection of what students are taught in terms of factual knowledge, methods, skills, and abilities.

Seely (2005) identifies the various impacts on civil engineering teaching that witnessed a transition from a ‘trade’ to a ‘professional’ discipline. An analysis of that evolution reveals why the current characteristics and techniques used in civil engineering dominate today’s curriculum.
Up to the 1920s, civil engineering education was based on the “master apprentice” paradigm. This form of teaching was a combination of rote learning, memorising of known facts and heuristics and of acquisition of knowledge through learning from examples. This model was highly popular in many disciplines but, unfortunately, it was also time-consuming, costly, and could only produce a very limited number of engineers due to the complexity of teaching and the subsequent examinations that were required to demonstrate understanding.

At the end of the 19th century, progress in sciences, particularly in mathematics and physics, changed the dynamics of engineering education as the “scientific” paradigm emerged. This form of teaching transformed teaching engineering to a scientific way of teaching, focusing on the mathematical and physics foundation of engineering rather than the ‘practice’.

According to Felder and Silverman (1987), their work on “learning and teaching styles in engineering education,” in 1987 highlighted a misalignment in the common learning styles of engineering students and the traditional teaching styles of engineering lectures. The authors suggested that this led to inattentive behaviours amongst some students in class, and/or students seeking a change to an alternative degree programme.
Today, the primary focus of civil engineering education is on analysis, on building quantitative understanding and numerical competence. However, civil engineering knowledge is still partially heuristic, although over the last century it has been supplemented by all kinds of mathematics and physics based theories, including complex mathematical models in fluids, statics, thermodynamics and finite element methods. This shift from art to science has elevated civil engineering standards but also ultimately led civil engineers to become arguably less competent in the use of technology and therefore inadequately prepared to deal with the complex challenges of the 21st century (Russell, et al., 2007).

Engineering education in general has always focused on teaching knowledge and principles related to the professional practice of engineering. However, the civil engineering knowledge associated with the application of technology is arguably less apparent, particularly in the last decade.

According to Arciszewski and Harrison (2010), the scientific paradigm used in civil engineering education today is insufficient in meeting industry demands and addressing employability. It has to be critically examined and expanded to suit the industry’s requirements, and be able to react to new changes and updates within the industry whilst preserving the traditional aspect of the civil engineering profession. In practical terms, the scientific paradigm must evolve into a new way of teaching that adapts to the current and future changes within the industry.
According to Sacks and Barak (2010), the lack of BIM skills and knowledge is a significant constraint that delays the use of technology by students. The authors argue that, unless BIM is introduced into undergraduate civil engineering curricula in a fundamental way, graduates will lack the skills needed to serve the industry in which 3-D models are the main medium for expression and communication of design intent and the basis for engineering analysis (Sacks and Barak, 2010).

Integrating the use and concepts of technologies within civil engineering education is essential to the long-term survival of civil engineering education. Wulf (2007) suggests that ‘the practice in engineering has changed enormously from what it was forty years ago. However, education hasn’t changed very much at all. Engineering education has to change, not just to keep up with the industry but to lead it” – the assertion is that civil engineering education is in danger of falling behind other engineering and physical sciences disciplines (Sacks and Barak, 2010).

4.2. The role of higher education in the teaching of BIM

Dean (2007) undertook a wide-ranging research study to examine whether or not BIM concepts and tools should be taught to students. The conclusions were that it should be – principally due to the results of a survey of over 420 industry professionals, approximately 70% of who indicated that they are either using or considering the use of BIM technology within their respective organisations. In
this study, approximately 75% of participants also stated that candidates with BIM skills were presented with a distinct advantage over candidates without them when seeking employment.

Correspondingly, some of the UK’s largest employers of engineering graduates frequently complain that they enter the industry with a lack of basic BIM knowledge and advanced computer skills, and most importantly lack the communication and teamwork skills that many graduates neglect as a result of studying engineering via the traditional methods described above.

Fox and Hietanen (2007) concluded from their studies that students/graduates with BIM knowledge and skills are important elements that can contribute to the inter-organisational use of building information models. Young et al. (2008) concluded from an extensive research that a lack of adequate training and education is the most significant impediment to BIM adoption. Furthermore, Hartmann and Fischer (2008) described “the lack of knowledgeable practitioners who are ready to move the industry into the BIM age as a major bottleneck”.

In 2013, the researcher undertook a survey (see Chapter 6 and Bataw and Kirkham, 2015) of final year civil engineering students in the UK. It indicated that only 23 students out of the 363 final year students who responded were aware of BIM, whilst only 9 admitted to knowledge of the maturity levels of BIM. This suggested that a very small number of civil engineering graduates
would be ‘BIM ready’ on graduation and thus presenting industry with a significant skills gap to bridge in the early years of professional practice.

4.3. Course content

Most, if not all HE institutions undertake both research and teaching but the mission focus and balance between these activities varies depending on the institution (Universities UK, 2013). It is argued that teaching and learning at undergraduate level in the UK will always lag behind both the research agenda and postgraduate level research study. Chapter 1 presented a number of BIM-related doctoral studies but the current landscape suggests that very little pedagogic research is currently being undertaken, beyond that of the work of the researcher and BAF. It is interesting to note that this activity is not being effectively transferred to the undergraduate curriculum of the majority of educational establishments across the world because implementing new technologies into a curriculum can be a difficult task, especially technology as complex as BIM.

There is evidence that traditional 2D/3D design using software tools such as AutoCAD remain firmly embedded in civil engineering curriculums. This is because schools are reluctant to implement new technologies in to curriculums (Ibrahim, 2007) due to reasons including staff training, accreditation requirements and risk-adverse teaching styles. However, students at the present time are entering higher education with greater abilities and
willingness to operate on computer software tools (Horne and Thompson, 2007); therefore, students are finding the existing curriculum in many universities incompatible with what they are familiar with in secondary education.

Universities struggle to implement new methods in to their curriculum, especially when it requires implementing technology-based methods such as BIM. This is due to the fact that changes to the curriculum often require long and complex committee approvals, discussions on which can often bring colleagues into conflict. Further to acceptance of the programme there is also acceptance required by the accrediting body/bodies; this can be the biggest obstacle, since the bodies are not simply reviewing an individual university's curriculum but the entire education of the subject (Taylor et al., 2007).

However, major accreditation bodies in the UK such as the Royal Institution of Chartered Surveyors (RICS), Institution of Civil Engineers (ICE), Chartered Institution of Building (CIOB), the Institution of Structural Engineers (IStructE) and the Royal Institution of British Architects (RIBA) have shown an increased interest in BIM throughout their recent conferences, publications and training programmes. However, in the case of civil engineering programmes in the UK, professional bodies are represented under the JBM to ensure that the quality of the civil engineering programmes are delivered according to their mutual requirements.
4.4. Accredited Civil Engineering programmes in the UK

Accreditation bodies are constituent parts of the quality assurance mechanism to ensure that a particular university programme prepares their students to meet the competences required to undertake professional practice. Accredited civil engineering programmes must meet the quality standards that are set by the JBM to ensure that the qualities of the education provided in these programmes are to the standard of that expected in the civil engineering profession. Accredited courses provide their graduates with the recognition to progress towards the various levels of registration with the Engineering Council UK but it is important to note that not all UK civil engineering undergraduate programmes hold accreditation by the JBM.

The JBM is an institution combined with the Engineering Council UK to represent The Institution of Civil Engineering (ICE), The Institution of Structural Engineers (IStructE), The Chartered Institution of Highways and Transportation (CIHT) and the Institute of Highway Engineers (IHE) to generate and publish sets of civil engineering course criteria for the purposes of course accreditation. The JBM also conducts regular accreditation visits to the universities to analyse and evaluate the content, assessment and administration of accredited civil engineering degrees against a set of criteria and to ensure that the programmes comply with its published guidelines for the curriculum content standards. The current list of UK accredited courses given by JBM in the academic year 2013-2014 is shown in Table 4.1.
Table 4.1. JBM accredited civil engineering programmes in 2014

| University of Aberdeen | Loughborough University |
| University of Abertay Dundee | University of Manchester |
| Aston University | Napier University |
| University of Bath | Newcastle University |
| Queen's University of Belfast | University of Nottingham |
| University of Birmingham | University of Oxford |
| University of Bradford | University of Plymouth |
| University of Brighton | Portsmouth University |
| University of Bristol | Queen Mary & Westfield College |
| Brunel University | University of Salford |
| University of Cambridge | University of Sheffield |
| Cardiff University | University of Southampton |
| City University London | University of Strathclyde |
| Coventry University | University of Surrey |
| University of Dundee | University of Wales, Swansea |
| University of Durham | University of Teesside |
| University of Edinburgh | University of Ulster |
| University of Exeter | University of Warwick |
| University South Wales (formerly University of Glamorgan) | University of Leeds |
| University of Glasgow | University of Liverpool |
| University of Greenwich | Liverpool John Moores University |
| Kingston University | University of London - University College London |

JBM accredited civil engineering programmes aim to ‘provide quality civil engineers to the industry collaboratively with industry and professional bodies. This has resulted in a curriculum that provides an appropriate blend of practical and theoretical knowledge to students. Recently, the JBM and industry have emphasised to universities the criticality of engaging with BIM and its applications in the areas of planning, design, construction, and asset management with respect to civil engineering projects. Although the challenge relies on finding individuals who are capable of working within BIM enabled environments, this is no easy task. Later in this thesis, the research report will
be presented on a number of focus groups with academics from JBM-accredited programmes along with professionals from JBM and industry to explore concerns and practices to provide the right blend of practical and theoretical knowledge of BIM to benefit both the students and the industry at large.

4.5. Barriers to the teaching of BIM in civil engineering programmes

Research by Minnesota State University (2012) identifies a number of barriers to the teaching of BIM in universities (not exclusively civil engineering), these include:

- Limited space for additional new modules in the existing curriculum.
- The required resources for developing new course units.
- The lack of existing textbooks on BIM and other educational resources for students.

In the Minnesota survey, the respondents also identified barriers such as the complexity of BIM, lack of support from faculty and/or administrators and the unwillingness of committing to the changes in the curriculum to BIM because many still fear that BIM might get supplanted with another technology programme or new ideology in the future (Sabongi and Arch, 2009).
These concerns were also highlighted by educators at The University of Northumbria (see Horne and Thompson, 2007), who believed that major changes to existing timetabling arrangements would be necessary to develop ideas and integrate BIM into an already-crowded curriculum. Educators were also concerned about the prospect of a high number of students requiring some hands-on sessions to apply the technology and whether the university could manage and accommodate this.

4.6. Broader challenges to the adoption of BIM in UK Universities ‘built environment’ programmes

In support of the literature review, the researcher undertook formal and informal discussions with BAF members as part of this process and to understand the concerns of academics and schools in regards to adopting and teaching BIM within civil engineering programmes in the UK. The main findings were (Bataw and Kirkham, 2015):

4.6.1 Academics

For academics, the main concerns centred on time and timetabling arrangements that would be necessary to embed BIM into existing arrangements; the time to develop ideas and integrate them into an already crowded curriculum was also a key issue.
While discussing the changes that might appear on the current curriculum to suit BIM concepts and tools, many academics seem to believe that new teaching requirements will have to be added to the existing curriculum. This is not really the case; rather than simply adding, one should also consider removing some of the old techniques and modules from the curriculum, especially the ones that are no longer used by the civil engineers in practice or have already been taught intensively to the students in their previous levels of education.

The curriculum should only teach the fundamentals, but the problem is deciding what these fundamentals are. The last major curriculum change in engineering was what is referred to as the “engineering science approach” in the 1920s; since then the fundamentals have pretty much been physics and continuous mathematics but, as mentioned previously, engineering is changing. Very few engineers in the future will produce a product that does not include the use of IT: “IT in engineering teaching is as fundamental as continuous mathematics” (Wulf, 2007).

The high number of students requiring some level of hands-on sessions to apply the technology in practical methods is another concern of academics. Some universities might not be able to manage and accommodate the training sessions within visual and practical labs. However, professionals within the AEC industry recognise the necessity of teaching BIM and suggest that the teaching required for BIM should focus on the core concepts rather than the
application interface and functionalities. Therefore, training and teaching courses should follow a different path than with conventional CAD training.

Sacks and Barak (2010) developed a mandatory course titled “Engineering Graphics” at the Technion University from the traditional concepts to be replaced by “Communicating Engineering Information”, which teaches both theoretical and practical aspects of BIM. The main lesson that Sacks and Barak learned from two years of teaching this class is that students find BIM tools spontaneous and therefore relatively easy to learn; the majority of lecture hours within this course were committed to the conceptual aspects of BIM and the principles for preparing models in a collaborative environment rather than training and teaching students on BIM tools and technologies. The skills that students have gained from this type of course in the USA indicated that graduates were able to meet the needs of the civil engineering profession in the BIM-enabled environment.

4.6.2 Schools (academic departments)

There are concerns that the requirement to embrace new technology and software brings additional financial pressures, so as part of this study the questions were posed:

• Can schools afford to teach BIM?
• Can schools afford not to teach BIM?
The “if it is not broke, don’t fix it” mindset could be one reason why some academics do not believe changes are necessary to the current curriculum. The relationship that academics have with industry is variable across UK HEIs – this often reflects the research profile versus teaching profile of each university. However, academics teaching in many universities in the UK do not appear to be connected with the industry in ways that could benefit students as well as teaching and learning strategies. Therefore, if changes appear in multiple dimensions, new changes are difficult to distinguish and so the fact that it is ‘broke’ might not be obvious.

The UK HE sector is facing continued challenges as the government makes changes to funding regimes with the planned implementation of teaching excellence frameworks and a focus on student satisfaction and ‘learning gain’. There is a growing sense amongst university administrators that efficiency gains must be made (Universities UK, 2015); the implications for BIM are that, whilst known approaches may not require significant additional resources to implement in the short-term, the ability to meet the costs that might be associated with purchasing new software licences, advanced computers and staff training will have to face competing priorities elsewhere.

Nevertheless, there are also costs with retaining the status quo. For example, outcomes based on accreditation systems; if accreditation institutions drive for the new BIM criteria in order to meet the industry’s requirements, it could
result in the loss of accreditation and reputation and so universities could fail to attract and retain sufficient numbers of students to meet expected demands.

Many employers in the UK who seek to recruit new graduates from accredited degree programmes will begin to increase their demands and expectations for BIM – particularly those with large public sector infrastructure projects on the books leading up to and beyond 2016. However, some firms report that their most significant training costs have not been in software usage but in enhancing the capabilities of their current graduates to the required levels.

Recruitment agencies, traditionally a major source of talent within the engineering sector, are also expressing their concerns - graduates are key to career development and succession planning but they are increasingly voicing concerns that they are struggling to meet their client’s needs – graduates must have the required foundation of knowledge in BIM (Reed Recruitment, 2014).

4.7. Teaching and learning

Proposals to embed BIM concepts into civil engineering degree programmes should be informed by an analysis of the available methods of teaching in order to understand the learning styles of students. Felder and Silverman (1987) observe that students in general ‘learn and cooperate in many ways by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorising and visualising; and drawing analogies and building mathematical
models’ in their study of ‘Learning and Teaching Styles in Engineering Education’.

Consequently, teaching methods are variable based on the nature of students but also on the educators and the course content. In civil engineering, educators typically prefer to lecture, demonstrate or discuss; depending on the modules, some focus on principles and others on applications. The ascendancy of the lecture remains an interesting discussion point in the context of the profession; civil engineers practice in teams but do they experience this in the education setting where individual summative assessment dominates?

Felder and Silverman (1987) further explore the different aspects of learning styles particular to engineering education, the preferred learning styles by students and favoured teaching styles by educators and the ways to reach students whose learning styles are not addressed by standard methods of engineering education. This study has formed a strong set of learning styles that have now become one of the most widely accepted standards in the engineering education community by identifying the following types of learning approaches:

1. Visual and Auditory Learners
2. Sensing and Intuitive Learners
3. Inductive and Deductive Learners
4. Active and Reflective Learners
5. Sequential and Global Learners
However, no two students approach learning in the exact same way. Some students learn better from visual images while others prefer verbal explanations; some students tend to prefer to learn from practical (“real-world”) information and others are more drawn to abstract theories and symbolism (theoretical), and so on. Keefe (1979) formally defines learning styles as “characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment”. Awareness of the different learning styles is essential in approaching teaching and learning strategies in the most effective manner.

Having already identified the most suitable learning styles of many engineering students to be visual, sensing, inductive, and active, Felder and Silverman (1987) also assert that some of the most creative students are global and that most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential. The observations of Felder and Silverman (1987) are interesting in the context of current teaching and learning styles in the majority of UK higher education engineering education establishments. Their work was published some two decades prior to this research but it remains the case that a ‘mismatching’ of the learning techniques of engineering students described above still exists; this can lead to poor student performance, frustration of the learners once they reach the professionalism stage, and a loss to society of many potentially excellent engineers.
Teaching and learning strategies should be designed and adapted to suit individual course unit needs, for obvious reasons. Consequently, the principle of ‘horses for courses’ should apply. As an example, the BIM software can simply be used to produce better graphical representations for problems, which can be used to assist students in developing visualisation skills. An alternative learning style is to use BIM capabilities to address the generated active data by enforcing the nature of the collaborated BIM process in group projects. Consequently, teaching concepts can vary with BIM depending on what the educator wants to contribute to and the structure of the course.

4.8. International approaches to the teaching and learning of BIM

It is important to understand how international developments on the teaching of BIM could influence UK practice. The final part of this literature review involved consideration of 125 university departments that are currently incorporating BIM into their curriculum; 97 departments in the United States and 28 in other countries (none in the UK). The evidence suggests that these departments adopted various teaching strategies; 70% had introduced the teaching of BIM within existing course units (sometimes referred to as modules) whilst 30% had generated a new course (programme) to teach BIM. The following were observed as common approaches to BIM teaching:
1.7.6 BIM integrated into existing units or modules

In simple terms, BIM tools, techniques and concepts were included within existing modules; this was usually done by developing the existing curriculum of each module to suit BIM practices. This structure appears to be the most preferred method by the schools.

1.7.7 BIM as a separate unit or module

BIM tools, techniques and practices were also integrated as a single module usually named BIM, but not isolated from the evolved course discipline.

1.7.8 BIM as a separate course

Some universities found it more functional to develop a set course that contains the teachings of all BIM tools, techniques, theories and practices. This teaching method was rarely used but seems to be very popular with students especially at postgraduate level.

Nevertheless, within these three techniques BIM was collaborated in three different categories: single-course; interdisciplinary; and distance collaboration. 70% of the institutions teach BIM within only one discipline, 27% integrated the practice of BIM by linking different disciplines within the same
school/university (interdisciplinary), while only 3% have integrated their courses with distanced universities. These categories are detailed below:

- **Single-course** - In this category, schools taught BIM to students from the same discipline (e.g. engineering or architecture).

- **Interdisciplinary** - BIM was taught to students from different disciplines together for real collaboration between students from two or more disciplines, at the same school.

- **Distance Collaboration** - This approach is similar to the interdisciplinary approach. However, BIM teachings were integrated for real collaboration with students from distant schools.

These approaches were designed in the initial steps of adopting BIM and were used by many civil engineering, construction and architecture courses around the world. However, educators in the UK are still unsure of which approach is appropriate to adopt and so are behind with teaching BIM to students at university levels. Hence this research will focus on determining the most suitable approaches to teach BIM at university levels in the UK from the student’s perspectives and preferences.

### 4.9. Current approaches to the teaching of BIM

As emphasised in section 4.8, a significant number of educational institutions have attempted to introduce BIM principles into their curricula. The techniques to integrate BIM are variable and these are described in Table 4.2.
<table>
<thead>
<tr>
<th>Institution</th>
<th>Year</th>
<th>Field/ Program</th>
<th>Method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Institute of Technology</td>
<td>2003</td>
<td>Architecture</td>
<td>Teach BIM techniques using pioneering BIM software</td>
</tr>
<tr>
<td>Texas A&amp;M University</td>
<td>2003</td>
<td>College of Architecture</td>
<td>Began to introduce BIM (MATC, 2003)</td>
</tr>
<tr>
<td>The Madison Area Technical College</td>
<td>2003</td>
<td>Postgraduate and undergraduate Architecture programs</td>
<td>Taught BIM software tools within the course “Introduction to Architectural Third Party Applications” (Autodesk, 2007).</td>
</tr>
<tr>
<td>Worcester Polytechnic Institute</td>
<td>2003</td>
<td>First and second year of civil engineering</td>
<td>Taught BIM within the existing course (Salazar et al., 2006).</td>
</tr>
<tr>
<td>California State University at Chico</td>
<td>2004</td>
<td>Civil Engineering</td>
<td>Specific BIM classes were taught (Kymnell, 2008)</td>
</tr>
<tr>
<td>The Tongji University</td>
<td>2005</td>
<td>Civil Engineering in the Construction Management course</td>
<td>Began to practice the interdisciplinary collaboration with the students (Hu, 2007).</td>
</tr>
<tr>
<td>The Nevada University</td>
<td>2005</td>
<td>Civil Engineering</td>
<td>Began to introduce BIM</td>
</tr>
<tr>
<td>Montana State University</td>
<td>2005</td>
<td>Architecture and Building Systems courses</td>
<td>Integrated BIM within existing courses (Livingston, 2006).</td>
</tr>
<tr>
<td>Institution</td>
<td>Year</td>
<td>Discipline</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>------</td>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>The Penn State University</td>
<td>2006</td>
<td>Architecture</td>
<td>Introduced an Integrated Design Studio using BIM for the first time (Önür, 2009).</td>
</tr>
<tr>
<td>The University of Utah</td>
<td>2006</td>
<td>College of Architecture and Planning</td>
<td>Began a process for re-structuring its curriculum through a research project (Scheer, 2006)</td>
</tr>
<tr>
<td>Montana State University</td>
<td>2006</td>
<td>Architecture</td>
<td>Began to teach BIM to architecture students in its digital graphics and design curriculum (Berwald, 2008)</td>
</tr>
<tr>
<td>The New Jersey School of Architecture and The New Jersey Institute of Technology</td>
<td>2006</td>
<td>BIM Course/ Architecture</td>
<td>Started offering specific BIM courses (Hoon, 2006)</td>
</tr>
<tr>
<td>Brigham Young University.</td>
<td>2006</td>
<td>BIM Course</td>
<td>Started offering specific BIM courses (BYU, 2006)</td>
</tr>
<tr>
<td>the Auburn University</td>
<td>2007</td>
<td>Civil Engineering</td>
<td>Began a study on the teaching of BIM with a group of students. After some studies, the students developed a collaborative project and then the programme also began to require a BIM model in the undergraduate capstone thesis project (Taylor et al., 2007).</td>
</tr>
<tr>
<td>University</td>
<td>Year</td>
<td>Program</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------</td>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>The University of Wyoming,</td>
<td>2007</td>
<td>Civil Engineering</td>
<td>The students collaboratively developed a complex project in which teams chose the model of collaboration and the roles of its members (Hedges, 2008).</td>
</tr>
<tr>
<td>The Texas Tech University</td>
<td>2007</td>
<td>Architecture/ Civil Engineering</td>
<td>Offered a course that unites building technology and representation/media as a pre-requisite for subsequent semesters of Design Studio with BIM (Rex <em>et al</em>, 2008).</td>
</tr>
<tr>
<td>The University of Wisconsin-Milwaukee</td>
<td>2007</td>
<td>Architecture/ Architectural Design Technology</td>
<td>1) Computers in Architecture - teaching students on how to use BIM tools in design (Online course) (Stagg, 2009);</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Virtual Modelling that integrates Fundaments of Studio I (Jordan and Tran, 2008);</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Microcosm Studio that explores BIM and prototyping (Talbott, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Integrating professional Practices with BIM in Design</td>
</tr>
</tbody>
</table>
Sabongi and Arch (2009) stated that the non-integrated, stand-alone courses do not meet the needs of the students looking to be employed. The current method of taking students through established modules to meet benchmarks often fails to integrate new developments in technology. This becomes a problem for graduates as, when in employment, they are expected to combine...
all parts of their curriculum (Sabongi and Arch, 2009). As it stands, current educational efforts struggle to meet industry expectations (Clevenger et al., 2010). BIM holds the potential to find its way into all corners of the programme and so does not require the stand-alone module (Taylor et al., 2007).

Colorado State University piloted a university course using BIM in collaboration with industry and facilities management. The course was offered as an eight-week independent study, in which students met with industry experts who demonstrated various software packages. The experts also worked directly with the students to assist them in creating models for various course work tasks (Clevenger and Rush, 2011). The Colorado State University has also tested a strategy for teaching BIM throughout their construction management curriculum. The strategy has two stages:

- Replacing the existing CAD introductory classes for the first academic year in construction management to a BIM introductory class where they were shown techniques and capabilities of a specific modelling programme.

- Developing an integrated BIM teaching module(s) into the latter academic years in construction management.

The Colorado State University undertook a survey of construction management students to gain feedback on the above strategy in order to understand how
students would best learn BIM. The feedback indicated that the students welcomed this strategy as they believed that, after gaining an understanding of BIM in their first year, they would be able to progress their understanding and capabilities throughout the rest of their education. Students also indicated that a BIM capstone course similar to that at Penn State University (Penn State University, 2010) would be a good way of utilising BIM and bringing everything together (Clevenger et al., 2010).

Auburn University have also attempted to integrate BIM into their accredited construction management curriculum. They expressed concern that an additional ‘BIM module’ in an already tight curriculum would be likely to create more problems than opportunities. Similar to Colorado State University, their desired approach involved an introductory course and a final ‘capstone’ dissertation project (Taylor et al., 2007).

Some of these universities have identified solutions or areas to review relating to the barriers identified previously. Colorado University expressed concerns that the implementation of BIM in teaching introduces some complications with the logistics of maintaining software platforms in the classroom. Despite the availability of technical support, the possibly of additional responsibility for maintaining BIM software rests with teaching staff. The university has developed taught modules using Adobe Captive software to manage this issue, a software programme capable of producing a rich electronic learning experience; once BIM programmes are completed using their native software
package the produced products are stand-alone and executable using Adobe flash player. This approach has relieved teaching staff from worrying about software management and training; it also allowed students to view the models without needing access to potentially expensive software tools (Clevenger et al., 2010).

Auburn University identified an insufficient number of textbooks to aid with the teaching of BIM, and that the literature in general struggled to keep pace with the rapid change in IT applications; the implication being that lecturers would have to redevelop sets of customised tutorial exercises and assignments as changes to software emerged. The Auburn students were, as a consequence, required to learn the software largely on their own and without the assistance of instruction; this led to a degree of frustration amongst the students. Taylor et al., (2007) suggest that BIM software is too complex to pick up on one’s own without some guidance and that this should be a consideration when introducing new software tools to students.

Additionally, the university has examined whether their students should be focussing on how to build the model or focus on how to understand the model? This led to the question of what will the graduates be required to do in industry? It was suggested earlier in this thesis that the industry requires a graduate to be able to do both. Consequently, Auburn elected to offer the students a general grounding in how to use BIM software and, more importantly, a full understanding of the concepts behind the technology of BIM
software tools (Taylor et al., 2007). However, through McGraw Hill’s Construction reports (2009), it is possible to observe that employers using BIM are currently interested in students who are capable and comfortable with BIM processes rather than their specific software expertise; the suggestion is that these skills can be acquired through training in later stages (McGraw Hill, 2009). This is supported with a report by Ibrahim (2007), which indicated that teaching BIM should change in the workflow process rather than the application interface and functionalities. These conflicts in experiences and outcomes have led the educational institutions feeling ‘stranded’ by a perceived lack of strategies and capabilities to effectively introduce BIM into existing and future programmes (McGraw Hill, 2008).

In 2007, the US BIM Forum conducted a survey with academics from eight educational institutions in the United States and three international schools (although this is a small percentage of educational intuitions, they were the only ones that were integrating BIM at that time). Of those surveyed, 82% confirmed teaching or discussing BIM in courses or projects, while 18% indicated that they began to introduce BIM in their curricula after 2002; 27% had introduced BIM before 2002 and 55% only started to introduce BIM from 2007.

However, there are no previous studies in the UK to determine the most suitable approach to teaching BIM within UK civil engineering programmes. Given that BIM is slowly being implemented in the UK to fulfil the
government’s 2016 strategy, many universities realise the need to incorporate and embrace the opportunities and overcome the challenges of teaching BIM in order to remain current and relevant to the industry, and to deliver employable graduates. Woo (2006) suggests that properly structured BIM courses would provide industry-acquired knowledge to prepare students for successful careers in the industry, although universities within the UK still have reservations on fully committing to teaching BIM as it can create significant issues and barriers that will require resources from the university and initially more work for faculty members. Also, it appears that UK universities are waiting for a detailed study to outline the best implementation strategies for BIM within the UK. Therefore, this research aims to discover whether BIM can be successfully integrated into UK civil engineering courses and, if so, how.

4.10. Summary

Drawing on the issues raised in this chapter, the literature suggests that the following themes are important considerations for the future successful integration of BIM into higher education degree programmes in civil engineering in the UK:

• **Committed leadership:** In the UK today, professional civil engineers are either educated through university engineering degrees (3-4 years) or trained in a technical apprenticeship (4–5 years) following a degree programme that is ordinarily accredited by the JBM. Professional
institutions will have to play a leading role in the further development of the profession to encourage universities to respond to the demands from industry and central government.

• **Encouraging ‘collaborative’ teaching and learning**: BIM places a significant emphasis upon collaboration. This is problematic in the context of higher education, which places a significant emphasis upon individual summative assessment. The consequence is that students leave university with an individualistic approach to learning, which could impact negatively on their propensity to act collaboratively in professional practice. In order to establish the need for BIM integration into UK civil engineering higher education degree programmes, one should consider individual and group learning styles alongside curriculum development and assessment strategy.

• **Is BIM the ‘fourth thread’?**: UK universities currently delivering civil engineering degree programmes must articulate the three ‘threads’ of design, health and safety risk assessment and sustainability across the curriculum. The question is: should BIM be the fourth thread?

This chapter has:

• Taken into consideration the varying approaches to teaching BIM and the associated learning theories.
• Related this understanding to appropriate methods of teaching and assessment.

• Identified the techniques to understand the learner’s a-priori knowledge and thus the most suitable approaches to teaching and learning from a BIM perspective.

• Identified the relevant requirements of professional organisations.

• Determined the benchmarks used by universities whilst developing programmes and curriculum content, courses etc. such as employability, industrial partners and professional institutions, and then adapt it to BIM accordingly.

As a result, the following questions emerge from the literature review:

• Is the civil engineering profession changing due to the evolution of BIM? If so, how?

• How can civil engineering undergraduate programmes evolve to reflect industry’s requirements for BIM?

• Are civil engineering students in the UK lacking BIM knowledge? Will this be an obstacle for them once they graduate?

• How can the balance between philosophy and tools of BIM be achieved in the design of civil engineering undergraduate programmes?

• What training and professional development is required to enable universities to enhance BIM skills in civil engineering undergraduate programmes?
• How could a framework support the integration of BIM within UK civil engineering programmes in the UK?

Chapter 6 will consider the most appropriate methods to collect the data that will inform the answers to these questions.
Chapter 5
Research Design and Methodology

5.1. Introduction

Chapter 4 identified a series of questions (see 4.10) that have emerged from the literature review and the secondary case studies. Having identified these questions, the purpose of this chapter is to explore and resolve the most appropriate research philosophy, approach, strategy and design considerations in the selection of the appropriate methods to address those questions.

Chapter 5 is comprised of two distinct parts. The first part provides a general outline to the issues that the researcher should consider in designing an appropriate methodology. The second part illustrates and justifies the selected methods used in this research and identifies how those methods will be executed.

According to Fellows and Liu (2007), research methodology refers to the principles and procedures of logical thought process that are applied to a scientific investigation. Adam et al. (2007) state that the research methodology consists of philosophy and science that support the investigation while Fellows and Lie (2007) believe that research consists of a careful search and a systematic investigation contributing to the sum of knowledge. Therefore, the research methodology can be considered as the overall strategy used in the scientific investigation that consists of the component of philosophy, approach, and techniques.
5.2 Research Aim and Objectives

The research described in this thesis aims to better understand the ‘actuality’ of BIM and to help resolve the theoretical and practical issues that currently frustrate the implementation of BIM, based on the opinion and knowledge of practitioners, academics, graduates and current students. In earlier chapters of this thesis, a number of important questions have emerged and these form the basis for the section of a range of qualitative methods to capture data that should inform further the understanding of BIM in a higher education context.

5.3 Structure of the Research Process

Research design is an essential process in shaping the integration of different methods within an overall sequence of actions that enables the central research questions to be successfully answered.

In Figure 5.1, a diagrammatic representation of this research is shown. The research process began by exploring and establishing the perceptions of BIM in the AEC industry and assessment of the demands for improvement. This was followed by justifications of the perceived gap between theory and practice. These objectives were undertaken by different approaches, mainly through an extensive investigation of existing literature combined with discussions at industry forums and, later, in focus groups.
The second step was an additional literature review carried out strictly on BIM; this review provides an in-depth study of BIM levels, BIM advantages and disadvantages and its implementation barriers along with a detailed comparison of international approaches. This led to the conclusion that one of the major barriers to implementing BIM within the UK is the lack of information and coverage on the educational side of BIM, which is arguably one of the main aspects to implementing BIM within the UK.

The third step was a study on the evolutions of civil engineering education, whilst identifying the different methods of teaching and how knowledge can be transmitted in civil engineering programmes in the UK followed by an investigation of the possible techniques of teaching BIM, collected from literature review, the BIM Academic Forum (BAF), and the international approaches of implementing BIM in curriculum. These steps enabled the researcher to obtain sequenced rational information of the research topic and achieve a continuous flow of data to develop research questions for the focus groups and a robust questionnaire survey. The questionnaire survey was developed from the conclusions to expand data and develop a model that is suitable to the original objectives and requirements to establish whether it is possible to adopt BIM within accredited UK civil engineering programmes.
Aim: To develop a framework to incorporate BIM within Civil Engineering undergraduate Programmes in the UK.

Determine the current status of BIM integration within CEng programmes.

Identify the educational criteria to teach BIM within CEng programmes.

Develop BIM teaching framework.

Literature research on BIM concept, BIM usage, BIM evolution, success factors and the implementation requirement from the UK’s perspectives.

Literature research on the evolution of education in CEng, the different approaches of teaching BIM.

Development of teaching categories and techniques that suits Accredited Civil Engineering programmes in the UK.

Outline the requirements for developing new techniques in Civil engineering undergraduate programmes.

Develop an approach to drive change in universities.

Develop a stakeholder map to outline whom is involved to drive the change in civil engineering undergraduate programmes.

Identify cases and units of Stakeholders’ influence to decision making.

Develop research Questions.

Select suitable research Methods.

Select suitable sampling techniques.

Construct focus group.

Prepare and develop Questions for the Questionnaire survey.

Undertake questionnaire Survey.

Explore the current BIM knowledge of the different stakeholders.

Identify and develop BIM learning outcomes.

Identify best teaching approaches.

Overall summary.

Develop BIM teaching impact matrix.

Develop BIM learning outcomes matrix.

Identify the following to Teaching BIM:

- Vision,
- Mission,
- And Objectives

Content analysis and writing up the feedback.

Figure 5.1: Structure of the Research process

Validating the finding and refinement.

Develop framework by conducting cross case analysis including literature review to support argument and complement data.

Generic framework validation.

Framework refinement and recommendation.

Writing up final report.
5.4. Research Design

Once the required data was outlined, the focus was on how this data could be achieved. In order to source the appropriate data correctly, the researcher must ensure the accurate selection of data collection techniques and the procedures for the subsequent analysis of the data. These two steps are essential to the success of any research (Saunders *et al.*, 2011) – this is summarised in the “research onion” approach described in Figure 5.2.

**Figure 5.2.** The research onion (Saunders *et al.*, 2011)
5.4.1. Research Philosophy

According to Saunders et al. (2007) research philosophy should articulate the assumptions about the way in which a researcher views the world. These assumptions will underpin the selection of research strategy and methods in pursuing the objectives. The main influence is the particular views of the relationship between knowledge and the process used to create it. Within the layer of research philosophy, the formation is made by two ways of thinking, namely epistemology and ontology.

According to Creswell (1994), in general, epistemology is the technical term for the theory of knowledge where it describes “how” a researcher knows about the reality and assumptions about how knowledge should be acquired and accepted. It is concerned with what constitutes acceptable knowledge.

However, in a field of study within this domain, according to Easterby-Smith et al. (2002) two philosophical paradigms have dominated debate in the social science research - Positivism and Interpretivism. Positivism suggests the use of quantitative experimental methods to test hypothetical-deductive generalisation while Interpretivism suggests the use of qualitative and naturalistic approaches to inductively and holistically understand and explain a phenomenon. According to Creswell (2009) the Interpretivism approach aims to increase the general understanding of the subject of research in which the research progresses through gathering rich data from which ideas are induced. In addition, according to Smith et al. (2002) the Interpretivist approach focuses on the ways that people make sense of the world, especially through sharing their experiences with others via the medium of language. As for this research, since the data collection objective was exploratory in
nature and required the researcher to explore and identify the criteria for teaching BIM, the research falls mainly within the interpretivism paradigm. The reason was because this research required the researcher to understand, explore, and elicit practices and perceptions only from the universities who started or were willing to teach BIM. In addition, the interpretivism paradigm allowed the researcher to obtain richer and deeper understanding of the approaches that each institution has undertaken. This data have assisted the researcher during the development of BIM teaching criteria.

On the other hand, ontology according to Saunders et al. (2007) is concerned with the nature of reality. There are two aspects of ontology: objectivism, which portrays the position that social science entities exist in reality external to social actors concerned with their existence; and subjectivism, which holds that social phenomena are created from the perceptions and consequent actions of those social actors concerned with their existence. Basically, it explains “what” knowledge is and assumptions about reality (Cresswell, 1994). As Remenyi et al. (1998) further suggest, it is necessary to study the details of the situation to understand the reality or perhaps a reality working behind them. It was suggested that it was necessary to explore the level of concern on teaching BIM within the UK’s educational sector.
5.4.2. Methodological choice

Research in general can be approached in different forms and dimensions using a variety of research methods and techniques depending on the research questions and the required data. The main dimensions considered are:

- Qualitative / Quantitative or Mixed methods.
- Deductive / Inductive

5.4.2.1 Qualitative / Quantitative or Mixed Methods

Every research study is typically carried out in either one of the three standard research methods: quantitative, qualitative or mixed quantitative and qualitative. Quantitative research is an inquiry-based approach used to identify and describe the outcomes from variable findings of different sources. To conduct this approach, the researcher specifies and examines narrow questions to locate or develop the required matter through different sources, then gathers data and answers questions while analysing facts in the form of numbers and percentages, e.g. number/percentage of universities teaching BIM. From the results of these analyses, the final conclusions are presented in a standard format, displaying researcher independence with evidence (Creswell, 2002; Mayring, 2000)

Qualitative research is a study-based approach used to explore and understand a crucial matter. To learn about the matter in hand, the researcher specifies and examines broad, general questions, then collects the detailed views of sources for description and themes while analysing the information in the form of words or
images. From this data, the researcher concludes the meaning of the information upon personal reflections and past research displaying the researcher’s biases and thoughts (Creswell, 2002; Johnson and Christensen, 2000)

Usually, combining the two methods in a research design is known as mixed methods, multiple methods or triangulation of methods (Tashakkori and Teddlie, 1998). Each strategy is better for performing different things and the selection of the most appropriate one depends on the research questions that need to be answered. However, Jankowicz (2000) suggested that choosing one type of strategy over another ultimately hinges on the objectives of the study. In addition to research questions, the arguments for and against the use of each research approach suggest that theories can also be used to determine which methodology will be most appropriate for a particular research. Saunders et al. (2007) suggested that if the researcher understands the phenomena underlining the study well enough and aims to develop a theory about factors influencing particular phenomena and to explore the setting further, a qualitative approach is more suitable. Furthermore, one goal of qualitative research may be the identification of variables affecting the phenomenon under study (Creswell, 1994). Both the quantitative and qualitative methods are concerned with exploring phenomena (Mack et al., 2005). However, qualitative analysis is primarily concerned with understanding an individual’s perceptions of certain phenomena based on an in-depth and insightful investigation and analysis, while the quantitative approach is concerned with issues such as “how much” and “how many” and seeks to document occurrences passively (Bell, 2005). Because qualitative research is an inherently exploratory undertaking, the potential for generating new theories and
ideas is significant. Amaratunga et al. (2002) further strengthen this stance. Quantitative data, on the other hand, is most valuable when research questions and theories have already been established and are being evaluated (Saunders et al., 2007; Fellows and Liu, 2007).

As discussed earlier, this research adopted the concept of developing a framework that could assist educational institutions in teaching BIM within accredited Civil Engineering programmes in the UK. The critical element of the research was firstly to understand the approaches of teaching BIM around the world. Subsequently, using a set of approaches that was developed from the literature review to identify the categories. Within this context, the research addressed the question of the way that best suits the parties involved to teach/learn BIM, and how it can be best implemented. The Focus Groups took the form of social inquiry that focused on the way people interpret and make sense of their experiences and the world in which they live. Seeking to gain insights and to understand people’s perception of worldviews whether as individuals or groups (Fellows and Liu, 2007). While the questionnaire was prepared to address the choices of students in percentages, it makes the questionnaire research quantitative. It therefore positions the focus groups’ research in the category of qualitative (Daymon and Holloway, 2003), which eradicates the selection of mixed methods approach.

The main source of data collection is people/respondents, and through their experience, thought, belief and understanding, the teaching categories and its criteria are modified and developed. The mixed approach allowed the researcher to broaden
the perspective needed for the research and increased the depth of the study (Morse, 2003).

According to Tashakkori and Teddlie (2003), mixed methods techniques are usually influenced by how the methods are merged, where methods can be sequenced and combined differently. Steckler et al. (1992) have identified four possible models to perform mixed methods research (Demonstrated in figure 5.3). In Model 1, the qualitative method is used first to contribute to the development of quantitative measures and instruments, (e.g. using focus groups to prepare questionnaire surveys). The Model 2 quantitative method is used to further explain and interpret the results generated from the initial qualitative method. Model 3 is the opposite approach of Model 2, where the quantitative results are used to explain and interpret the initial qualitative findings. In Model 4 the two methodologies are used in parallel and equally to build upon and cross-validate each other's results.

In Models 1, 2 and 3 the methodologies are used sequentially, one method after the other (e.g. interviewing before surveying) where the research results are more integrated. In Model 4 the data is collected using the methodologies simultaneously (at the same time), where the two methodologies are used separately as two parallel studies and only merged once the data are being analysed. Therefore, the use of both methodologies (Model 4) was used for this research, where the qualitative and quantitative methods were used simultaneously, enabling triangulation and validation of the generated data (Tashakkori and Teddlie, 2003).
5.4.2.2. Deductive / Inductive Approach

Typically, one often refers to the two broad research approaches as the *deductive* and *inductive* approaches.

Figure 5.4.1, demonstrates the deductive approach mechanism, also known as the "top-down" approach, approaching research from the more general data to the more specific. The researcher using this approach can commence the research by examining
the theory of the topic of interest to narrow down the data and generate hypothesis from findings for more specific information. This is followed by testing and examining the actuality of the generated hypothesis in the observation stage. And finally analyse the observed hypothesis for confirmation of specific data generated from the original theory (Trochim, 2010; Babbie, 2001).

![Diagram](image)

**Figure 5.4.1.** Mechanism of deductive approach (Trochim, 2010)

Conversely, the inductive approach, also known as the "bottom up" approach, is at variance with the approach described in 5.4.2. The researcher proceeds from very specific observations to broader generalizations and theories. Approaching the study by examining specific observations and measures to detect patterns and regularities in order to formulate some tentative hypothesis that can be explored leading to the development of general conclusions or theories (Trochim, 2010; Babbie, 2001).
As explained above, these two approaches have very different "reasoning". The deductive approach is narrower and requires testing or confirming hypothesis; the inductive approach is more open-ended and exploratory, especially at the initial stages. These two approaches emphasise different benefits as shown in table 5.1. In addition, the context specific to teaching BIM, especially within the UK, suffers from a limited literature source in addition to the nature of BIM topic, which is fairly new. Therefore, it will not allow the required teaching criteria to be developed deductively.

Consequently, to identify the teaching criteria, an inductive approach will be engaged. The inductive approach has allowed richer and deeper information to be gathered and thus increased the researcher’s understanding. Furthermore, the inductive approach positioned the research in a more natural setting where respondents are free to provide their response since the predefined index is absent (Yin, 2009). In this context, the situation in which respondents are influenced by a set of indexes could also be avoided.
<table>
<thead>
<tr>
<th>Deductive</th>
<th>Inductive</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Scientific Principles</td>
<td>• Used to gain an understanding of the human attach to events</td>
</tr>
<tr>
<td>• From Theory to generating data</td>
<td>• Close understanding of the research context</td>
</tr>
<tr>
<td>• Used to explain casual relationships between variables</td>
<td>• Used to collect qualitative data</td>
</tr>
<tr>
<td>• Used to collect quantitative data</td>
<td>• Flexible Structure</td>
</tr>
<tr>
<td>• Highly Structural approach</td>
<td>• Researcher is part of the research</td>
</tr>
<tr>
<td>• Researcher independence of what is being researched</td>
<td>• Less concern with the need to generalise.</td>
</tr>
<tr>
<td>• Must select samples of sufficient size in order to generalize conclusions</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.1.** Comparison between Deductive and Inductive approaches (Saunders *et al.*, 2003)

**5.3. Research Methods**

According to Thomas (2004) there are two types of information sources: primary and secondary (Figure 5.5). Secondary sources are the obtainable qualitative and quantitative forms of information from existing data, such as existing soft copies and hard copies of articles, books, journals, and literature reviews. On the other hand, the primary sources are the obtainable data from information collected by researchers such as interviews, questionnaires, experiments, and social surveys (Hackley, 2003). These methods, together with their advantages and disadvantages, will now be discussed and analysed.
5.3.1 Secondary Methods

- As illustrated in Figure 5.6, qualitative secondary sources are the information data that can be found from other researches in the form of newspapers, articles, books, journals, novels, TV programmes, diaries, historical documents, literatures etc.

The advantages are:

- Can provide rich data
- Assist in understanding how people review certain matters

The disadvantages are:

- Authenticity - data could be forged
• Lack of credibility - could be biased or untrue
• Representative - unsure who the research represents or who participated in it
• Analysis – the research might have not been interpreted or analysed correctly

❖ As illustrated in Figure 5.6, quantitative secondary sources are the calculated data that can be found from other researches in the form of user rates reports, e.g. crime rate reports, implementation rates, and awareness rates.

The advantages are:
• Provide important information
• Provide reliable facts with proofs
• Cheap, free to use and analyse
• Concluded from large samples
• Can cover different time span, providing past data
• Allow user to compare various groups and professions

The disadvantages are:
• Statistics could be biased
• Could be relying on false data
• Might only cover the concerns of the researcher
Figure 5.6. Detailed quantitative and qualitative secondary sources
5.3.2 Primary Methods

Primary methods are the available sources that can be used to collect new forms of data. Many common quantitative and qualitative primary methods were obtainable to undertake this research. However, only certain methods can insure achieving the best information available. Therefore, investigations were carried out to understand the advantages and disadvantages of each method and to decide on the most suitable form of procedures, methods and techniques to undertake the research questions and objectives. Primary research methods are:

1. Closed written questionnaires
2. Open-end questionnaires (interviews)
3. Structured interviews
4. Unstructured interviews
5. Semi-structured face to face interviews
6. Postal/Self-completion questionnaires (survey)
7. Telephone interviews
8. Experiments
9. Participants observation
10. Focus groups
11. Case studies
12. Pilot studies
These techniques, together with their advantages and disadvantages, will now be reviewed in accordance with Esterby-Smith et al. (2002), Alvesson (2003), Yin (2009), Robson (2002), Patton (1990) Saunders et al. (2003) and Gibbs (2007):

- **Closed written questionnaire** - asking participants to answer a list of certain questions in writing. The advantages are:
  - Easy for participants to answer the questions as they are usually straightforward
  - Quick to complete
  - Easy to analyse
  - Allow easy comparison to be made with other sets of data
  - Easy to repeat

The disadvantages are:

- Not possible to provide further explanations of the questions to participants
- Cannot follow up with extra questions to gain richer data
- Participants might not agree with any of the available answers
- Only generates quantitative data

- **Open-end questionnaires (interviews)** are less structured than closed questionnaires; usually consists of a set number of questions without limited set of answers so the participant can express their opinion. The advantages are:
  - Participants are not limited by set of answers so they can express what they really mean and explain why
• The interviewer can follow up with more questions to gain richer data
• Data is generated from a discussion, therefore it can be detailed and in more depth
• Can generate different points of view in different interviews, which can provide better discussion points for the report

The disadvantages are:
• Different opinions might confuse the researcher
• Data could be interpreted differently to what the participant actually meant

Structured interviews - asking closed questions in a face-to-face interview, discussing pre-set questions with selection of set limited answers. The advantages are:
• Questions can be explained to overcome knowledge problems
• Known to be very reliable data as all participants are choosing from the same set of answers

The disadvantages are:
• Interviewer cannot probe and ask further questions
• This data is usually used for quantitative reports and more difficult to convert to qualitative data
• Data is not as rich in comparison to the open-ended questionnaires
• Time consuming in comparison to the other methods that can provide similar outcomes
• Similar data can usually be generated from previous researches (secondary sources)

Unstructured interviews - asking open questions in a face-to-face discussion; without the preparation of questions or answer choices. The advantages are:

• Allows the interviewer to have an open conversation/discussion with the participant to cover a wide subject
• Interviewer can ask follow up questions, which can create better interaction for richer and more valid data
• This kind of interview can remove formal behaviours and allow the participant to give more open and honest answers
• Questions can be changed to suit the different background of each participant
• Participants are not limited by a set of answers, therefore they can express what they really mean and explain why
• Can generate various points of views, which can provide better discussion topics for the report

The disadvantages are:

• Take longer time, therefore it could be difficult to find people who are willing to participate
• Questions will probably change in the different interviews, therefore the data could be less reliable
• Difficult to replicate the study
• Data can be more difficult to analyse and inflexible to compare
Semi-structured face-to-face interviewing (CIT interview system) is a new form of data collection. Consisting of face-to-face meeting/interview, briefly prepared with a set of closed/open questions (general to the main topic), which usually leads to sub-questions to counter the participant’s responses. The advantages are:

- Generates direct answers (from the main questions)
- Ability to have an open conversation/discussion with the participants
- Ability to ask follow-up questions, which can provide better interaction for richer and more valid data
- Can be viewed as an informal meeting, removing formal behaviours and allowing the participant to give more open and honest answers
- Questions can be changed to suit the different background of participants
- Produce both qualitative and quantitative data
- Can generate broad conclusions

The disadvantages include:

- Can only be adopted with highly skilled/highly experienced members (difficult for this research topic)
- Some of the questions will probably change for each interview

Postal/Self completion questionnaires (surveys) – a pre-selected set of questions with a set of answers, either posted or sent online for participants to fill out themselves and return back to the researcher. The advantages are:

- Relatively inexpensive, particularly when undertaken through online portals
• Results can be readily obtained
• Participants can respond at a time convenient to them
• Participants are more likely to give personal or embarrassing responses, if they had the privacy of self completion
• Can produce a large amount of data
• Less chance of researcher bias in comparison to other methods of research

The disadvantages are:

• Response rate can be low
• Usually only a certain group of people tend to be interested in taking part
• Unclear as to who has actually completed the survey
• Unable to ask follow up questions or explain the questions

➤ Telephone Interviews. The advantages are:

• Save time from travelling long distances
• Suitable if there are no other methods of communication available

The disadvantages are:

• Less effort is made to choose accurate answers
• Have to be arranged for a particular time and date
• It is not viewed as the most suitable method to gain valuable information
• A lot of preparation needs to be done beforehand
• Facial and body language are not visualised, and so both parties can be misunderstood.

- Experiments - (more common to natural sciences; also in social sciences particularly psychology).

- Participant observation is where the researcher joins in with the sampled group to understand the behaviours of the observed group and appreciate their reaction to things in certain ways; this is usually used to understand people's behaviours etc. and will not be required for this research. However, it is essential to understand the diverse sociologies of different people, as it might be needed to understand some people's points of view and reactions towards the research topic.

- Focus group is an informal discussion among a group of selected individuals on a particular topic, gathering more than one participant for a data collection session (Wilkinson, 2004). Focus groups can be preformed structured or semi structured in different scenarios, can either be from a group of professionals gathered for an intense discussion for data collection or a group of family members gathered around the TV discussing their favourite movies (Wilkinson, 2004). According to Howard & Bjork (2008) and Gu & London (2010) the type of activities involved varies from one workshop to another depending on the purpose of the workshop. Howard & Bjork (2008) and Langford & McDonagh (2005) have outlined many focus group methods, for example, discussion groups, Design Decision Groups, group meetings and user workshops. According to Saunders et al. (2007), “group
interview” is a general term to describe all non-standardised interviews conducted with two or more people, and the term “focus group” is used to refer to those group interviews where the topic is defined clearly and precisely and there is a focus on enabling and recording interactive discussion between participants. The approach of focus group workshops is similar to focus group interviews. However, the workshop involves activities along with responses to the set of questions as seen in Marshall-Ponting & Aouad (2005), Lee et al. (2003) and Sacks et al., (2010).

➢ Case study - carrying out an investigation on a particular project to learn from its real life contents. The advantages are:
  • Very suitable for the construction industry
  • Can give a full picture of the task in hand
  • Useful to prove literature studies

The disadvantages are:
  • Not many BIM projects available
  • Difficult to gain much information on the use of BIM within projects

➢ Pilot study - Carrying out experiments on real-life projects to test logistics and gather information prior to the full implementation of BIM, in order to test it and highlight required improvements of quality and efficiencies. The advantages are:
  • Very useful to obtain an insight of the task in hand
  • Improve understanding
  • Enhance research accuracy
• Enhance the supporting evidences
• Very suitable for future research

The disadvantages are:
• Require a lot of preparation
• Require a lot of time and effort

5.3.3. Key Steps

Sampling methods - in order to carry out any of the above-mentioned research methods, the researcher should first allocate the method of choosing the participants. Saunders et al. (2003) state that participants can be identified and selected by the following techniques (these sampling techniques are described in section 5.6):

➢ Randomly - picking names out of a hat.
➢ Systematic - selecting participants from a register/list in a systematic way.
➢ Stratified - making the participants as representative as possible by dividing them into a number of smaller groups, such as BIM professionals, architects, QS and academics, and then randomly withdraw individuals from each group to carry out the research.
➢ Quota sampling is used only if the research requires fixed percentages of certain groups.
➢ Cluster sampling - taking random samples at various stages of the sampling process.
- Snowball sampling - used when sampling is difficult to obtain due to the lack of information or the lack of available participants.

- Factors that can influence the choice of research method include:
  - Timeframe and budget; large, longitudinal surveys require significant resource to complete effectively
  - Availability of data through other methods and/or existence of data elsewhere
  - Experience of the application of research methods to the study of BIM.

- Triangulation is the use of more than one research method within one research to enhance the reliability of evidence and accuracy of the undertaken research. Triangulation can also offer new insight of examining the tasks in hand especially when using very different types of research methods, e.g. pilot studies and structured interviews (Patton, 1990).

- The research must be carried out with the consideration of “reliability” to get the best data possible, “validity” to provide the best picture, “representativeness” of participants and researchers (from primary sources) and “ethics” to get as honest and accurate studies as possible. These points are demonstrated in Figure 5.7 and discussed in section 5.7 of this thesis.
Figure 5.7: Key issues to consider during research and data collection.
5.4. Methods Used

The methods adopted to execute this research evolved to fit the purpose of the research question and its contribution to knowledge. Over the time of this research, a wide investigation was undertaken in two stages. In the first instance, qualitative inferences were produced by collecting data from a large number of different sources such as journal articles, books, and relevant reports. These sources were quantitative, qualitative and mixed methodologically. However, further case studies were also observed to enhance the credibility, and to increase the breadth and depth of this data. The researcher has also attended various meetings and conferences, which provided the truth-value of findings and enhanced search reliability to confident conclusions (triangulation).

The qualitative and quantitative methods were used simultaneously; the mixed methodology approach of this research offered the advantages of enabling triangulation. The researcher has approached triangulation by 1) using a variety of data sources (data triangulation), 2) using different researchers (investigator triangulation), 3) using multiple perspectives to interpret the results (theory triangulation), and 4) using multiple methods to study a research problem (methodological triangulation).

In summary, the principle methods used to undertake this research are:

1. Literature Review
2. Case studies
3. Qualitative Comparative Analysis
4. Focus Groups
5. Questionnaires
5.4.1. Literature Review

The literature review concentrated on identifying and evaluating the existing literatures covering more than 320 articles in English that mainly referred to ‘BIM’ ‘building information modelling’ ‘UK construction Industry’ ‘use of technology’ ‘information modelling’ ‘UK Education’ ‘Knowledge’ ‘theories of knowledge’ ‘Education in civil Engineering’ ‘BIM Teaching’ ‘BIM in education’ ‘BIM in Academia’ ‘Research Methodology’ ‘Research Philosophies’, downloaded from Google Scholar, Harvard Business Review, Science Direct, EBSCO etc. This enabled the researcher to obtain a wide range of knowledge in topics such as the “the current industry”, “the importance of technology in all industries”, “Building Information Modelling”, “Education in Civil Engineering” and “BIM in Education”. These topics were selected as important factors to ensure success in regards to achieving a comprehensive assessment to understand the value of the research problems and questions through sources such as:

- Books accessed online through Google Books etc.
- Related theses and dissertations
- Electronic Journals acquired from University databases e.g. Harvard Business Review, Science Direct etc.
- Journals and books acquired from the library
- Professional Bodies
- Government Bodies
- Internet Sites
- Literature Reviews
This literature review was completed using the five-steps process developed by Cooper (1998) and Levin (2005) as follows:

1. Defined the scope and limitations of the research (found in chapter 1).
2. Selected suitable sources (as discussed above) and commenced data collection.
3. Evaluated the collected data from the studied literature, identified the purpose of each literature and the outcomes to understand the results. In order to extract the useful information and highlight the commonalities, differences and criticisms.
4. Analysed and interpreted the information to generate conclusions and information to support the argument of the research.
5. Presented the information in a readable manner within its allocated chapters and headings.

5.4.2. Secondary case Study

Adopting Stake’s (1995) view, a case study - ‘.... is expected to catch the complexity of a single case - a study of the particularity and complexity of single case, coming to understand its activity within important circumstances’. The case studies used in this research are designed to provide insight into the actuality of data generated from the
literature review in order to gain a better understanding of the BIM landscape.

The secondary case studies used in this research were to examine specific scenarios, gain in-depth knowledge and investigate its real life context using multiple sources of evidence (Hackley, 2003; Saunders et al., 2003; Yin, 2003; Thomas, 2004). The data collection techniques employed in these case studies were multi-technique approach via observation and documentary analysis which enabled for specific and detailed views on the topic (Saunders et al., 2003; Yin, 2003).

5.4.3 Qualitative Comparative Analysis

The Qualitative Comparative Analysis (QCA) was used by the researcher in chapter 4 to compare and analyse the different approaches of adopting BIM into education curriculum around the world. Ragin first introduced QCA in 1987 as a method to compare 5-50 cases and presented the outcomes in a so-called ‘truth table’. This approach was used to describe all the cases of BIM adoption into education around the world as possible. Because of the strong focus on cases that QCA permits, the researcher was able to highlight the best possible cases and the repeated practice in order to decide on the most common practices of BIM in education (Rihoux and Ragin, 2008).

5.4.4. Focus groups

According to Krueger and Casey (2000) a workshop technique is considered to be a
useful and effective data collection method as it provided a conductive platform for making sense of the various concepts. The workshop is considered to be a highly efficient technique for qualitative data collection (Robson, 2004). In addition, the focus group workshop is the most appropriate and effective in obtaining information, insight, experience, and knowledge of a large group of industry players in the shortest period of time. The workshop has helped understanding the UK educational sector and BIM adoption within education and the industry; it also provides an excessive discussion between the industry and academia to share and clarify their views on various BIM adoption issues such as common understanding of benefits, hurdles, requirements, and expectations of teaching BIM.

The researcher sensibly chose to use focus groups to maximize the ability of accessing knowledge, ideas, story-telling, self-presentation, and linguistic exchanges from the executive participants (Barbour and Kitzinger, 1998) Stated simply, focus groups can help capture the required experiences from participants that cannot be "meaningfully expressed by numbers" (Berg, 1995). However, to gain the most reliable information from the greatest possible number of students the researcher chose to undertake questionnaire surveys. In return, these two methods will allow the researcher to pay more attention to the original voices of participants in their everyday life, in order to observe and present a broader view of social reality (Schratz, 1993; Hoepfl, 1997).

Specifically, focus groups allow each of the individuals to provide a rich source of information about their experience, knowledge and opinion on BIM in an incentive and natural atmosphere (Glitz, 1998). For instance, within a focus group discussion, a comment can encourage a train of thought where participants can develop new ideas.
and connecting their personal experiences to share (Hillman and Liggett, 1997).

Ashar and Lane, (1991) described the data obtained from focus groups as "extremely rich" and "high quality". Furthermore, Krueger and Casey (2000) suggested that focus groups could produce data from multiple realities of people's experiences, which can be very precious. However, all of the above depends on the participants and the researcher undertaking these focus groups.

Like any other research method, focus groups are not appropriate for every data collection situation especially those researches on sensitive topics. However, it has been proven that researchers undertaking educational researches similar to this research could consider using focus groups as a method for examining the social world i.e. students and educators (Glitz, 1998; Krueger and Casey, 2000). Furthermore, Morgan and Krueger (1993) have explored the uses of focus groups for educational researches, and found that many educational researchers have relied on focus groups to achieve various objectives and important decision-making, such as:

• The formulation of new marketing strategies for educational programmes (Ashar and Lane, 1993);

• The evaluation of students’ knowledge or attitudes about curriculum issues (Boardman and Palmer, 1996; Pugsley, 1996);

• The development of learning tools that will appeal to students’ interests and needs (Rienzo and Frazee, 1997);

• The enhancement of survey results in education research (Hillman and Liggett,
Focus groups can produce rich data to assist in decision making for the development and modification of curriculum and learning tools that might not be possible to gain from other research methods (Williams, 2001).

As for this research, the focus group workshop was the most appropriate and effective way of obtaining information, insight, experience and knowledge from academics and professionals in the shortest period of time. It was also be used as a platform for generalisation and method triangulation.

The researcher considered careful planning considerations to undertake throughout the process of the focus group research. Fortunately, there are many of explicit and comprehensive guides to assist researchers on "how to "undertake a focus group project. Krueger (1988), Morgan (1988), Morgan (1993), Barbour and Kitzinger (1998), and Krueger and Casey (2000) have gathered a wide collection of articles addressing the methodology of focus groups. The researcher has chosen to adopt the approach used by Brown and Ross (1996), who specified a step-by-step guidance for undertaking a focus group research as described and demonstrated further in chapter 6.

5.4.5. Questionnaires

Throughout the study, the researcher has used data from existing questionnaire surveys. These surveys were interpreted and utilised in this research to validate the initial information gained from the exploratory studies and literature reviews.
The literature review and findings led to the preparing of a questionnaire survey to produce reliable data and enhance the reliability of evidence and accuracy to understand the requirements of BIM teaching within the UK from the students’ perspective. The questionnaire was based on the findings of the undertaken studies and the theoretical approaches of teaching.

The questionnaire design reflects an aspiration to ensure adequate coverage of the issues emerging from the literature review balanced with concisely written questions to ensure a degree of brevity - this is important in encouraging respondents to participate appropriately. This was achieved through a series of pilot studies with a number of PhD students and other professional colleagues on LinkedIn to remove any potential issues of bias and distinguish the required time to answer the questionnaire and whether it was reasonable to expect participants to spare this amount of time to provide their answers. As a result, amendments to the questions and the questionnaire were made on several occasions, such as the ordering of questions, the type of questions (open/closed), representation of the questionnaire, the used phrases and wording, the ways that some questions were asked and the proposed choices of answers. Further discussion and explanation is found in Chapter 7.

5.5 Research Population

First of all, one should outline the required data to be collected. After stipulating and elucidating the commonly used BIM Teaching Techniques and relevant Learning
Styles, it was concluded from a mixture of theories that UK Civil Engineering Education requires clear strategies to teach BIM in higher education. As stated in the conclusion for chapter 4, in order to discover whether BIM integration in UK education is possible or not, one must, in order:

- Consider the different approaches of BIM teaching and learning theories
- Relate to suitable teaching methods and assessment
- Identify the learner's required knowledge and suitable approaches to learning BIM
- Identify relevant requirements of organisational goals and required knowledge within the industry
- Determine what universities use as a benchmark while developing their programmes, courses etc. such as employability, industrial partners and professional institutions, and then adapt it to BIM accordingly
- Develop a model that is suitable to the original objectives and requirements
- Validate the generated model to assess the credibility to UK’s Civil Engineering Education

Consequently the population was drawn accordingly using different methods as shown in Figure 5.8. The population was from the industry (organisations and professional individuals), education (universities, educators and students) and accreditation bodies.
5.6. Research sampling

As with any other research, it is important to obtain data from a representative sample of the total population. Usually, the population is too large. Thus a small, but carefully chosen sample can be used to represent the population. However, the sample must reflect the characteristics of the overall population. Therefore, great attention must be taken to choosing the sampling strategy.

There are two sampling methods: probability or representative sampling and non-probability or judgmental sampling. According to Saunders et al. (2003) and Thomas (2004), probability sampling is most appropriate when the chance of each case being selected from the population is known, whereas in non-probability the probability of each case being selected from the total population is not known.
According to Ghauri and Gronhaug (2001), Saunders *et al.*, (2003) and Thomas (2004) the benefits of using probability-sampling techniques are:

- To generate statistical inferences (generalisations)
- Every member will have a greater chance of being selected for the sample
- Everyone in the population has equal opportunity for selection
- Increases sample’s representativeness of the population
- Can also minimise sampling errors and sampling bias

On the other hand, the non-probability sampling is:

- Very easy to carry out with fewer rules than probability sampling
- Less costs and time to carry out non-probability sampling in comparison to probability sampling
- No limits but that could also mean that population parameters may be unknown

According to Patton (2002) and Kuzel (1999) there are three types of probability sampling techniques: simple random sampling, systematic sampling and stratified random sampling.

**Random sampling** (simple random sampling) is known as the richest method of probability sampling. With random sampling, each member of the population has an equal chance of being selected for inclusion in the sample.

After the required sample size has been calculated, the researcher would select a set number from the population at random, usually by using random number
tables. However, in cases where the population is very large, it is difficult or even impossible to identify every member of the population, and so the collection of available samples becomes biased.

**Systematic sampling** (Systematic random sample) is often used instead of random sampling. Like simple random sampling, each member of the population has an equal chance of being selected for inclusion in the sample. Its only advantage over the random sampling technique is simplicity, where systematic sampling is often used to select a specified number of records from a computer file rather than a random format.

After the required sample size has been calculated, every member is selected from a numbered list systematically where units are selected in an ordered way (e.g., every 8th unit). This sampling method is as good as the random sampling method.

**Stratified sampling** (Stratified random sampling) is the most commonly used probability method, and is usually used for large populations to control and reduce sampling errors. Unlike random sampling and systematic sampling, with the stratified sampling, there is an equal chance of selecting each unit from a particular stratum (group) of the population when creating the sample.

With stratified sampling the population is usually divided into two or more relevant and significant layers (“strata”) based on one or a number of attributes. In other terms, the sampling frame is divided into subsets (Hussey and Hussey, 1997; Saunders *et al.*, 2003).
On the other hand, the non-probability sampling techniques are quota sampling, purposive or judgemental sampling, convenience sampling, snowball sampling and self-selecting sampling (Ghauri and Gronhaug, 2001; Saunders et al., 2003; Thomas, 2004). However, research projects can integrate various sampling techniques at different stages.

**Quota sampling** is the non-probability equivalent of stratified sampling but does not involve random selection. Like stratified sampling, the researcher first identifies the different groups and their proportions as represented in the population to end up with sample groups (e.g., male vs. female students) then proportion the population being studied.

**Purposive** or judgemental or expert’s choice sampling is a commonly used non-probability method where the researcher selects the samples based on judgment. The participants are selected on the basis of their experience related to the research topic. Purposive sampling is usually used when working with small samples or when collecting informative data (Hussey and Hussey, 1997; Saunders et al., 2003).

**Convenience sampling** is a non-probability method used for preliminary research where the researcher is concerned with obtaining an inexpensive approximation of the truth from the most readily available people or objects for the study without incurring the cost or time as required selecting a random sample. As the name implies, the sample is selected as convenience. However, representativeness is difficult to determine.
**Snowball sampling** (networking) is a special non-probability method commonly used when it is difficult to identify the characteristics of the desired members.

Snowball sampling relies on referrals from initial contacts to generate additional members. Although this technique can dramatically lower search costs, it comes at the expense of introducing bias because using this technique can decrease the likelihood that the sample will represent a good cross-section from the population. However, there are certain techniques that can be introduced to avoid biases.

**Self-selection sampling** is a non-probability method used to allow units or cases to decide whether to take part in the research or not before being approached directly by the researcher. As the name indicates, the key component is that participants volunteer to self-select themselves to take part in the research.

### 5.7. The credibility of research findings

In satisfying the criteria for credibility in the research findings, the following considerations are necessary:

#### 5.7.1. Research Ethics

The University of Manchester is committed to good practice in research, part of which is ensuring all relevant research receives independent ethical review. All projects involving research using interviews or subjects require approval from the University’s Senate Committee before the research commences.
Therefore, the researcher has considered various ethical matters while conducting this research in order to establish an ethical protection to the rights of all research participants. The main principle for the voluntary participants is to ensure that people are not pressured into participating in the research; in regards to this matter, all participants were fully informed about the procedures and reasons of the research. The researcher has also examined terms and conditions of the involved participants, institutions and organisations (when needed) to guarantee the participants’ confidentiality, anonymity and privacy conditions.

Furthermore, the researcher has reviewed and agreed to all of the procedures of research within the University of Manchester to ensure consideration of all relevant ethical issues in formulating research plans and executing data collection systems.
Chapter 6
Focus Groups

6.0 Introduction

This chapter addresses the purpose of the focus groups, the planning that was done prior to doing focus groups, how the focus groups were conducted and analysed with more emphasis on the technical procedures and finally followed by a report of the findings. The framework for this chapter is based on Kirk and Miller’s (1986) general description of the four phases of focus groups: planning, observation, analysis, and reporting.

6.1. Purpose

The benefits of using BIM in professional practice are largely understood and spreading widely; however, integrating BIM in academia, especially in civil engineering programmes, is divergent from practice. The purpose of this focus group activity is to collect information on how groups of professionals from universities, industry and professional institutions think or feel about embedding BIM within UK Civil Engineering BEng courses. The focus group approach was used to develop greater insight into why certain opinions are held, provide a means to evaluate existing programmes and to improve the planning and designing of teaching BIM within the existing curriculum.
6.2. Planning

From the outset, the researcher planned to have realistic expectations not just with regards to the time and budget but also in terms of the total amount of effort that is necessary to produce the desired data. As is always the case, the quality of the data depends on the quality of the preparation (Morgan, 1997): “Careful planning cannot guarantee insightful results, but a careless approach to the design and execution of the research is almost certain to produce poor results” (Morgan, 1997).

Since the focus groups consisted of bringing together several participants, it required great attention to who the participants are and how the researcher can interact with them as a group. To do so, three obvious factors were considered during planning the focus groups: ethical concerns, budget issues, and time constraints (Kitzinger, 1995; Parsons and Greenwood, 2000).

In regards to ethical concerns, according to Punch (1986) and Smith (1995) one of the biggest ethical issues in focus groups is the fact that what participants tell the researcher is naturally shared with other group participants as well, which can raise privacy concerns and effectively limit the kinds of topics that the researcher can pursue. However, even though the participants were academics from different institutions, they were happy with sharing information on the identified issues in order to develop the understanding of BIM in academia.

Also issues concerning invasion of privacy are especially important whenever recording is the primary means of data collection. However, audio recorders along with written record were used to advance the accuracy of transcription of the
information exchange among participants. Therefore the researcher made sure that all participants were made aware of the voice recorders and were informed that only the researcher can access the recordings.

In regards to budget and time limitations, sampling is usually time-consuming, especially when all participants are from very large specialised populations. However, since the participants are academics and members of professional institutions, the researcher carried out the snowballing sampling technique from relative LinkedIn groups and from forums such as the BIM Academic Forum in UK (BAF) to invite and receive responses in a relatively short period. Nevertheless, in the observation phase, each focus group was planned to take 3 hours including coffee breaks. Finally, in terms of the analysis and reporting stages, it was very time-consuming due to the great consideration of the collected data and the discussed information.

During the planning of the focus groups, the researcher carefully considered a number of important decisions on how the data can be collected, who can be invited to participate in the groups and how structured can the groups be i.e. the size of each group and the number of focus groups in the total project.

Consequently, the researcher reviewed and examined a number of “rules of thumb” to capture the most common choices that researchers should consider with regards to making decisions for the planning of the focus groups. According to Morgan (1996) and Krueger (1988) focus group projects most often (a) use homogeneous strangers as participants, (b) rely on a relatively structured interview with high moderator involvement, (c) have 6 to 10 participants per group, and (d) have a total of three to five groups per project. The researcher adopted these “rules of thumb” to plan and
organise the focus groups; some amendments are made to enhance relevance to the research being undertaken:

A) Use homogeneous strangers as participants: To get people to attend, the researcher personally invited academics and professionals who are either involved in teaching UK BEng Civil Engineering courses or BIM. These individuals were found and invited via LinkedIn, email groups and forums. Once participants showed interest, focus group times were established. Potential participants were contacted via emails twelve days prior to the focus group asking them to fill in a short form to classify their current roles, past experiences and BIM knowledge (if any). Later on, one week before the session, it was followed by a personalised email to remind the participants and give them more information about the session including time and venue.

B) Rely on a relatively structured interview with high moderator involvement: the researcher used general questions at the beginning of the focus group sessions, followed by more specific and more focused questions later in the session. Even though the researcher was highly involved in organising the sessions, the questions were open-ended in order to make sure that no influence was made by the researcher whilst asking the questions to achieve more data from the discussion. The questions were systematically prepared but had a natural flow to them. (Pilot test focus group interviews were carried out to receive feedback on the set of questions from other PhD students and colleagues prior to undertaking the focus groups).
C) Have 6 to 10 participants per group: 22 members were invited to the focus groups. However, they were separated into 3 different groups to discuss the questions separately and accordingly.

D) Have a total of three to five groups per project: Even though participants were separated into smaller groups, each of the small groups were asked to discuss the same questions under the same procedures and by the researcher as one project. All participants grouped accordingly (strategically place those who are more excited about BIM with those who are not very keen on teaching BIM, including at least two participants from each profession to generate richer data).

6.3. Observation

During the focus groups, the researcher's role was to keep discussions flowing, on track and make transitions into the next question when appropriate.

The pattern of the focus groups followed a structure of:

1. Welcome,
2. Overview and topic,
3. Ground rules,
4. Discussion, and
5. A brief conclusion and closure at the end.
During the welcome stage, the researcher extended a greeting to the focus group and then invited participants to briefly introduce themselves. The overview stage was to provide an open discussion on the purpose of the study and the importance of the group discussion in order to encourage people to discuss the questions and answers freely. Ground rules were outlined to help the participants to understand the focus group process while assuring them of ethics and confidentiality concerns.

The researcher then assigned each participant a copy of the questions that would be discussed in the session to allow them to write bullet points, brief thoughts and answers (with refreshments) before the discussion started. Once the discussion started, the researcher commenced by asking the first question, going around the table for each participant to give an initial answer; the answers were noted by the researcher before moving on to the next question; these answers were clarified with the participants to allow for further explanation and to observe the levels of familiarity between participants. This process was carried out for each question. Once all questions were answered and discussed, the researcher asked each participant whether they had further answers or information that they would like to share. To end the focus group the researcher read out a brief conclusion of the session to clarify the collected data.

6.4. Analysis

As mentioned above, the analysis process began during the focus group sessions through the small talks of observing levels of familiarity between participants. Also the debriefing stage was part of the data analysis and clarification.
The researcher wrote down summary comments during the sessions. However, the researcher also listened to the complete tape recordings and read the answers and comments on the hand-outs to transcribe and achieve a complete summary of the discussion using NVivo software.

Each summary was prepared within hours after the session and before the next focus group. This helped the researcher to capture notes on the following steps to consider whilst preparing the conclusions in later stages:

- Participant characteristics,
- Descriptive phrases or words used by participants as they discussed the key questions,
- Indicating the points of views held by participants with common characteristics,
- Description of participant enthusiasm,
- Consistency between participants’ comments and their reported experiences,
- Body language, and
- Overall mood of discussion.

The analysis process was continued by gathering together all the reported brief summaries, tape recordings, answered questions handouts and transcripts from each focus group. All summaries and transcripts were reviewed together in NVivo to highlight potential trends and patterns.

The use of NVivo facilitated the organisation and analysis of the data, which increased the transparency of the research outcomes with the ability of returning to the original
context of the coded materials to generate robust and transparent outcomes without the researcher's biases. It also helped to demonstrate the development of the ideas in memos and models to easily find illustrative quotes and visualise them to arrive at conclusions. In order to achieve the above from the NVivo analysis, the researcher performed the following steps:

1. Uploaded all recordings, summaries and written notes into NVivo software.

2. All recordings were then transcribed into txt in Nvivo.

3. Every focus group and each participant were accordingly inserted as nodes (Figure 6.1)

4. Each data source was assigned to its relevant participant (Node) accordingly (Figure 6.1)

5. Executed the “Text Search query” to distinguish the issues and themes that were mostly stated by the participants.

6. Created a node for each theme to see what each participant said according to each theme.

7. Participants were classified into Academic Institutions, Industry and Accreditation bodies according to tables 6.1, 6.2 and 6.3.
8. Ran the “Matrix Coding query” to see how many participants in each classification talked about each of the themes.

9. Every theme was coded across with the participants accordingly.

10. Ran a “Coding Comparison query” to assess the level of agreement.

11. Visualised and observed the generated nodes and codes to arrive at conclusions.

12. Conclusions were made under each theme; these themes are outlined and analysed in section 6.6.

6.5. Reporting

As a general rule, numbers and percentages are not appropriate for focus group research and should not be included in the report. Therefore, the reporting of these focus groups is descriptive in order to present the meaning of the data taken from the analysis.

This form of data is usually examined and reported through three levels: the raw data, descriptive statements, and interpretation (Kreuger, 1988).

As mentioned previously, the researcher started by ordering and categorising the data by relevant topics and natural familiarities in the form of raw data where the researcher presented statements of just how the participants shared them during the focus groups discussions.

The second stage of the reporting was extracting Descriptive statements, where the
researcher summarised the participants’ comments and provided illustrative examples using the raw data.

The final and most complex stage of the reporting phase was the **interpretation** stage. The interpretation was built on the descriptive data, where the meanings of the data were presented rather than simply summarising the data. Throughout the interpretation phase, the researcher did not reflect on his own biases; rather, the researcher reflected on the participants’ characteristics, the descriptive phrases and words used by participants, the points of view held by participants with common characteristics, description of the participants’ enthusiasm, the consistency between participants’ comments and their reported experiences.

### 6.6. Results and discussion

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Background</th>
<th>Industrial Experience</th>
<th>BIM Experience</th>
<th>From</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Head of School</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>2 years</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>A2</td>
<td>Senior Manager</td>
<td>Civil Engineering</td>
<td>11-15 Years</td>
<td>None</td>
<td>Industry</td>
</tr>
<tr>
<td>A3</td>
<td>Engineer</td>
<td>Civil Engineering</td>
<td>6-10 Years</td>
<td>1 Year</td>
<td>Industry</td>
</tr>
<tr>
<td>A4</td>
<td>Fellow member</td>
<td>Civil Engineering</td>
<td>6-10 Years</td>
<td>1 Year</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>A5</td>
<td>Programme leader</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>3 years</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>A6</td>
<td>Fellow member</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>3 years</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>A7</td>
<td>Senior Engineer</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>None</td>
<td>Industry</td>
</tr>
<tr>
<td>A8</td>
<td>University Professor</td>
<td>Project Management</td>
<td>11-15 Years</td>
<td>None</td>
<td>Academic Institution</td>
</tr>
</tbody>
</table>

**Table 6.1.** Background of participants in the 1st Focus group
Table 6.2. Background of participants in the 2\textsuperscript{nd} Focus group

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Background</th>
<th>Industrial Experience</th>
<th>BIM Experience</th>
<th>From</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Programme Leader</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>None</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>B2</td>
<td>Senior Engineer</td>
<td>Civil Engineering</td>
<td>11-15 Years</td>
<td>1 Year</td>
<td>Industry</td>
</tr>
<tr>
<td>B3</td>
<td>Engineer</td>
<td>Civil Engineering</td>
<td>6-10 Years</td>
<td>1 Year</td>
<td>Industry</td>
</tr>
<tr>
<td>B4</td>
<td>Fellow member</td>
<td>Civil Engineering</td>
<td>6-10 Years</td>
<td>2 Years</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>B5</td>
<td>Fellow member</td>
<td>Civil Engineering</td>
<td>6-10 Years</td>
<td>3 years</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>B6</td>
<td>Senior Engineer</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>2 Year</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>B7</td>
<td>Senior Lecturer</td>
<td>Project Management</td>
<td>&gt;20 Years</td>
<td>None</td>
<td>Academic Institution</td>
</tr>
</tbody>
</table>

Table 6.3. Background of participants in the 3\textsuperscript{rd} focus group

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Background</th>
<th>Industrial Experience</th>
<th>BIM Experience</th>
<th>From</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Programme Leader</td>
<td>Project Management</td>
<td>&gt;20 Years</td>
<td>2 years</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>C2</td>
<td>Senior Engineer</td>
<td>Civil Engineering</td>
<td>11-15 Years</td>
<td>1 Year</td>
<td>Industry</td>
</tr>
<tr>
<td>C3</td>
<td>Senior Engineer</td>
<td>Civil Engineering</td>
<td>11-15 Years</td>
<td>None</td>
<td>Industry</td>
</tr>
<tr>
<td>C4</td>
<td>Chartered member</td>
<td>Civil Engineering</td>
<td>1-5 Years</td>
<td>None</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>C5</td>
<td>Fellow member</td>
<td>Civil Engineering</td>
<td>11-15 Years</td>
<td>2 Years</td>
<td>Accreditation body</td>
</tr>
<tr>
<td>C6</td>
<td>Senior Lecturer</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>None</td>
<td>Academic Institution</td>
</tr>
<tr>
<td>C7</td>
<td>University Professor</td>
<td>Civil Engineering</td>
<td>&gt;20 Years</td>
<td>3 Year</td>
<td>Academic Institution</td>
</tr>
</tbody>
</table>
BIM in Civil engineering education was the main discussion topic in every focus group in the format that was explained above. However, NVivo was used to generate the following themes from the most common topics mentioned by the participants during the focus groups:

6.6.1. BIM effect on Civil Engineering within profession and current courses

Civil Engineering is a profession that combines the knowledge of the mathematical and physical sciences together (by study), developed through experiences and practices to apply with judgment in utilising the materials and forces of nature in the design, construction and maintenance of the physical and natural built environment, such as roads, bridges, canals, dams and buildings. The civil engineering profession is moving forward due to the widespread demand for sustainability, energy, advanced transportation, safe waste disposal and technology.

Whilst the acronym BIM includes the word ‘building’ it is not limited to building projects; it has applications in all forms of infrastructure too, including roads and highways (Strafaci, 2008). Since BIM is an integrated approach and process, civil engineers can use it to design for constructability and road safety whilst analysing and testing several alternatives (Strafaci, 2008).

The participants generally agreed that BIM model-based design tools can enable civil engineers to have better control of the design while having the ability to regularly check, test, monitor and alter the design model. They also indicated that the geospatial capabilities of BIM can allow civil engineers to overlay the site design
within the immediate area surrounding the site. Discussion in the first focus group led to the implication that BIM technology tools can also allow the engineers to easily monitor the surrounding area to measure for road safety and site preparations while Civil Engineers can use BIM applications to lay out the site, using laser scanning technologies to assist capturing “as-built” construction whilst carrying out the measuring required of levelling etc.

Likewise, the discussion in the second focus group led to the integrated analysis tools within BIM such as geospatial and stormwater analysis tools, indicating that these tools can assist civil engineers to propose environmental solutions with consideration of environmental impacts and environmental concerns (Bennet, 2010). Furthermore, the discussion in the second focus group implied that BIM could provide engineers with the capability to integrate hydraulic and hydrologic analysis technology to weigh options and choose the most sustainable solution. While in the third focus group, participants agreed that BIM tools can assist engineers to design and install mechanical, electrical and plumbing systems with clash detections features and specified solutions whilst enabling for engineering calculations directly in the model.

Overall, the participants believe that, by using BIM, civil engineers are not just calculating and operating to find the best design solutions; they are also required to manage, collaborate and share their solutions with members from the construction and design teams, which requires the engineers to understand and become familiar with every building object including the geometric definitions and associated data and rules. This change in the way civil engineering operates, revolutionises the manner in which tomorrow's civil engineers are prepared through education to enter professional
practice. Several participators have emphasised that these resulting changes have raised concerns for some faculty members, students, engineers, recruiters and employers.

The importance of teaching BIM at university level for a successful implementation has been highlighted by many researchers, such as Deutsch (2011), Kaner et al. (2008), Kiviniemi et al. (2008), Aranda-Mena et al. (2009), Smith and Tardiff (2009), Oluwule (2011), Arayici et al. (2011) and Eastman et al. (2011). Meanwhile, according to some of the academics participating in the focus groups, the higher education institutions are currently unable to meet the demand for BIM education within civil engineering university programmes.

However, some of the academic staff members perceive BIM as a threat to their current roles as they are not equipped with BIM knowledge. This led the participants to the conclusion that teaching BIM in civil engineering university courses will require staff training.

According to Eastman et al. (2011) and Arayici et al. (2011) staff training on BIM can be divided into two types, like any other training courses required for university staff members: formal training and informal training. The formal training consists of two levels, beginner, which can be provided by the software vendors or CPD BIM training: according to the participants, the majority of software vendors offer free training and packages to university staff in the UK as part of the software purchase agreement. The other type of staff training is the advanced level training, which requires the universities to seek a professional training provider in the form of classroom settings or online training. However, this type of advanced training should only be compulsory
to those who are required to provide intense training to students on specific BIM software tools. The informal training can be included within the university staff development programme to make sure staff members are confident and up-to-date. Participants supported the need of informal training programmes for university educators as part of teaching BIM-enabled civil engineering courses.

Another concern highlighted by the participants is the need for continuous education associated with technical knowledge, software updates and new versions not only to students but also to the educators.

### 6.6.2. BIM effect on the Universities

According to Alshawi (2007), the success of BIM implementation in universities is highly associated with the ability of the university to learn and incorporate the proposed systems into the current taught programmes. However, the participants suggested that the ability of incorporating any new development into a curriculum is determined by the enthusiasm of the management and the academic teaching staff.

In most cases, enthusiasm is limited to the business objectives. Therefore, unless the JBM classify BIM within their guidelines for the curriculum content standards, enthusiasm for teaching BIM will continue to be limited to individual efforts. Meanwhile, participants B6 and C1 shared their experiences of introducing BIM within their course modules; this consisted of capturing knowledge regarding BIM benefits to the civil engineering profession and lessons learnt to present and share the knowledge among the staff for BIM awareness. Participant A5 provided guidance and
introduction sessions to university teaching members to discuss the importance of teaching BIM within their course modules and to identify solutions.

Participant A5 stated another successful approach, where A5 was involved in a university course module to introduce professional practices of BIM within the civil engineering profession. This module was developed in order to generate a lesson learned by monitoring and recording the performed techniques and the feedback given. Lessons learned is a well-known form used to capture and articulate knowledge. According to Kaner et al. (2008), Arayici (2011) and Eastman et al. (2011), lessons learned is usually presented in the form of a research journal; they argued that it is not only valuable to organisations but also industrial-wide as it can be used as a source of reference to identify the challenges that need to be addressed including the advantages and the disadvantages of each experience. A5 has later shared the main criteria of the gathered information that was recorded and analysed for lesson learning; the criteria are as follows:

i. Recorded information and insights about the developed course, the module and the students

ii. The preparation notes and what the teaching and admin members discussed to prepare for the developed module including the outcomes of these pre-teaching discussions.

iii. The list of all activities that were agreed and how they were carried out to complete the mechanisms including the reading lists, materials, BIM models, processes used and delivered tasks.
iv. The amendments to the existing module as a result of the pre-teaching discussions

v. Tracked records of the experience along with performance monitoring of both students and educators

vi. Solutions to problems encountered while performing a particular task and recommendations for best practice

According to the experience of A5 and other participants, if these compiled documents and lessons learned manuals were recorded in the form of a teaching framework it can assist academics while developing their competency; it can also be a great form of reference and a learning point, which can speed up the implementation process and enhance confidence in teaching BIM within civil engineering programmes.

However, according to Alshawi (2007) the knowledge framework needs to be made available and shared throughout the relevant organisations. Therefore, an appropriate sharing environment is required among the staff and the different universities. However, the issue of universities’ willingness to share knowledge and the method used for sharing knowledge can affect this process and perhaps affect the data in the framework. Participants have specified methods that were successfully used in the past by different universities on similar scenarios. In the forms of formal and informal socialisation, usually in a forum settings where universities can set up and join a forum to share experiences and knowledge, mentorship, brainstorming sessions and group work discussions.
It was suggested that the universities create the right environment to support learning and knowledge sharing among the staff, where all staff members are encouraged to attend training courses when necessary. Several participants also suggested that certified qualifications should be introduced specially for staffs that require training to teach certain BIM tools. Certificates would not only give educators the confidence in teaching, but will also encourage other members to undertake these training courses when necessary.

6.6.3. BIM effect on the professional institutions

As discussed in chapter 4, upon graduation, students realise a high demand for BIM skills in the industry. The more knowledge and confidence graduates have on BIM, the more likely they are to be favoured by the employers. The majority of the participants agree that BIM has a positive impact on the industry and so graduates with BIM knowledge are seen as the sparklers for these impacts.

Consequently, the Professional Institutions have developed a high range of quality training (CPD) for their professional members and are also working towards developing suitable teaching standards for the students. As a start, the JBM has published “good practice guide for building information modelling in degree programmes” (JBM, 2015).

This implies that JBM recognises the importance of BIM to all the industry in general and civil engineering specifically. This report indicated that JBM is considering BIM as a crucial function in engineering design, analysis and management while working
collaboratively within the multi-discipline environment during the operation of the completed asset. The JBM has clearly specified that, to be an effective engineer, one has to understand and have the skills and capabilities to work with open shareable asset information throughout the life cycle of projects such as BIM.

Participants from the professional institutions have agreed with the rest of participants that BIM should be taught to civil engineering undergraduate students as modelling approaches to solve engineering problems, rather than training the students on how to use particular software. To do this, the civil engineering courses need to focus on developing the student’s skills the fundamentals of BIM concepts so that the next generation of engineers understand the central role that BIM can play to coordinate engineering works and also to understand how to operate appropriately on structured data to enhance the fundamental engineering principles.

These opinions led to the conclusion that JBM supports the introduction of BIM within civil engineering programmes. JBM also considers BIM as the fundamental vehicle for the early learning stages of engineering principles. Comments made by participants from the professional institutions were that the professional institutions consider BIM as the beginning of the use of digital data within engineering to suit the engineers’ role in the 21st century.

All participants’ comments have acknowledged that the professional institutions fully support the UK Government BIM Strategy, where the professional institutions are aiming to make the civil engineering profession fully engaging with the BIM implementation agenda. However, participants from the professional institutions feel that universities are not engaging or reacting to BIM as they should be.
Participants B5 and C5 are members of the ICE BIM Action Group; this group was formed by The Institution of Civil Engineering (ICE), containing members of the ICE Expert Panels, members of the Information Systems Panel (ISP) and other invited guests. The ICE BIM action group was formed to collect all BIM-related activities from associated ICE groups within the ICE Learned Society whilst engaging with all interested parties such as the Association for Geographic Information (AGI), the Royal Institution of Chartered Surveyors (RICS) and the Chartered Institution of Civil Engineering Surveyors (ICES) alongside the Royal Institute of British Architects (RIBA), the Chartered Institution of Building Services Engineers (CIBSE), the UK Contractors Group (UKCG) and the Chartered Institute of Architectural Technologists (CIAT) to support work on BIM ‘Best Practices’, as well as BIM Standards and Classification Systems to influence and advise academic programmes (extending into research). They also advise and encourage JBM to include BIM principles in their academic programmes and accreditations criteria. This emphasises that individual institutions will share knowledge and practices to develop and promote institutional responses beyond their remit to educate and endorse industry knowledge. The BIM action group does not only demonstrate the passion that these professional institutions have toward implementing BIM within Civil Engineering education but it also demonstrates a new vision for the industry with collaboration and team working, leaving behind the past divisions and individual efforts.

ICE have also recently published their policy position statement on BIM stating that ICE aims to promote the use of BIM as a means of collaborative working, increasing the knowledge and understanding of BIM across the membership and throughout the industry, whilst out-reaching to other professional institutions and stakeholders who
are interested in delivering BIM. Furthermore, the ICE has sponsored research at the University of Reading to feed into the Government BIM strategy which illustrates that ICE aspire to support the UK Government with the BIM implementation strategy. This certainly categorises ICE as a BIM-driven organisation and so they will prioritise BIM in their accredited degree programmes.

6.6.4. BIM Tools

According to Iverson and Kalyandurg (2004), information technology education in primary and secondary schools can serve as the foundation for engineering education at the university level. Therefore, universities may not have to teach the technology of BIM tools within the civil engineering courses as “technology education”; rather to teach the techniques and process behind it.

Discussions in the focus groups indicated that it is not essential for BIM software tools to be taught in detail; participants recognise that today’s students pick up a lot of computer skills on their own without the need for structured training. According to the academic participants, it is very common to teach a CAD class and find that many students already have very good skills in using software application tools. Participants believe that this strength will keep its momentum when using BIM application tools.

As discovered in section 4.9, various university courses across the world have undertaken different approaches to teaching BIM tools, where the majority of university courses offer the students a general understanding on the use of BIM
software tools with an understanding of the concepts behind the technology of the collaborative platform within BIM. On the other hand, the majority of the participants suggested that students could explore, on their own, the different software tools within BIM. However, it was suggested that each educator should be required to teach the techniques and processes of BIM tools according to the taught discipline, module and task.

There are plenty of computer software tools these days used throughout all stages of design, construction and post-construction. However, the BIM tools are tools that have been tested and verified to work together to produce the required collaborated information model. These tools vary in capabilities, use and functions as shown in Tables 6.4 to 6.6.

i. Primary tools:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Manufacturer</th>
<th>Primary Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadpipe HVAC</td>
<td>AEC Design Group</td>
<td>3D HVAC Modelling</td>
</tr>
<tr>
<td>Revit Architecture</td>
<td>Autodesk</td>
<td>3D Architectural Modelling and parametric design.</td>
</tr>
<tr>
<td>AutoCAD Architecture</td>
<td>Autodesk</td>
<td>3D Architectural Modelling and parametric design.</td>
</tr>
<tr>
<td>Revit Structure</td>
<td>Autodesk</td>
<td>3D Structural Modelling and parametric design.</td>
</tr>
<tr>
<td>Revit MEP</td>
<td>Autodesk</td>
<td>3D Detailed MEP Modeling</td>
</tr>
<tr>
<td>AutoCAD MEP</td>
<td>Autodesk</td>
<td>3D MEP Modeling</td>
</tr>
<tr>
<td>Software</td>
<td>Company</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>AutoCAD Civil 3D</td>
<td>Autodesk</td>
<td>Site Development</td>
</tr>
<tr>
<td>Cadpipe Commercial Pipe</td>
<td>AEC Design Group</td>
<td>3D Pipe Modeling</td>
</tr>
<tr>
<td>DProfiler</td>
<td>Beck Technology</td>
<td>3D conceptual modeling with realtime cost estimating.</td>
</tr>
<tr>
<td>Bentley BIM Suite</td>
<td>Bentley Systems</td>
<td>3D Architectural, Structural, Mechanical, Electrical, and Generative Components Modeling</td>
</tr>
<tr>
<td>(MicroStation, Bentley Architecture, Structural, Mechanical, Electrical, Generative Design)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fastrak</td>
<td>CSC (UK)</td>
<td>3D Structural Modeling</td>
</tr>
<tr>
<td>SDS/2</td>
<td>Design Data</td>
<td>3D Detailed Structural Modeling</td>
</tr>
<tr>
<td>Fabrication for AutoCAD MEP</td>
<td>East Coast CAD/CAM</td>
<td>3D Detailed MEP Modeling</td>
</tr>
<tr>
<td>Digital Project</td>
<td>Gehry Technologies</td>
<td>CATIA based BIM System for Architectural, Design, Engineering, and Construction Modeling</td>
</tr>
<tr>
<td>Digital Project MEP Systems Routing</td>
<td>Gehry Technologies</td>
<td>MEP Design</td>
</tr>
<tr>
<td>ArchiCAD</td>
<td>Graphisoft</td>
<td>3D Architectural Modeling</td>
</tr>
<tr>
<td>MEP Modeler</td>
<td>Graphisoft</td>
<td>3D MEP Modeling</td>
</tr>
<tr>
<td>HydraCAD</td>
<td>Hydratec</td>
<td>3D Fire Sprinkler Design and Modeling</td>
</tr>
<tr>
<td>AutoSPRINK VR</td>
<td>M.E.P. CAD</td>
<td>3D Fire Sprinkler Design and Modeling</td>
</tr>
<tr>
<td>FireCad</td>
<td>Mc4 Software</td>
<td>Fire Piping Network Design and Modeling</td>
</tr>
<tr>
<td>Product Name</td>
<td>Manufacturer</td>
<td>Primary Function</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Cadpipe Commercial Pipe</td>
<td>AEC Design Group</td>
<td>3D Pipe Modeling</td>
</tr>
<tr>
<td>Revit MEP</td>
<td>Autodesk</td>
<td>3D Detailed MEP Modeling</td>
</tr>
<tr>
<td>SDS/2</td>
<td>Design Data</td>
<td>3D Detailed Structural Modeling</td>
</tr>
<tr>
<td>Fabrication for AutoCAD MEP</td>
<td>East Coast CAD/CAM</td>
<td>3D Detailed MEP Modeling</td>
</tr>
<tr>
<td>CAD-Duct</td>
<td>Micro Application</td>
<td>3D Detailed MEP Modeling</td>
</tr>
</tbody>
</table>

Table 6.4. BIM Authoring Tools (Reinhardt, 2009)

ii. Drawing and fabrication tools:
Table 6.5. BIM Tools for drawing and Fabrication (Reinhardt, 2009)

iii. BIM construction management and scheduling tools:

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Manufacturer</th>
<th>BIM Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navisworks Manage</td>
<td>Autodesk</td>
<td>Clash Detection and Scheduling</td>
</tr>
<tr>
<td>Navisworks Scheduling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ProjectWise</td>
<td>Bentley</td>
<td>Clash Detection and Scheduling</td>
</tr>
<tr>
<td>Digital Project Designer</td>
<td>Gehry Technologies</td>
<td>Model Coordination</td>
</tr>
<tr>
<td>Visual Simulation</td>
<td>Innovaya</td>
<td>Scheduling</td>
</tr>
<tr>
<td>Solibri Model Checker</td>
<td>Solibri</td>
<td>Spatial Coordination</td>
</tr>
<tr>
<td>Synchro</td>
<td>Synchro Ltd.</td>
<td>Planning &amp; Scheduling</td>
</tr>
<tr>
<td>Tekla Structures</td>
<td>Tekla</td>
<td>Structure-centric Model &amp; Schedule driven link</td>
</tr>
<tr>
<td>Vico Office</td>
<td>Vico Software</td>
<td>Coordinate, Scheduling and Estimating</td>
</tr>
</tbody>
</table>

Table 6.6. BIM Construction Management and Scheduling Tools (Reinhardt, 2009)

All participants were shown Tables 6.4 to 6.6 and were asked to choose the tools they see most suitable for civil engineering. The following BIM tools were first selected by the participants individually and then by a conversation with the rest of the group.
members to express their opinions. However, as mentioned above, the participants concluded that educators should choose the relevant BIM tool according to the taught discipline, module and tasks.

**Bentley Systems** - functions within BIM in a different way, it integrates the project model by a family of application components such as Bentley Architecture (Microstation Triforma), Bentley Structures, Bentley HVAC, etc. However, it is advisable to deploy the entire family of Bentley products in order to get the highest levels of interoperability.

**Graphisoft** – is used to create a virtual building model on easy access. By using ArchiCAD application, users can access virtual models through an instant and reliable data-exchange network both within the office and over the internet rather than being accessed as the central repository for the entire model.

**Nemetschek** - provides a BIM platform approach by offering a database layer to allow third-party design and analysis applications to interface with the building objects in the model.

**Autodesk REVIT** is perhaps the most literal function of a single BIM as a central project database. Autodesk REVIT has the ability to coordinate all building elements in one platform and provide users the ability to immediately see the results of design changes.
5.7. Summary and Conclusions

Participants were asked to list any BIM skill sets that civil engineering students should have once they graduate. Responses included: general understanding of BIM concept, ability to input and read data on BIM, ability to operate BIM analysis tools, ability to collaborate and solve problems, knowledge on relevant software tools, an understanding of the project management and design communication processes through BIM. However, the majority of the participants indicated that a basic to intermediate level of BIM knowledge is expected upon graduation: “Civil Engineers are not required to be advanced or experts in BIM to carry out their jobs, although relevant basics of BIM knowledge are essential” (participant B6).

Responses received by participants from the industry indicated that BIM is becoming very important in the industry and the expected level of student BIM knowledge upon graduation is increasing. None of the responses suggested that BIM knowledge was not important in the industry. Overall, the majority of the participants viewed BIM knowledge as an important factor for civil engineering students once they graduate: “The demand of BIM knowledge is growing in the industry, and universities are required to satisfying industry’s demands” (participant C7).

Also highlighted were the following:

- Is the Civil Engineering profession changing due to the evolution of BIM? If so, How? Q1
How can civil engineering undergraduate programmes evolve to reflect industry's requirements for BIM? $Q_4$

The incorporation of BIM in civil engineering undergraduate programmes should focus on the core concepts of BIM rather than the application interface and functionalities. $Q_4$

Teaching BIM in civil engineering university courses will require staff training. $Q_5$

How could a framework support the integration of BIM within UK civil engineering programmes in the UK? $Q_6$

Informal training programmes must be introduced to develop staff skills and knowledge for BIM process and tools.

Teaching staff must keep up-to-date with BIM education and elements.

Universities must develop appropriate means with the industry to capture knowledge and practical data on BIM.

Must develop the appropriate environment to support learning and knowledge sharing among the staff and students.

The JBM recommends that their sets of guidelines should be considered together in the development of degree programme content, context and delivery.

In response to the growing demand of BIM in the industry, BIM research and funding grants have also been growing in academia but not many emerge in civil engineering. When academics were asked if research on BIM was conducted, only a few of the respondents stated that they recognise research conducted on BIM in
civil engineering programmes within UK Universities. It is believed that an increase of research grants and research programmes within Civil Engineering can raise the knowledge and awareness of BIM within the UK and make the integration of BIM within the curriculum more feasible.
Chapter 7

Questionnaire data collection and analysis

7.0 Introduction

This chapter describes the questionnaire survey, the planning that was considered prior to undertaking the process, how it was conducted and analysed with more emphasis on the technical procedures and finally followed by the report of findings.

7.1. Questionnaire overview

A questionnaire survey was developed and issued to students undertaking accredited civil engineering programmes in the UK in all academic years 1, 2, 3 and 4 during the academic year 2013-2014. The survey collected data from students regarding their views on BIM and the best practices of implementing BIM within the curriculum. The surveys requested information about whether or not BIM was realised within the current civil engineering courses and, if so, how. The survey also asked what the students’ expectation was of BIM knowledge upon graduation and who they believed to be responsible for teaching this knowledge.

The students of the accredited civil engineering university courses were surveyed for this study as representatives of Civil Engineering courses across the UK. At the time of the survey, there were 44 accredited civil engineering programmes in the UK. A link to the survey was emailed on three occasions to the sample of students in these
universities within a three-month period, between the months of January and April 2014. Responses were received from 1,337 civil engineering students from different programmes and academic years, generating a response rate from 29 universities.

7.2. Sampling approach

As mentioned in section 5.6, there are two sampling methods: probability or representative sampling and non-probability or judgmental sampling. According to Saunders et al. (2003) and Thomas (2004), probability sampling is the most appropriate when the chance of each case being selected from the population is known, whereas in non-probability the probability of each case being selected from the total population is not known. However, this research focused on particular characteristics of a population, which are the undergraduate civil engineering students from the 43 accredited civil engineering programmes in the UK (Table 7.1.1). Where each programme consists of 4 years, each year contains an average of 60 students and so the population is known. Hence the probability sampling technique was possible and appropriate to use to choose a sample of universities to carry out this questionnaire survey. However, the student population in the sampled universities was too large and was almost impossible and time consuming to identify every student of the population in order to choose a specific sample for this questionnaire. Therefore, the non-probability sampling was possible and appropriate to use for this stage.
The probability-sampling technique was used to increase the sample's representativeness of the population in order to generate statistical inferences and allow for generalisation, where every programme and every academic year had greater chance and equal opportunity for selection, while sampling errors and sampling bias were minimised.

However, the non-probability sampling was used due to the difficulty of accessing information on each and every student in the sampled programmes and academic years. Also, the non-probability sampling technique was much easier, quicker and cheaper than probability sampling in order to achieve more data.

The process started by breaking down the list of each programme to four academic years as described in the example in table 7.1.2. Each academic year was then assembled separately where similar academic years were gathered in one table as demonstrated in table 7.1.3; this process was carried out with every academic year. Once all the academic years were assembled and the population was distinct, the researcher used the simple random sampling technique to randomly select 25 of each year (i.e. 25 x 1st year programmes, 25 x 2nd year programmes, 25 x 3rd year programmes and 25 x 4th year programmes) adding up to 58% of the UK's civil engineering accredited programmes from 29 different universities. The simple random sampling technique was used for this stage to guarantee equal chance (probability) for each university and each academic year to be selected for inclusion in the sample.
<table>
<thead>
<tr>
<th>9 - Aston University Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - Aston University Year 2</td>
</tr>
<tr>
<td>11 - Aston University Year 3</td>
</tr>
<tr>
<td>12 - Aston University Year 4</td>
</tr>
</tbody>
</table>

**Table 7.1.2. Breakdown of Academic years in each University**

<table>
<thead>
<tr>
<th>1- University of Aberdeen Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - University of Abertay Dundee Year 1</td>
</tr>
<tr>
<td>3 - Aston University Year 1</td>
</tr>
<tr>
<td>4 - University of Bath Year 1</td>
</tr>
<tr>
<td>Cont...</td>
</tr>
</tbody>
</table>

**Table 7.1.3. Grouping academic years for sampling**

Once the samples of the universities and academic years were selected, it was easier for the researcher to identify and contact academic teaching members in these universities rather than the students; hence the researcher used the snowballing sampling technique as it is the most suitable and usable technique for sampling such a large number of students; the teaching academics were initially contacted to identify further suitable members (students). According to Hussey (1997) and Saunders *et al.* (2003), the snowball sampling technique can identify the only possibility when populations are difficult to identify.

As discussed in section 5.6, snowball sampling is a type of non-probability sampling technique used to gain samples from populations that are hard-to-reach and/or hidden. The researcher adopted a two-step approach to create the snowball sample:

- Identified academics teaching in the randomly sampled programmes and academic years;
• Used these academics to find suitable students and so on until the sample size was met.

The academic members were willing to coordinate and distribute the questionnaires to their students; this increased the number of participators and enhanced the quality of feedback. It also simplified the process of contacting the students and the replies were received very quickly. The questionnaire was administered via emails, including a brief about the study and a link to the questionnaire via SurveyMonkey.com.

The only disadvantage in using the snowball sampling technique was that it does not select units for inclusion in the sample; therefore, it was hard to determine the possible sampling errors and make statistical inferences from the sample according to the population, and so the sample will not be considered as representative of the population being studied. However, the researcher has undertaken the following steps to override these obstacles and enhance the possibility of determining sampling errors to make statistical inferences and produce representative samples of the population.

7.3. Questionnaire Design

The survey questionnaire requested both quantitative and qualitative information from the respective respondents. The survey was developed using the online survey tool, SurveyMonkey. There were a total of 7 questions in the survey all on one page; the first question was an open-ended question and 6 closed-ended questions with Multiple Choices (4 questions with single answer choice and 2 with multiple answers
choice) including 3 with a follow up section “please describe” as showing in Appendix A. The survey was divided into three sections as follows:

7.3.1. Demographics

The first two questions of this survey asked for demographic information. First, participants were asked to confirm their university email; this was to make sure that only students from the accredited civil engineering courses completed the survey and also to outline which university each participant studies in for demographical information across the entire questionnaire. Second, the students were asked which year of study they are currently undertaking to break down the population of students. These two questions enabled all answers to be organised and rated according to the university and the level of study each of the participants belong to.

7.3.2. BIM-specific demographics

The second section of the survey queried BIM-specific demographic information. The survey asked the students about their BIM knowledge and abilities and whether they received any form of learning on building information modelling (BIM). These questions gave the participants the opportunity to describe their BIM knowledge and express their learning experience including knowledge of BIM software and the types of teaching that was provided i.e. seminars, workshops etc.
7.3.3. Expectations and philosophy

The third section of the survey asked the students their preferred methods of learning BIM and who they believe to be responsible for preparing the students/graduates to work in the industry with the right BIM capabilities. The complete survey is located in Appendix A.

7.4. Considerations

When designing the questionnaires, the researcher has considered the instructions provided by Ghauri and Gronhaug (2001), Saunders et al. (2003) and Thomas (2004) to ensure no bias in designing the questionnaire and also to ensure that the questionnaire is sufficiently brief and reads well to encourage students to participate. The questionnaire was tested and improved through a series of pilot studies with a number of PhD students and others professional colleagues on LinkedIn to remove any potential issues of bias and distinguish the required time to answer the questionnaire survey and whether it is reasonable to expect participants to spare this amount of time to provide their answers. As a result, amendments to the questionnaires were also made on several occasions, on matters such as the ordering of questions, the type of questions (open/closed), representation of the questionnaires, the used phrases and wording, the ways in which some questions were asked and the proposed choices of answers.
7.5. Data analysis

The data analysis phase involves three steps;

- Organising the data for analysis (Data Preparation)
- Describing the data (Descriptive Statistics)
- Testing Hypotheses and Models (Inferential Statistics)

7.5.1 **Data preparation** involved logging, checking and tracing the data received from the questionnaires, where the researcher created a structured categorised database on “Microsoft Access” to record incoming data to enable access at any time and view the recorded data and the outstanding results. This has also retained the original data records for a reasonable period of time with an affordable advantage of tracing results from the data analysis back to the original forms on which the data was collected.

7.5.2 **Descriptive statistics** were used to describe the basic features of the collected data. The researcher intended to provide simple descriptive summaries about each sample to break down the data and ease the process of creating graphics analysis and calculations in order to describe the data in a manageable form and reach conclusions that extend beyond the immediate data alone.

A large number of responses were expected from the questionnaire surveys. Therefore, the researcher used three simple steps of analysis (distribution, central tendency and dispersion) to help describe the statistics in a sensible manner.
The distribution helped the researcher to summarise the frequency of individual values and ranges of values. For instance, a typical way to distribute the participating students is by year of study, listing the number or percentage of responding students at each year. Although the data is described in the form of a table, the researcher has also allocated the data in the form of histograms and bar charts.

Once all data was distributed into the most suitable form and description, the next step was the central tendency of distribution; this was used to estimate the "centre" value of distribution by using the common methods of mean, median and mode.

Finally Dispersion; in this step the researcher allocated the values around the central tendency by using one of the most common measures of dispersion, the range (the highest value minus the lowest value).

7.5.3. **Inferential statistics** (investigate questions, models and hypotheses). The researcher adopted the inferential statistics technique by using the statistical analysis tools in Microsoft Excel to draw conclusions from the data to generalise the conditions and describe what is going on in the data while reserving only the most critical analysis summaries.
7.6. Questionnaire results

The results obtained from the questionnaire surveys were divided into three sections; demographics, BIM specific demographics and expectations and philosophy. The results are shown as a combination of frequency histograms and percentages and include bullet point summaries of comments made by respondents.

7.6.1 Demographics

At the beginning of the survey, students were asked to provide their university email address. This question was essential for many reasons; critically, it is to make sure that these students are all studying at the accredited civil engineering programmes stated in table 7.1. Also to avoid duplicate completions and also to outline which university each participant studies at for demographical information across the entire questionnaire. Responses were received from 1,337 civil engineering students from 29 different universities, yielding a high response rate.

Students were also asked about the discipline they are currently undertaking to confirm whether they were civil engineering students or not. As demonstrated in Figure 7.1 from the data analysis, there were 1,469 responses; 1,337 (92%) of those were civil engineering students, whilst the other (8%) 132 respondents were architecture and construction students.

Note, since the research is only concerned with civil engineering students, moving forward in this analysis the researcher only analysed the feedback received from the 1,337 civil engineering students and observed it as 100% of the responses.
Figure 7.1. Represented disciplines (N = 1,457)

Which course are you studying?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Engineering</td>
<td>91.8%</td>
<td>1337</td>
</tr>
<tr>
<td>Architecture</td>
<td>1.4%</td>
<td>20</td>
</tr>
<tr>
<td>Surveying</td>
<td>2.5%</td>
<td>37</td>
</tr>
<tr>
<td>Project Management</td>
<td>4.3%</td>
<td>63</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

answered question 1457
skipped question 0

Table 7.2. Represented disciplines (N = 1,457)

When students were asked about their year of study, 42% (N= 561) of the responding students were in their 1st year of study and 26% (N= 348) were in their 2nd year of study, whilst only 14% (N= 187) were 3rd year students and 18% (N= 241) were 4th year students. This led the researcher to follow up on the distribution of the questionnaires to make sure that all students from all academic years had equal opportunity to take

224
part in this survey. The received feedback confirmed that the questionnaire surveys were distributed equally. However, students at higher academic years (year 3 and 4) did not feel comfortable in completing the questionnaire or did not feel that they had enough knowledge to participate. This led to the conclusion that universities have not developed a learning strategy for civil engineering students to learn about BIM, which means that civil engineering students will lack BIM knowledge and might be a great obstacle for them when graduating and looking for jobs (Q3).

![Pie chart](image)

**Figure 7.2.** Represented years of study (N = 1,337)

<table>
<thead>
<tr>
<th>Year of study?</th>
<th>Response</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Year</td>
<td>42%</td>
<td>561</td>
</tr>
<tr>
<td>2nd Year</td>
<td>26%</td>
<td>348</td>
</tr>
<tr>
<td>3rd Year</td>
<td>14%</td>
<td>187</td>
</tr>
<tr>
<td>4th Year</td>
<td>18%</td>
<td>241</td>
</tr>
</tbody>
</table>

*Table 7.3. Represented years of study (N = 1,337)*
7.6.2 BIM-specific demographics

The survey also asked for information on BIM-specific demographics, where respondents were asked a number of questions specifically on BIM. First, students were asked to describe BIM from the multiple choices provided with an the ability to choose more than one option or describe it according to what they think is more suitable to define BIM in the “other” option or tick the “Never heard of BIM” option if it is applicable to them. This question was essential to understand the student’s knowledge on BIM.

As show in figure 7.3, 749 civil engineering students (56%) described BIM as collaborative working, with 682 of these 749 students (51% of the respondents) also describing BIM as 3D Modelling. 441 civil engineering students (33%) described BIM as simulation – virtual reality, 29% as computer software, 19% as “a new buzzword in the industry” and 8% as a complicated way of working. However, 201 civil engineering students (15%) have never heard of BIM and did not choose any of the choices provided to describe BIM nor did they express their thoughts in the “other” option; 124 of these students were in their final year of studying civil engineering, which also suggests that civil engineering graduates will lack BIM knowledge and may not fulfil the BIM criteria that many major employers have started expressing an interest in (Q3).

Comparably, 19 students felt comfortable to further describe BIM in the “other” option, which indicated that they had a good understanding of BIM as shown in the following comments:
• Integration
• A new culture- collaborative way of working supported by technology (i.e xD modelling, data sharing etc)
• Better Information Management
• Multi-dimensional modelling
• Very high cost to implement
• The present and future of civil engineering.
• New way to manage a large complex project
• 7D modelling which is interdisciplinary
• Using one model for all parts of a design (structural, services etc)

![Figure 7.3. Respondents describing BIM (N = 1,337)](image-url)
How would you describe Building Information Modeling (BIM)?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D modeling</td>
<td>51%</td>
<td>682</td>
</tr>
<tr>
<td>Computer Software</td>
<td>29%</td>
<td>378</td>
</tr>
<tr>
<td>Complicated way of working</td>
<td>8%</td>
<td>107</td>
</tr>
<tr>
<td>Collaborative working</td>
<td>56%</td>
<td>749</td>
</tr>
<tr>
<td>A new buzzword in the industry</td>
<td>19%</td>
<td>238</td>
</tr>
<tr>
<td>Simulation - Virtual reality</td>
<td>33%</td>
<td>442</td>
</tr>
<tr>
<td>Never heard of BIM</td>
<td>15%</td>
<td>201</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td>19</td>
</tr>
</tbody>
</table>

Table 7.4. Respondents describing BIM (N = 1,337)

The 5th question asked the students “Has or will BIM be taught in your current course?” with one option to choose from “Yes”, “No”, “Not sure” and “if yes (please describe)”: 35% (N= 468) responded “Yes”, 45% (N= 602) responded “No”, while 20% (N= 267) responded with “Not sure”.

The 45% (N= 602) who responded with “No” were civil engineering students from 18 different universities, which means that at least 18 UK accredited Civil Engineering Programmes are not teaching BIM to their students; these students will soon be graduates seeking work within the industry but without any BIM knowledge, BIM qualifications or BIM experience (Q3).

The 35% who responded with “Yes” were civil engineering students from 8 different universities; at the start it appeared that a great number of universities are teaching BIM within civil engineering programmes. However, when theses students were asked, “If yes, please explain”, most of descriptions indicated that students were referring to
teaching CAD rather than teaching BIM. However, some courses seem to have introduced BIM as explained below by students:

• We had two modules which included the topic of BIM
• Taught in 3 modules with a focus on BIM’s use during construction and post completion of project
•Introduced in Project Management module
• We were invited to a guest lecture involving the integration of BIM in construction projects, i.e. the new University of Ulster Belfast campus
• It has been taught in a number of the project management modules
• Just a small introduction to what BIM is and how it works
• One lecture in a module - Project Management
• Revit replaces CAD module, as far as I know for new entrants
• We got introduced to it in second year of study, which we completed coursework on
• Taught in modules and I am also undertaking my dissertation on BIM
• BIM is involved in one module, but little
• We have been taught about BIM processes along with using programmes such as Revit to complete coursework and demonstrate how BIM can be used practically
• Not really taught, we had to teach ourselves using video tutorials
• It has been touched upon but not enough to develop a true understanding or use any software
• As part of an AutoCAD module
• Only a few hours tuition
• At the moment include only the 3d modelling
• We’ve used architectural BIM to virtually build a building
• A individual module with coursework
• Only one section
• Not taught very detailed, mentioned as a part of the management module
• Will be taught in 2nd year
• I was introduced to BIM in my second year of study. The experience I gained helped me on my placement year when I used TeklaBIM software for the project I was working on.
• We are undertaking a BIM module
• Taught, but very brief
• Given a few classes on brief introduction to BIM and how it works
• Taught within a project management module briefly
• Very briefly

Figure 7.4. Has/ will BIM be taught in your current course? (N = 1,337)
Has/ will BIM be taught in your current course?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>35%</td>
<td>468</td>
</tr>
<tr>
<td>No</td>
<td>45%</td>
<td>602</td>
</tr>
<tr>
<td>Not sure</td>
<td>20%</td>
<td>267</td>
</tr>
<tr>
<td>If yes (please explain)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>answered question</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>skipped question</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.5. Has/will BIM be taught in your current course? (N = 1,337)

7.6.3 Expectations and philosophy

Question number 6 in the survey asked the students “which way do you prefer to learn BIM?” The respondents were asked to select “all that apply” when answering this question. The responses revealed that 64% (N= 856) of the responding students prefer to learn BIM integrated within their existing courses, 17% (N= 228) of the responding students prefer to learn BIM (ONLY) within multidiscipline module, combining different disciplines together, 35% (N= 462) of the responding students prefer the combination of the above i.e. learn BIM within the existing courses and within multidiscipline modules, combining different disciplines together, 8% (N= 108) of the responding students prefer dedicated BIM degree, while 9% (N= 120) prefer to learn BIM in independent BIM training courses.

- The responses indicated that (64% of the participants) 856 current civil engineering students prefer to learn BIM integrated within their existing courses, which means that this method of learning BIM could be the most preferred by the
students in the UK, which is also the case in the USA. Furthermore, 462 of these civil engineering students also prefer to learn BIM within multidiscipline modules, combining different disciplines together for a better understanding of the teamwork reality and enhance their understanding of other disciplines. However, this last option may not be possible in some universities as they only teach civil engineering programmes. The feedback indicates that students would still rather to study civil engineering with the integration of BIM within the existing curriculum.

Other comments by the students included:

• Possibly integrate BIM into the BSc Courses and teach just the principles in BEng. Although BIM is used at an engineer’s level the majority of the complicated work i.e. software design etc applies more to technical staff and at the minute these members of staff tend to be experience orientated rather than qualified as such.

• Have an extra BIM course run for 3 days in the university in an intense learning course.

• Don’t know as haven’t really experienced it yet
Figure 7.5. Which way do students prefer to learn BIM (N = 1,337)

<table>
<thead>
<tr>
<th>Which way do you prefer to learn BIM?</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM integrated within your course</td>
<td>64%</td>
<td>856</td>
</tr>
<tr>
<td>Only as a multidiscipline module, combining different disciplines together</td>
<td>17%</td>
<td>228</td>
</tr>
<tr>
<td>Combination of the above</td>
<td>35%</td>
<td>462</td>
</tr>
<tr>
<td>Dedicated BIM degree</td>
<td>8%</td>
<td>108</td>
</tr>
<tr>
<td>Independent BIM training courses</td>
<td>9%</td>
<td>120</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>answered question</td>
<td></td>
<td>1337</td>
</tr>
<tr>
<td>skipped question</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7.6. Which way do students prefer to learn BIM (N = 1,337)

In the last question, the students were asked “Who should have the most responsibility in preparing Students/ Graduates to work with BIM?” with one option to choose from either “University” “Employer” or “software companies”. 74% (N= 992)
suggested that the university should have the most responsibility, while 23% (N= 301) suggested that the employer should have the most responsibility and only 3% (N= 35) suggested that the software companies should have the most responsibility in preparing students/graduates to work with BIM; 9 students provided their own comments, as follows:

- A mixture of software companies designing the programme and someone within the construction industry
- Both employer and university
- HNC & HND courses, developed by members in the industry.
- Both study and practical support. Can't have a well-taught subject without any experience in real projects.
- I think it rests with both university and employers
- A mixture of all three really, but predominantly university.

This demonstrates that the majority of students in the accredited civil engineering programmes mostly rely on their universities to prepare them for the industry. It indicates that universities are required to rearrange some of the current programmes to better equip students for the continued growing demand of BIM within industry. However, universities should prepare their programmes with the assistance of the industry’s major employers and software companies, to provide a theoretical background to their students, with practical experiences and approaches in unison with the software companies to give practical examples of how it is intended to work.
Who should have the most responsibility in preparing Students/ Graduates to work with BIM?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>74%</td>
<td>992</td>
</tr>
<tr>
<td>Employer</td>
<td>23%</td>
<td>301</td>
</tr>
<tr>
<td>Software companies</td>
<td>3%</td>
<td>35</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answered question</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Skipped question</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7.7. Responsibility in preparing students/ graduates to work with BIM? (N=1,337)

7.7. Summary and conclusions

It is essential to comment on the response rates for this questionnaire survey; of the 44 accredited civil engineering programmes in the UK, responses were received from 29 institutions (overall institutional response rate of 66%). This was encouraging for the
researcher and will also be encouraging to educators and industry professionals supporting the transition of BIM. The survey results showed that:

- The positive response rates indicated that students are taking an interest in learning BIM.
- While BIM is variously described by the respondents, the majority of respondents have indicated a good understanding of BIM.
- In terms of teaching BIM, none of the results indicates real implementation of BIM within the curriculum.
- Nearly half of the respondents (from 18 different universities) indicated that BIM was not introduced within their courses, which means that these students will soon be graduates seeking work within the industry but without any BIM knowledge, BIM qualifications or BIM experience (Q3).
- Even though it was not specifically asked in the questionnaire, the majority of the respondents stated that they are currently undertaking Autodesk Revit, which indicates that universities are capable of teaching such technology and students are willing to learn the use of software tools such as BIM tools.
- Some 3rd and 4th year student have indicated that BIM research topics have been introduced as one of the options for the dissertation topics that they have to undertake as part of completing their programme. However, no teaching was given.
- The majority of the respondents described their philosophy in implementing BIM is to fully integrate BIM within their current courses. More than the third
also prefer to learn BIM within multidiscipline modules, combining different disciplines together.

- The integration of BIM principles within the current civil engineering programmes approach means that the currently taught civil engineering curriculum will not change its core standards. Rather, BIM standards and capabilities can be introduced within the current curriculum to assist the student's understanding of engineering concepts and to enhance their practical abilities and problem solving.

- None of the respondents stated or implied that they did not feel that BIM was important for their learning curve.

- As interest in the implementation of BIM grows, schools across the UK should rearrange some of the current curriculum to better equip students for the growing demand of BIM knowledge in the industry and also as a response to the growing student interest in BIM.
8.0 Introduction

Following the findings of the focus groups and subsequent analysis of the questionnaires, this chapter presents a framework of recommendations for the implementation of BIM into civil engineering degree programmes in the UK. The findings include recommendations for the up-skilling of teaching staff members, enhancing student employability and developing suitable learning styles and techniques. The framework is not prescriptive, but is intended to provide a structured set of considerations that will guide the process for BIM integration into civil engineering degree programmes. It is accepted that individual universities will be characterised by unique features, processes and procedures that are unsympathetic to all the features of this framework; nevertheless, it provides a solid basis from which to work. The recommendations within the framework are aligned with the EC-UK Spec and with the Joint Board of Moderators ‘Good Practice Guide’ for the integration of Building Information Modelling in accredited degree programmes.

8.1 Contribution factors

From the requirements of driving change within universities, a number of contributing factors must be outlined and justified in order to form a practical and
realistic approach to adopting BIM within civil engineering programmes.

The contributing factors are a number of important issues and themes that were outlined from the focus groups and questionnaire surveys in this research, and also were highlighted in the literature review as barriers to BIM adoption and implementation within higher education. These factors are 1) the knowledge that civil engineering students are expected to have upon graduating, 2) influences to student employability, 3) the required up-skilling of teaching staff, 4) developing BIM teaching techniques to address all learning styles, 5) the essential preparations and considerations that universities are required to consider to develop BIM enabled programmes and 6) the strategies required to introduce and teach BIM tools. These factors are discussed below:

8.1.1 Expected knowledge in graduate civil engineers

According to the BIM Academic Forum report (2013), higher educational institutions are already facing increased calls from industry to provide students with BIM knowledge before entry into professional practice.

In terms of BIM knowledge, civil engineering graduates are expected to have the ability to deliver projects using BIM principles and with an acceptance of the importance of collaborative team working. In addition, graduates must demonstrate an understanding of virtual design and virtual construction and its processes with the capability of evaluating and undertaking constructability analyses, cost estimating and project scheduling while providing dimensionally accurate 3-D models with significant
descriptive data via BIM.

Large UK contracting and consultancy firms are already operating on BIM platforms and are driving the demand for graduates equipped with the requisite skills. To outline the expected BIM knowledge of civil engineering graduates, the researcher has observed a large number of BIM-related vacancies that are currently advertised for civil engineering. The following criteria was described as the minimum requirement for a ‘BIM ready candidate’:

• Understanding of BIM benefits;

• Able to understand and use the features within civil engineering BIM tools;

• Knowledge of BIM legal contracts and criteria;

• Able to work collaboratively via the use of technology;

• Aware of the challenges imposed by existing practices; and

• Capable of creating, viewing, amending and analysing information data within BIM.

Also, the Joint Board of Moderators describe the following criteria as the competence of graduate engineers:

• The ability to acknowledge the different types of software tools and recognise the most suitable for design, analysis and management;

• The ability to understand and perform the calculation processes and address fundamental engineering problems via BIM software;
- The ability to operate on digital models and structuring data in order to interact and co-ordinate with other team members through digital technology on shared engineering tasks;

- The ability to capture data from hand sketches, rough calculations, laboratory testing and physical modelling to adjust the digital models accordingly;

- The ability to critically analyse and interrogate computer models, calculations, engineering propositions and assumptions to reflect on the validity, efficiency and accuracy of particular techniques and processes rather than just inputting data;

- The awareness of the basic standards of digital processes and procedures for using BIM technologies in engineering.

**8.1.2 Student employability**

The increasing importance of BIM gives rise to the question, should civil engineering students be exposed to BIM in the early years of higher education? Over the previous decade, the results suggest that BIM has been ‘briefly’ integrated into undergraduate teaching and learning through seminars, workshops, in-class activities and some coursework projects. However, since the UK government mandate, the demand for BIM knowledge has grown and the requirement for appropriate education has grown. Anecdotally, there is evidence that the push is also emerging from the employer panels (sometimes known as industry panels) that sit within individual schools; these are comprised of practicing civil engineers who provide steering to schools in
developing programme and course unit content.

As the industry take-up of BIM gains further momentum, students require updated knowledge to suit the transformation within the industry. The UK’s Higher Education Academy is seeking to develop the student’s abilities and knowledge to be not only successful, but to become future leaders within the industry. Therefore, the current civil engineering courses in UK universities are required to be more than just transmission of facts in order to prepare civil engineering students with practical knowledge and experiences.

8.1.3 Up-skilling of staff

The implementation of BIM within the civil engineering curriculum can generate a steep learning curve for staff and students alike. However, it can be time consuming for educators to become familiar with the use of the software as well as the administrative procedures required to set the environment for student projects. However, this can be arranged with the software suppliers, where many software suppliers have set a number of educational packages to educate academic members along with the software licenses packages. Also, getting the required software working perfectly and maintained on student computers and lab computers can be challenging. However, this is a common challenge that schools have dealt with in the past while using CAD or other similar software packages.
8.1.4 BIM teaching techniques to address different learning styles

There is no one desired method of teaching and learning insofar as BIM is concerned. The design of courses will reflect the individual characteristics of the school, the profile of the staff and their respective research profiles – nevertheless a set of suggestions have been developed based on the findings of the literature review, focus groups and questionnaire data:

- **Motivate learning** - As much as possible, educators should keep up-to-date with the latest developments within the industry and relate the material being presented to civil engineering (*inductive/global*).

- **Background and theory** - Educators must provide a balance of actual information of engineering such as facts, recorded data etc (*sensing*) and theoretical concepts of mathematics and physics such as relevant principles, theories, mathematical models etc (*intuitive*) while balancing the materials that emphasises practical problem-solving methods with BIM tools (*sensing/active*) with the materials that emphasises fundamental understanding (*intuitive/reflective*).

- **Use different BIM tools to visualise and illustrate data** such as schematics, graphs, and sketches frequently whilst presenting verbal material (*sensing/visual*). Provide demonstrations of BIM tools and work being done (*sensing/visual*), hands-on by taking students on site, if possible (*active*).
• Provide students with the opportunity of cooperating with each other on team projects to the greatest possible extent (active). Students generally learn best when they interact with each other, especially whilst using BIM tools and methods of working on a “real-life project”

8.1.5 University preparations

The following recommendations are developed for universities to consider while preparing for BIM enabled civil engineering programmes:

• University programmes should focus on developing systematic foundations of engineering techniques and procedures and how to apply them within digital tools and technologies.

• University programmes should form a continuous thread of digital engineering for students to challenge engineering problems and practically develop problem-solving techniques

• The universities must provide a suitable learning environment to encourage students to explore the opportunities of digital engineering; for example, creating engineering designs, carrying out digital simulations and adjusting digital models within laboratories and real-life field environments.

• University programmes must develop taught modules to introduce students to the potential of digital ways of working within professional practice. For
example, in professional practice, work is carried out using digital tools within a collaborative environment; therefore, the undergraduate courses should cover basic use of standard processes and procedures in team-work environment and introduce live projects to prepare the graduating engineer to work as part of a professional team.

8.1.6 Recommendations for teaching BIM tools

Until recently, architecture programmes have led the adoption of computer design tools into the curriculum leaving engineering and construction programmes lagging significantly behind.

Enterprises that are currently using BIM seek graduates who are capable and comfortable with BIM processes, but do not require software expertise. Therefore, it is not essential to teach BIM tools in detail. Today’s students pick up a lot of skills on their own without training. It is very common to teach a CAD class and find many students in fact have very good skills in using the application and getting results out of it, where students usually prefer to be taught the basic knowledge about CAD and left to explore, on their own, the different technology features to shape their own opinion and understanding. According to Hietanen and Drogemuller (2008), understanding the idea is more important than mastering the use of CAD. This strength keeps up its momentum when using BIM applications. As established in chapter 6, Bentley, Graphisoft, Nemetschek and Autodesk REVIT are the most appropriate BIM tools for civil engineering education and use.
8.1.7 Teaching the software

The most popular software tool being taught to Civil Engineering students is CAD. Teaching CAD to civil engineering students usually follows a traditional process of: drafting, programming and data modelling. This method was developed to get the full benefits of such technology tools without getting involved with the technicality of system programming etc. (Streich, 1992). It is suggested that most of the BIM tools are sympathetic to the teaching style used in conventional CAD teaching, and therefore can be taught similarly.

Therefore, in considering how to teach BIM tools and techniques to civil engineering students, it is recommended to use the three steps of drafting, programming and data modelling as follows. The first step is to develop the student’s ability to create and draft basic elements and drawings using the technology tools; this can be done through workshops and seminars to build the foundation knowledge for students to use the tools comfortably. However, as mentioned above, students tend to find it better to learn independently with the ability to seek help when needed; this can also allow students to be more creative with the technology and its features. The second step is to enable students the ability to change, amend and create drawings according to their calculations and solutions. The third step is to provide the students with the ability to clarify the fundamentals behind the data-modelling concept (Krawczyk, 1998).
8.2 Framework for learning

A framework for incorporating BIM within accredited civil engineering courses is created to provide a template to help shape and approve the adoption of BIM and assist the civil engineering programmes to move forward quickly and confidently. Therefore, this framework relied on the feedback received from current students, academic members, members of the chartered institutions and professional civil engineers. This process generated valuable data to provide wider understanding of the industry and academic requirements of introducing and implementing BIM within civil engineering curriculum.

The generated outcomes from the focus groups and questionnaire surveys are presented for each level (year of study). The first two years should focus on the individual skills of modelling and analysis of the model while the final years should focus more on teamwork and complexity through collaboration including a multidiscipline project in collaboration within a working group, as further explained in the following framework:

8.2.1 Year 1: An introduction to Building Information Modelling

BAF (2013) and BAF (2015) stated that students in their 1st year of the programme should be provided with an overview of BIM terminology and practices. Participants from the focus groups also indicated that an introduction to the concepts necessary to understand how BIM is involved must be provided to 1st year civil engineering students. The findings of the research groups suggest that, by the of 1st year civil engineering programmes, students should be able to:

- Recognise the importance of BIM;
• Understand the background of the industry and the existence of BIM;
• Appreciate how the industry works;
• Define common BIM terminologies;
• Acknowledge the importance of collaboration;
• Understand how BIM is used for communication and collaboration;
• Recognise BIM benefits;
• Understand the modelling process;
• Distinguish issues associated with BIM; and
• Design a model using BIM tools.

8.2.2 Year 2: BIM technology

It was indicated in the focus groups that second year civil engineering students must be provided with a general introduction to BIM tools. Therefore, students should be able to acknowledge the existence of the different tools and functions within BIM, where BIM tools can be introduced according to the taught topics and functions. The findings of this research suggest that, by the of 2nd year civil engineering programmes, students should be able to:

• Understand the phased structure of a BIM project;
• Acknowledge the classes of BIM tools;
• Operate on at least one BIM application;
• Understand how BIM tools and functions are incorporated to undertake a project;
• Understand how information is prepared, shared, issued and employed using BIM;
• Understand the impacts of BIM in terms of life cycle and whole life cost on projects.

8.2.3 Year 3 and 4: BIM process, adoption, and integration

According to the JBM (2014) report, civil engineering graduates should be able to create and execute a BIM model with real integration in a single project. Therefore, the final years of the civil engineering undergraduate programmes should focus on providing students with the real life experience on process, systems and people with the use of BIM. The findings of this research suggest that civil engineering graduates should be able to:

• Recognise the process, adoption and integration of BIM within a real life project;
• Understand the roles and responsibilities of participants in a typical project using BIM;
• Work interactively and be capable of working within a team collaboratively;
• Understand the process of communicating data via BIM models;
• Provide engineering solutions and design solutions using BIM tools;
• Deliver projects using BIM;
• Create, Visualise, Amend, Evaluate, Process and Manage data on BIM models.

According to BAF (2015) and the focus group participants, it is also recommended that students be exposed to the legal side of BIM to give them a better insight into how the BIM model works in a fully integrated project. This will provide students with the ability to examine BIM within contract terminology and determine best practices for integrating BIM into project contracts while providing an in-depth
understanding of intellectual property rights, insurance and risk allocation. This legal knowledge will give students and understanding of BIM background and processes.

8.3 Validation of the developed model

The conceptual validation approach was used to validate the finalised framework and the recommendations of this research. Conceptual validation is best tested against the opinion of experts with different backgrounds. This approach was used to determine whether the above framework accurately represents the true understanding of the feedback received from the focus groups and the questionnaire. The focus group participants and BAF members were asked to review the above framework in order to simplify the recommendations and the points of the framework to achieve realistic approaches and ensure that the framework and recommendations were credible, realistic and reflected a true representation of the feedback received from the focus groups and questionnaire findings.
Chapter 9
Discussion, conclusions and recommendations

9.0 Introduction

The final chapter of this thesis presents a discussion of the results obtained during the course of the research and the subsequent analysis that was performed; the narrative draws upon the original aim and objectives of the research and considers the likely implications, limitations and original contributions to knowledge. Recommendations for further research are presented, the emphasis of which lies predominantly on the pedagogical design considerations that are essential to the successful integration of BIM in civil engineering undergraduate programmes.

9.1. Discussion

Building Information Modelling (BIM) is irrevocably changing AEC industry ‘norms’, so much so that some observers refer to a ‘paradigm change’ in the industry (Takim, 2013; Eastman et al., 2008). The BIM agenda is dominating the software debate, and the vendors are keen to grow market share through rapidly-evolving platforms and solutions. Software is a key enabler in ensuring the complete and accurate communication of design and construction information across the supply-chain but it is not the sole preserve of BIM (Gilligan and Kunz, 2007). BIM can also enable modelling of the building’s elements and components including its functions and behaviour throughout the building life cycle (Sacks et al., 2004); this introduces added benefits to the facilities management/asset management communities and further reinforces the perceived benefits of techniques such as whole life costing. The
widespread use of BIM has been demonstrated in major civil engineering schemes such as the Panama Canal, Heathrow Airport expansion, Crossrail and numerous highways infrastructure programmes. BIM has also been theoretically explored, measured and proven to be beneficial to civil engineering by Birx (2005), Sacks and Barak (2008), and Khanzode et al. (2005). However, the lack of BIM knowledge and skills in the UK generates a significant constraint to the use of BIM in UK civil engineering projects, creating great concerns for many civil engineers working within the industry especially with the fast approaching deadline for the BIM level 2 implementation requirement. Many recent extensive surveys on BIM determined that the lack of suitable training and education was the greatest obstacle to BIM adoption in the UK (Arayici et al., 2009; Young et al., 2008). Therefore, unless BIM is introduced into undergraduate civil engineering curricula in a fundamental way, graduates from UK civil engineering programmes will lack the skills and knowledge needed to serve the industry.

Internationally, civil engineering schools are taking an interest in implementing BIM into curricula as a means of adequately preparing students for the industry. By implementing BIM as a response to the industry’s demands, the majority of schools aim to provide students with the basic to intermediate level of BIM knowledge upon graduation and felt that knowledge of BIM was important in satisfying industry demands.

Hence, various universities in the UK have started to investigate the possibilities of implementing BIM in curricula. However, it appears that CAD and similar technical tools are being taught rather than the principals of BIM, while BIM is perceived as a
more sophisticated or complex subject.

The framework for comprehensive civil engineering programmes must collect and evolve knowledge of this new paradigm to accommodate the future requirements of the industry. According to McGraw Hill (2009) the effective inclusion of BIM into curricula will be critical in the preparation of future employees for industry.

9.2 Review of research aim and objectives

The original aim of this research is to propose a framework to support the integration of Building Information Modelling (BIM) principles into undergraduate civil engineering programmes in the United Kingdom. To achieve this aim, the objectives of the research were to:

- Critically examine the literature on Building Information Modelling (BIM), both from a UK and international perspective. The review will explore the origins of object oriented modelling of buildings, the varying definitions and interpretations on BIM and the standards and guidance currently used in industry to harness the benefits of increase knowledge sharing, collaboration and common data platform.

- Explore the nature of the construction industry in the UK, and elsewhere, to understand the challenges and opportunities that lie in BIM-oriented ‘ways of working’ and the constraints that the characteristics of the industry place on the desire to implement BIM.
• Evaluate, through a series of case studies, current practices in the integration of BIM in teaching of civil engineering and generate a greater understanding of the current position taken by universities in terms of curriculum design and implementation.

• Identify the enablers and barriers to implementing BIM principles and concepts into civil engineering courses in the UK.

• Provide recommendations on how to effectively transfer lessons learned to real-life practice.

• Design a framework to facilitate the most appropriate approach to curriculum evaluation, re-design and operation.

• Validate the proposed framework using an appropriate methodology.

• Make recommendations for further research based on the outcomes of the investigation and subsequent analysis.

9.3. Research questions

In order to achieve the aim and objectives of this research and to provide a framework to support the integration of BIM principles into undergraduate civil engineering programmes in the UK, the research focused on answering the following research questions, which were obtained from the critical review of the literature:

• Is the Civil Engineering profession changing due to the evolution of BIM? If so, how?
• How can civil engineering undergraduate programmes evolve to reflect industry’s requirements for BIM?
• Are Civil Engineering students in the UK lacking BIM knowledge? Will this be an obstacle for them once they graduate?
• How can the balance between philosophy and tools of BIM be achieved in the design of civil engineering undergraduate programmes?
• What training and professional development is required to enable universities to enhance BIM skills in civil engineering undergraduate programmes?
• How could a framework support the integration of BIM within UK civil engineering programmes in the UK?

9.4 Research methods

As described in chapter 5, the use of primary and secondary qualitative and quantitative research methods was used to fulfil the aims and objectives of this research project. The literature-based research thesis aimed to fully understand the concepts related to the topics in hand. Investigation was carefully conducted in order to integrate only the most relevant and useful information available from different combinations of secondary sources such as relevant books, journals, articles, consulting professionals, attending workshops and conferences organised by professional bodies and the Government, and electronic journals acquired from university databases e.g. Harvard Business Review, Science Direct etc.
The primary research methods were also used to generate effective conclusions. The following list shows the main methods by which the data was collected and analysed for the purpose of this research:

### 9.4.1 Case studies

The case studies were used in this research to explore the actuality of data generated from the literature review to gain a better understanding of the debate. Examining specific scenarios enables the researcher to gain in-depth knowledge and investigate its real life context using multiple sources of evidence as argued by Hackley (2003), Saunders et al. (2003), Yin (2003), and Thomas (2004).

### 9.4.2 Qualitative comparative analysis

The Qualitative Comparative Analysis (QCA) was used by the researcher in chapter 4 to compare and analyse the different approaches of adopting BIM into education curriculums around the world. Due to the strong focus on cases that QCA permits, the researcher was able to highlight the best possible cases and the repeated practice in order to decide on the most common practices of BIM in education (Rihoux and Ragin, 2008).

### 9.4.3 Focus groups

The focus group project was the most appropriate and effective way of obtaining information, insight, experience and knowledge from academics, members of professional institutions and professionals in the shortest period of time (Williams, 2001). The Focus Groups were used to produce rich data to assist in decision-making
for the development and modification of the curriculum and learning tools that were not possible to gain from other research methods. The Focus Groups allowed each of the participants to provide a rich source of information about their experiences, knowledge and opinions on BIM in an incentivised and natural atmosphere.

9.4.4 Questionnaire surveys

Questionnaire surveys method of research was the most appropriate method to obtain data from the large population of current civil engineering students. The literature review and findings led to the preparation of a questionnaire survey to produce reliable data and enhance the reliability of evidence and accuracy to understand the requirements of teaching BIM within the UK from the students’ perspective. The questionnaire was based on the findings of the undertaken studies and the theoretical approaches of teaching.

9.5 Limitations of the study

During this research there were two limitations. The first limitation emerged during the literature review stage, where the researcher was challenged with the very little amount of literature that was available on the research topics and sub themes. As for BIM, it is a new topic of research and so the literature was very limited especially within the education theme.

The second limitation appeared during the sampling phase for the questionnaire survey, where it was impossible to adopt the probability sampling technique due to the large number of the students’ population and the difficulty of identifying them.
individually. This in return has restricted the potential for generalisation; however, the pragmatic approach was adapted with the aim of providing efficient data to understand the students’ experiences and preferences within BIM Education.

9.7 Contribution to knowledge

The research study has significant academic and practical implications for BIM adoption within civil engineering programmes in the UK. The research was undertaken with the objective to explore the position of BIM in UK higher education in general and in civil engineering programmes specifically to perceive the gap and to identify critical success factors to guide higher education institutions with decision-making. This research not only highlighted the pragmatic framework for integrating BIM into civil engineering programmes in the UK but also categorised the factors contributing to introducing BIM into higher education. Key features of the produced framework are in line with the highlighted perspectives and factors of contribution. This in-depth framework was generated from valuable student responses in great quality and quantity along with knowledgeable focus group discussions; these resulted in the identification of valuable factors that are proven to be essential for civil engineering programmes and has not been reported in previous research.
9.8 Literature review outcomes

Literature reviewed in chapters 2 and 3 indicated that BIM is widely expected to lead the changes in the performance of professionals in the Architecture, Engineering and Construction (AEC) sector, specifically with regard to civil engineers. This led to the conclusion in chapter 3 that it is essential for the engineers to be aware of BIM and to understand the concepts of BIM while undertaking studies at an academic institution.

Many enterprises in the industry are currently using BIM or considering the use of BIM, where industry members are generally enthusiastic to what BIM offers in providing better project construction outcomes, reduced errors, omissions and conflicts, and assist business development.

The literature has recorded that education is becoming an important part of BIM implementation around the world, due to the process and technological changes that BIM has brought to the industry. Therefore, in order for the implementation to be successful, professionals within the industry need to be up-skilled. Hence, growing demands for such educational programmes are required to be hosted by academic organisations. However, only a handful of BIM-enabled civil engineering programmes currently exist around the world and none in the UK.

Ongoing efforts to include BIM in curricula were documented in the literature: 125 schools have included BIM into their curriculum; 97 schools were based in the United States and 28 in other countries excluding the UK. These schools adopted different approaches from each other, where some taught the use of BIM software, or how to create, develop and analyse BIM models while others taught BIM concepts and
simulating with real collaboration either within existing courses or as a separate course. 70% of these schools have introduced the teaching of BIM within existing courses while 30% have generated a new course to include BIM teaching. However, BIM was introduced differently as highlighted below:

1. **BIM integrated into existing modules**

   In simple terms, BIM tools, techniques and concepts were included within existing modules; this was usually done by developing the existing curriculum of each module to suit BIM practices. This structure appears to be the most preferred method by the schools.

2. **BIM as an Individual Module**

   BIM tools, techniques and practices were also integrated as a single module usually named BIM, but not isolated from the evolved course discipline.

3. **BIM as an Individual course**

   Some universities found it more functional to develop a set course that contains the teachings of all BIM tools, techniques, theories and practices. This teaching method was rarely used but seemed to be very popular with students especially at postgraduate levels.

Nevertheless, within these three techniques BIM was collaborated in three different categories: single-course, interdisciplinary, and distance collaboration. 70% of the institutions teach BIM within only one discipline, 27% integrated the practice of BIM
by linking different disciplines within the same school/university (interdisciplinary), while only 3% have integrated their courses with distanced universities. These categories are detailed below:

1. **Single-course**
   In this category, schools taught BIM to students from the same discipline (e.g. engineering or architecture).

2. **Interdisciplinary**
   BIM was taught to students from different disciplines together for real collaboration between students from two or more disciplines at the same school.

3. **Distance Collaboration**
   This approach is similar to the interdisciplinary approach. However, BIM teachings were integrated for real collaboration with students from distant schools.

These approaches were designed in the initial steps of adopting BIM and were used by many courses around the world. However, educators in the UK are still unsure as to which approach is appropriate to adopt and so are behind with teaching BIM to students at university levels. Hence this research has focused on determining the most suitable approach to incorporate BIM into civil engineering courses in the UK with perspectives and preferences from all evolved stakeholders.
9.9 Conclusions

This research study presents the author's development of investigating BIM in civil engineering higher education to generate findings and conclusions that will inform future pedagogic development of curricular. Fundamental to this effort is balancing student and industry desires with academic staff expertise, whilst maintaining the core syllabus of civil engineering principles described in the EC-UK Spec and the JBM accreditation requirements. The research methods described in this thesis and the subsequent analysis of the results lead to the following conclusions:

9.9.1. The necessity for committed leadership

The publication of the “Good Practice Guide for Building Information Modelling in Degree Programmes” published by the JBM emphasises the importance of BIM in the teaching and professional practice of civil engineering and the leadership that is necessary to encourage and reform curriculum content and development in the UK. The report states that JBM considers BIM as a crucial function in engineering design, analysis, management and collaborative working within the multi-discipline environment during the operation of the completed asset. JBM considers an effective engineer to be one who has the skills and capabilities of working with open shareable asset information throughout the life cycle of projects. This indicates that JBM believes that the civil engineering profession is changing due to the evolution of BIM (Q₁).
Although JBM has yet to outline a clear requirement in their accreditation criteria, the necessity to introduce BIM concepts into the teaching of civil engineering programmes is obvious. The focus group participants believe that BIM should be taught within civil engineering undergraduate programmes to develop student skills and enhance their understanding of the central role that BIM plays in creating collaborative project behaviours that improve risk management, health and safety, productivity and design quality. The conclusion that should be drawn is that civil engineering education must be prepared to be flexible in responding to industry and accreditation body requirements.

Professional institutions have shown great interest in BIM. The Institution of Civil Engineering (ICE) has formed a BIM working group known as the ICE BIM Action Group, constituted of members drawn from the ICE expert panels, members of the Information Systems Panel (ISP) and other invited guests. Its purpose is to collect all BIM-related activity from associated ICE groups whilst engaging with other professional institutions such as AGI, RICS, ICES, CPI alongside RIBA, CIBSE, UKCG and CIAT to support work on BIM ‘Best Practices’ for standards and classification systems and to influence and advise academic programmes including JBM. This emphasises that individual institutions will share knowledge and practices to develop and promote institutional responses beyond their remit to educate and endorse industry knowledge. However, members of these professional institutions recommended that a BIM teaching Framework is essential to determine the most suitable approach to teaching BIM within UK civil engineering programmes (Q6).
ICE has also announced their policy position statement on BIM, stating that it is aiming to promote the use of BIM as a means of collaborative working and to increase BIM knowledge and understanding across its members and throughout the industry, whilst out-reaching to other professional institutions and stakeholders who are interested in delivering BIM. Furthermore, the ICE has also sponsored research at different RUSSELL group universities to feed into the government BIM strategy. This illustrates that ICE is aspiring to support BIM implementation within the UK and certainly categorises ICE as a BIM-driven organisation and so will prioritise BIM in their accredited degree programmes.

9.9.2. Focus on students

When students were asked “Has or will BIM be taught in your current course?” 35% (N= 468) responded “Yes”, 45% (N= 602) responded “No”, while 20% (No 267) responded with “Not sure”.

The 45% (N= 602) who responded with “No” were civil engineering students from 18 different universities, which suggests that at the very least 18 UK accredited civil engineering degree programmes may not be teaching BIM principles to their students. The concern for industry is that these students may soon graduate without the required BIM knowledge and experience that industry demands (Q3). Moreover, the feedback received from the questionnaire surveys indicates that students in the higher years of study (years 3 and 4) did not feel comfortable in completing the questionnaire or did not feel that they had appropriate knowledge to participate. This led the
researcher to the conclusion that some universities have not enacted a learning strategy for civil engineering students to develop awareness and understanding of BIM; this could have consequences for their future employability (Q3).

The positive response rates indicate that students are highly interested in learning BIM where responses were received from 1,337 students from all levels in 29 (66%) accredited civil engineering programmes in the UK. When these students were asked in the questionnaire survey to specify, “which way do they prefer to learn BIM?” the respondents were asked to select “all that apply” when answering this question. Out of the 1,337 responses, 64% (N= 856) Desired to learn BIM integrated within their existing courses, 17% (N= 228) prefer to learn BIM (ONLY) within a multidiscipline module, combining different disciplines together, 35% (N= 462) prefer the combination of the above i.e. learn BIM within the existing courses and within multidiscipline modules, combining different disciplines together, 8% (N= 108) wanted a dedicated BIM degree, and 9% (N= 120) prefer to learn BIM in an independent BIM training courses.

The Questionnaire survey indicated that 856 current civil engineering students prefer to learn BIM integrated within their existing courses. Therefore, this method of learning is the most preferred by the students in the UK, which is also the case in the USA.
9.9.3. Commitment to civil engineering

Participants from the focus groups in principle view BIM as a collaborative way of working to improve communication and teamwork for all civil engineers rather than a discipline subject or specialism. In this view, BIM is seen as a set of skills to be added to the current civil engineering practice rather than just software tools. Therefore, it is not essential to teach students on particular application software tools; rather, it is better to concentrate on the ideology of BIM. This indicates that teaching BIM in civil engineering programmes should focus on the core concepts of BIM rather than the application interface and functionalities ($Q_4$). This is in line with the BIM definition provided in the BIM Handbook (Eastman et al., 2008), which describes BIM as the process of compiling a building model “we use ‘BIM’ as a verb or an adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation. Therefore BIM describes an activity, not an object. To describe the result of the modelling activity, we use the term ‘Building Information Model’, or more simply ‘Building Model’ in full” (Eastman et al., 2008).

Viewing BIM as an essential skill suggests that it should be taught integrally throughout the existing course modules from the outset of the degree programme, making BIM one of the central components of the student’s abilities to communicate engineering design information. It was also concluded from the focus groups and questionnaire surveys that BIM courses are not required; rather, it is the existing civil engineering courses integrated with the BIM concept. This represents a paradigm shift
from teaching a skill alone whether engineering graphics and drafting or BIM to teaching a conceptual approach to civil engineers (Clough et al., 2005) ($Q_4$).

The importance of benchmarking the findings from this research with the existing Joint Board of Moderators ‘Good Practice’ guide (covering Design, Sustainability, Project Management, Communication and Teamwork) for civil engineering courses in the UK was emphasised in the focus groups.

The required knowledge, capabilities and skills for civil engineering courses are very common. Universities and professional institutions tend to use the similar frame of references whilst evaluating their accredited courses. Some universities have recently added BIM as one of their teaching outcomes requirements. However, the majority are not willing to add BIM as their course outcomes of design, sustainability, project management, communication, and teamwork are certainly among the foremost. These outcomes indicate great correspondence with BIM process and concepts, where BIM can provide substantive contributions to the advancement of each outcome as follows:

9.9.3.1 Design

In the undergraduate civil engineering programmes, much effort is focused on the details of designs. Whether it is structural or infrastructure, students are usually taught to design from a set of proposed decisions via CAD. Learning BIM has the advantage of providing the opportunity for students to engage in the design process, evaluate and operate. This can strengthen student design skills and decision making,
while also educating them on the process of producing, viewing and amending designs.

**9.9.3.2 Sustainability**

As demonstrated in chapter 2, BIM is capable of producing significantly better information for sustainable designs, while the compatible software within BIM can further analyse the data provided from the models. These features can improve student knowledge on sustainability in general and to visualise the importance of sustainable projects in terms of materials and designs.

**9.9.3.4 Project management**

As demonstrated in chapter 2, BIM is a preeminent project management tool. Incorporating BIM within civil engineering programmes can assist students while making management decisions and allow them to understand and learn project management fundamentals such as estimating, scheduling, project sequencing and producing quantity take offs. BIM can also be used as an instrument in leading projects by managing student projects through a common platform and allow the students to communicate critical information in an interactive way.

**9.9.3.5 Communication and teamwork**

As demonstrated in chapters 2 and 3, communication is essentially one of the main purposes of BIM: to communicate information in a usable way. BIM almost forces users to work much closer than ever before. Incorporating these communication practices within civil engineering programmes can allow students to collaborate
together in a natural manner and gain valuable information and lessons learned from each other. This will also enable students to understand the benefits of BIM and communication while observing teamwork as a natural behaviour within civil engineering.

The importance of teaching BIM at university level is variously described in the work of Deutsch (2011); Kaner et al. (2008); Kiviniemi at al. (2008); Aranda-Mena et al. (2009); Smith and Tardiff (2009); Oluwule (2011); Arayici et al. (2011) and Eastman et al. (2011). Meanwhile, according to some of the academics participating in the focus groups, the higher education institutions are currently unable to meet the demand for BIM education within civil engineering university programmes. Many academic staff members perceive BIM as a threat to their current roles as they are not equipped with BIM knowledge, which led the participants to the conclusion that teaching BIM in civil engineering university courses will require staff training. (Q3)

9.10 Recommendations for further research

The recommendations of this research were developed with input from industry, professional institutions and academics in collaboration with students and their requirements for focusing on creating a ‘BIM enabled’ teaching environment in civil engineering courses whilst not changing the underlying principles of civil engineering. This framework was evaluated by a group of professional institutions and academic experts and scaled with the adopted approaches of teaching BIM around the world from internationally recognised universities. However, the recommended framework
was not put into practice by civil engineering programmes in the UK.

Therefore, further research to evaluate the framework of this research by embracing the qualitative/anthropological evaluation approach (to adopt, observe and evaluate the proposed framework) is suggested. In other words, practical evaluation should be carried out to examine the effects and outcomes of the proposed framework in teaching practice, to investigate the plausibility of the framework in generating demonstrable learning outcomes and to assess the overall effects of the framework from a holistic perspective.
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Appendix A: Questionnaire Survey
BIM Implementation

Students! Have your say on BIM.

Strong evidence suggests that the effective inclusion of BIM into the educational curriculum will be critical in the preparation of future employees for the industry (McGraw Hill, 2009). Therefore, as part of our study we seek to capture data from current students, to seek the input of students with respect to the incorporation of BIM into curriculum. We would like to invite you to take part in our study to give us an opportunity to identify challenges and opportunities to teaching BIM within universities and contribute to the wider debate on an effective BIM implementation strategy.

1. Please confirm your University Email Address. (All data will remain Anonymous)

2. Which course are you studying?
   - [ ] Civil Engineering
   - [ ] Architecture
   - [ ] Surveying
   - [ ] Project Management
   - Other (please specify)

3. Year of study?
   - [ ] Foundation
   - [ ] 1st Year
   - [ ] 2nd Year
   - [ ] 3rd Year
   - [ ] 4th Year
   - [ ] PG

4. How would you describe Building Information Modeling (BIM)?
   - [ ] 3D modeling
   - [ ] Computer Softwares
   - [ ] Complicated way of working
   - [ ] Collaborative working
1. A new buzzword in the industry
2. Simulation - Virtual reality
3. Never heard of BIM
4. Other (please specify)

5. Has/ will BIM be taught in your current course?
   - Yes
   - No
   - Not sure
   If yes (please explain)

6. Which way do you prefer to learn BIM?
   - BIM integrated within your course
   - As a multidiscipline module, combining different disciplines together
   - Combination of the above
   - Dedicated BIM degree
   - Independent BIM training courses
   - Other (please specify)

7. Who should have the most responsibility in preparing Students/ Graduates to work with BIM?
   - University
   - Employer
   - Software companies
   - Other (please specify)

Done
Current Position and Associated Challenges of BIM Education in UK Higher Education

Professor Jason Underwood
Dr Oladotun Ayoade
CURRENT POSITION AND ASSOCIATED CHALLENGES OF BIM EDUCATION IN UK HIGHER EDUCATION

This study is supported by the BIM Task Group and the Higher Education Academy, and conducted by the BIM Academic Forum.

BIM Academic Forum

With the HM Government’s 2011 Construction Strategy now gathering momentum the necessity for an informed and equipped workforce becomes a growing priority. Alongside this is the requirement on all HEI’s to respond to the changing need across industry, and although many programmes have begun to recognise this, the need for guidance and consistency has also come into focus. The BIM Academic Forum (BAF) is a group of representatives from a large number of UK universities and the BIM Task Group, which was established in late 2011 to respond to this need and to promote the academic aspects of BIM.

BAF operates under the following values and principles:

VISION

To foster integrated collaborative working on projects over the lifecycle of the asset through academic involvement and enhancement of BIM.

MISSION

To create a dynamic group to develop and promote the training, learning and research aspects of BIM through strong collaboration and co-operation.

OBJECTIVES

- focus on and elevate the training and learning and research aspects of BIM;
- collective promotion of BIM (expand wider market not extend own market);
- establish open medium for communication thus sharing knowledge, experience, case studies, views, etc.;
- collaboration for joint activities and research projects;
- collective voice in both teaching and learning and research matters, so to contribute to policy issues, funding priorities and agenda setting;
- attempt to minimise duplication and create standard practices while celebrating diversity.

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BIM matrix: Strategic considerations
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APPENDIX B: BIM TASK GROUP LEARNING OUTCOMES FRAMEWORK
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EXECUTIVE SUMMARY

In May 2011 the Cabinet Office published the Government Construction Strategy, announcing the Government’s intention to require collaborative 3D BIM (with all project and asset information, documentation and data being digital) on its projects by 2016. Together with industry the UK Government has set out on a four year programme to reduce capital expenditure and the carbon burden from the construction and operation of the built environment by 20% through a modernisation of the sector. Such proposed transformation of the construction sector has significant implications for Built Environment education providers in ensuring they meet the demands required of future professionals. To this end, this study assessed the current position and associated challenges along with perspectives of BIM education in UK HE through surveys targeted at BIM-related Academic networks across the UK. Key areas focused on included:

- The Definition of staff resource
- State of BIM in HEI (Higher Education Institutions).
- BIM adoption Strategy
- BIM awareness and associated issues
- Generation implications

Findings from the study indicated a nuanced appraisal of BIM readiness in UK HEIs. There are clear distinctions between the category of top performers and low performers concerning investigated concepts with clear defining parameters. However the disconnect between these two tiers exists in a state of inertia that is counterproductive to the overall strategic role/contributions of HEIs to the ongoing BIM digital revolution.

A BIM assessment matrix was developed from the key investigated issues. This represents an update to the optimum requirements for BIM teaching among HEIs in the UK. This update mapped additional crucial strategic considerations concerning BIM in HEIs.
SUMMARY OF FINDINGS

- There is clearly a huge disconnect between built environment disciplines. Despite average/infused to high embedded levels for BIM related disciplines, this has not reflected on neither the BIM maturity levels, BIM policy awareness nor the consistency expected for the appropriation of BIM components (People, Process and Technology).

- There is no correlation between software adoption and generation categories. The implication for software vendors is not absolute as for now, however it is apparent that BIM software adoption in HEIs is dominated by the trio of Revit (Arch, struct, MEP), Autodesk Naviswork and Sketch Up., with limited choice variability.

- At the cutting edge where BIM is fully embedded into majority of the programmes/modules, architecture maintains a significant edge over all other Built Environment disciplines. Moreover, similar cutting edge levels of BIM delivery are most common at Undergraduate Level 6 (NQF) /Level 10 (SCQF). On taking the entire Built Environment disciplines into consideration there are overall low levels for BIM maturity awareness.

- HEIs are largely underperforming with generally low levels of engagement with industry. This might have further severe consequence on the Level 2 BIM targets for 2016, as the study identified links between the low levels of both direct and indirect external involvement with industry and perceived low BIM maturity levels.

- Despite the general level of support for the importance of BIM-related accreditation criteria of courses in academic institutions, the level of conviction for actual change is however not evident.

- About 40% still consider themselves not adequately informed on BIM and the UK government implementation strategy. This high level of detachment remains a setback.

- The pattern of responses to certain BIM strategic considerations, particularly in the aspects concerning ambitious and proactive Intended Learning Outcomes (ILO), practical inclination of curriculum developments, cost implications, and specialised ILO were closely associated with the age of respondents (i.e. generation category). Unsurprisingly, the Pre-war generation category
(considered digital immigrants of having adopted digital technology as adults and gained proficiency but interact with it in a fundamentally different way and therefore remain immigrants in contrast with digital natives who have grown up with digital technology and therefore have no meaningful memory of life without it, having become fluent in it) appeared to show more scepticism, perhaps restraint in their responses concerning the aforementioned considerations.
As we move towards a digitized built environment we are rapidly having to reassess education against the backdrop of a digital future. Academia will need to quickly adapt to radical changes in educational needs focusing on reimagined professions that are more integrated and driven by data intelligence. Generation Y (born between 1980 and 2000) will expect to be equipped with new hard and soft skills that will allow them to rapidly create, manage and analyse data as part of their core ability.

The work of the BIM academic forum (BAF) is helping to shape this agenda and the draft BAF report looking at the current position and associated issues of BIM education in UK Higher Education is an important milestone in realising this goal. The BIM Task Group takes this opportunity to thank the BAF members for their commitment to the level 2 programme and imbuing its components within their respective programmes.

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BACKGROUND

Information regarding BIM adoption strategy in the UK has been garnering attention in the contemporary built environment discourse for a while now. In going forward, BIM development should be coordinated in tandem with built environment requirements which traditionally build upon a creative and collaborative process based on a knowledge intensive and generative framework (Berente, et al., 2010). The UK Government’s approach has been broad based, focused mostly on deriving significant improvements in cost, value and carbon performance. This however, lacks specificity; hence developing an informed and equipped workforce remains an ever growing priority (Wolstenholme, et al., 2009).

Huge strides are being made in this regard, particularly in areas concerning the amount of support available for BIM implementation through UK standard/guides etc. as being developed through the UK BIM Task Group. However, to achieve an efficient alignment of BIM UK targets with the built environment, inherent obstacles clogging the flow of seamless interaction between the numerous built environment workplaces and Higher Education Intuitions (HEI) has to be identified and tackled to systematically overcome what appear to be evolving challenges. To achieve these goals, a proactive and co-ordinated HEI response towards embedding BIM in their academic development framework needs to be facilitated. To this effect this study’s investigation has focused on the following key areas:

- How providers in teaching and training and learning respond/react to the inception of BIM learning and training in HEIs.
- ‘Attitude’ and predisposition within the existing built environment professional workforce.
- Unravelling areas of concern for HEIs in BIM adoption.
- The need for an appropriate updated assessment matrix of BIM readiness among individual HEI stakeholders.

AIM AND OBJECTIVES OF THE STUDY

In order to unravel areas of concern for HEIs in BIM adoption, identification of factors that influence attitudes, perception and behavioural inclinations inherent in HEIs is considered crucial (Clarke, 2008). Therefore, this study aims to: ‘Investigate the current position and associated challenges of BIM education in higher education.’
To achieve this aim, the study adopted the following objectives;

1. Understanding BIM requirements and development from an industry and higher education perspective.

2. Explore the aforementioned issues regarding the current position and associated challenges of BIM education in UK HE as identified from literature through workshop consultations and interviews.

3. Identify key indicators required to investigate the current position and associated challenges of BIM education in UK HE.

4. Update/develop the BIM Teaching/Training Impact Matrix (BTIM) for HEIs.

EMBEDDING BIM IN THE EDUCATION FRAMEWORK: IMPLICATIONS FOR HEIs AND INDUSTRY

In May 2011 the Cabinet Office published the Government Construction Strategy, announcing intentions to require collaborative 3D BIM (with all project and asset information, documentation and data being digital) on its projects by 2016. Together with industry, the UK Government had set out on a four year programme to reduce capital expenditure and the carbon burden from the construction and operation of the built environment by 20% through the modernisation of the sector.

Such proposed transformation of the construction sector has significant implications for Built Environment education providers in ensuring they meet the demands required of future professionals. In order to address these implications, the BIM Academic Forum (BAF) was set up with the aim of creating a dynamic collaborative group to enhance and promote teaching and learning together with the research aspects of BIM, therefore serving as a conduit between industry demands and BIM education in HEIs.

According to BAF (2013), the core learning outcomes for levels 4, 5, 6 (undergraduate) and 7 (postgraduate) contents (Appendix A) are expected to be ‘BIM aware’, ‘BIM focused’, and ‘BIM enabled’. This is designed to facilitate knowledge and understanding, practical skills and transferable skills. These outcomes stand the risk of being hampered if inherent obstacles to HEIs fully embracing BIM are not measured and tackled. This study has carried out related investigations of potential sources of obstacles focused on four key areas and requirements, i.e. up-skilling of staff, industry engagement and HEIs, framework for learning and keeping pace with BIM development in IT and Built Environment-
related industries.

**Up-skilling of staff**

Long before the advent of the UK Government’s drive towards BIM adoption, the approach to work and employment has continually experienced shifts, particularly in deskilling, up skilling of workforce (Watson, 2008). Clearly, rigorous debates have rejected the concept of deskilling as a workplace management strategy in favour of up skilling as a strategic response to employee flexibility (choice, discretion, autonomy and so on), particularly during the adoption of, and reaction to new technology/knowledge; see Braverman (1974). To better understand this phenomenon as an incentive to the appropriate BIM strategy, attitude is fundamental, i.e. how stakeholders in teaching and training and learning respond/react to the inception of BIM in HEI. This in particularly becomes an issue when faced with a supposed steep learning and training programme referred to BAF (2013), which poses a challenge to HEIs.

In the UK sphere, most HEIs have relied on basic training focused on technology and its relative functionality. This might not be sufficient for an effective BIM transition if a phased process that accommodates industry requirement is taking into consideration. Apparently, the phased approach allows time for both HEI and industry to prepare for the development of new standards and training in line with the Government Construction Strategy (Cabinet Office, 2011). These limitations in BIM education have been further highlighted in a BAF (2013) report which found out existing lapses in HEI progress, i.e. current developments in BIM education appear to largely focus on only the most fundamental aspects, which alone is not sufficient to support the knowledge and understanding required by the push for overall BIM adoption.

**Industry engagement and HEIs**

As technology changes rapidly and diffuses readily, keeping up with the level of sustained investments in education and training will require an adequate educational system, that equips students to become critical players in future waves of innovation. However, leaders in technological innovations such as the UK are projected to experience critical skill shortages in this aspect, due in part to their aging populations and, paradoxically, by an increasing percentage of their population being relatively "well educated": this, according to Oxford Economics (2012), can actually result in a saturation of generic skills that lack specialisation,
hence offering less room for meaningful improvement. Furthermore, jobs and required skills are continuously shifting to reflect changes in business, technology and client expectations which require constant upskilling of employees. However, there is bound to be skills gap if HEIs lag behind in filling existing lapses in academic curriculum and learning outcomes. Moreover, amidst dwindling resources, HEIs are expected to be at the forefront of taking advantage of opportunities that exists in BIM training and re-skilling, people planning and designing engagement strategies within the Built Environment industry in the UK (Oxford Economics 2012, cited in The Canadian Chamber of Commerce 2013). Consequently, with this increasing awareness of BIM across the industry, more than ever there is an increasing need for HEIs to face up to these challenges in the aspects of funding, training and research development for the construction sphere.

**Framework for Learning**

The strategies towards BIM implementation have been focused largely on construction applications such as lean procurement processes; use of whole life, outcome based specifications targeted at encouraging supply chain innovation; applying cost targeted integrated approaches to procurement (Cabinet Office, 2011). To make up for the practical skill demands necessary to fulfil the requirements of these approach, HEIs are already struggling to cope with the subsequent demands for BIM-ready graduates, i.e. those capable of demonstrating discipline specific benefits of BIM within existing skill gap irrespective of targeted industries (BAF, 2013). The training options for learning available to businesses are constantly growing in the UK due to new entrants. Options considered by businesses include, in house, external supplier, either on-site or off-site. The delivery methods are also diverse and constantly evolving, due in a large part to information technology, and the need to build upon a great deal of research into what is most effective, both of which could be costly.

BAF’s recommendation involves a measured mix of these formats, resulting in learning outcomes derived through knowledge and understanding, practical skills and transferable skills, with HEIs expected to play a central role in dissemination (Appendix A). Alternative views from an industry perspective argue that an HEI centred training developed by academics and guided by institutional specialisation might no longer be fit for purpose. Critics believe there is limited industry input in terms of checks and balances, because training requirements are usually validated through academic peer review structures, rather than industry driven critique.
processes/protocols. Other identified constraints include existing inflexibility in HEI course time frames, which makes it difficult for work-based learners, despite derivable benefits such as retention and upskilling of employees, improving staff motivation, and improvement in company competitiveness. However, these benefits appear challenging for HEIs and their inherent traditional course delivery routes (Martin, et al., 2010). More recently, collaborative efforts between BIM Task Group and BAF have resulted in the development of a Learning Outcomes Framework (LOF) that encourages industry’s procurement and delivery of training and education courses in order to grow strong capacity and capability of BIM Level 2 in the UK market, underpinned by a consistent learning outcomes definition (Appendix B). The 2015 version of the LOF now accommodates the BIM Level 2 foundation documents and includes academic and industry feedback on its applicability, presentation format, structure, and content. However, it appears that the supposed levels of disconnect between industry and HEI will require evaluation to ensure LOF targets are realised.

**KEEPING PACE WITH BIM DEVELOPMENT IN IT AND INDUSTRY**

In keeping pace with recent BIM development in industry, HEIs are normally faced with the options of either adapting their existing curricula towards this (Integrated approach) or as a separate standalone arrangement (Sacks & Barak, 2008). On this issue, Wong, et al (2011) suggested that the integrated approach is in line with industry requirements. However, this will require inculcating avenues that cater to new developments in technology or new methods of training delivery to their students. Moreover, Forsythe, et al (2013) suggested the adoption of active and regular collaborative design charrettes with industry, staff and students as a useful tool to facilitate up to date industry involvement. However, a survey by Kiviniemi et al (2008) identified traditional parameters like software choice, upgrading costs and education as major obstacles. Forsyth, et al (2013) also highlighted the crucial need to investigate these soft issues before embarking on significant technological implementations. Moreover, due to the rapidly evolving nature of BIM, adopters (HEI, student and industry), and supposed historical preservationist thinking in HEIs (Davidson & Goldberg, 2010), this study recognised the need for an appraisal of ‘attitude’ and predispositions towards investigated transition strategies ‘for and within’ UK HEIs. This would also include technological and accreditation implications.
ATTITUDE TOWARDS BIM IN HEI: CMC/CBL AND GENERATION INFLUENCES

BIM represents a succession to Computer-aided Drafting (CAD) which gained prominence through the 1980’s (Wong, et al., 2011). This evolution apparently signifies a paradigm shift in PBL (Problem-based learning and CMC (Computer-Mediated Communication) applications inter-generationally. PBL functions as an approach that emphasise students’ learning through active inquiry in groups and integrating their conceptual knowledge with their procedural skills (Gallagher, 1997). Furthermore, this fosters intrinsic motivations and hence encourages questioning and association with and reflection on previously acquired knowledge (Teo & Wong, 2000): an approach of “learn[ing] how to learn” via. “real-life” problems (Boud & Feletti, 1999). Much credence has been given to the effectiveness of PBL, as literature suggests that students consider PBL to be an effective learning method over the lecture format (Antepohl & Herzig, 1999). BIM attributes as an embodiment of a digitally mediated problem based learning model can be associated with the transitional process experienced with the prior advancement of technology in computer-mediated communication (CMC). Likewise BIM allows interaction, collaboration and communication among students through digital medium exchanged dialogue (Lo, 2009). BIM learning compared to CMC and CBL at inception does face significant challenges posed as either conflicting perceptions or physical limitations among intended adopters. This could be due in part to facilities and space; the difficulties involved in finding the time and resources to initiate the appropriate technological support (Ertmer, et al., 1999; Vannatta & Beyerbach, 2000; Parr, 1999). Predicators such as intergenerational disparities in the workplace could also influence technology adoption impacting organisational experiences and perceptions (Macky, et al., 2008).

The impact of generational differences on beliefs and perceptions might be underestimated, however several research have highlighted the significant impacts of having four distinct generation cohorts in the academic workplace as a significant issue facing HEIs (Hannay & Fretwell, 2011; Murray, 2011). Also crucial is the significant implications of how each generation experiences life, including education and work. This could stem from the effects of the social and cultural values of the society within which they mature and by the technologies available (Underwood, 2014). Even more pronounced is how this influences manifest among the ‘digital natives’, who have grown up with technology, have no meaningful
memory of life without it, and have become fluent in it, and ‘digital immigrants’ who have adopted it as adults; resulting in possible variations in brain structure and thinking patterns (Underwood, 2014; Koutropoulos, 2011; Prensky, 2001).

A report by Ipsos MORI buttressed Rhodes’ (1983) view on the impact of generation disparities and the influence of factors such as; external events or a general cultural shift; lifecycle effects; growing older through significant life stages; cohort effects, i.e. where opinions gradually shift over time from one generation to the next (Rhodes, 1983; Duffy, et al., 2013). In order to explore generation impacts, the study also investigated perceptions on associated issues concerning BIM integration in traditional built environment disciplines in HEIs based on the following Ipsos MORI four adult generational classifications:

- The Pre-war Generation (represents those born before 1945)
- The Baby Boomers (represents those born between 1945 and 1965)
- Generation X (represents those born between 1966 and 1979)
- Generation Y (represents those born between 1980 and 2000)

**THE SURVEY: CONSULTATIONS**

A series of workshops was conducted by the BIM Academic Forum (BAF) which as mentioned earlier was set up with the aim of creating a dynamic collaborative group to enhance and promote teaching and learning together with the research aspects of BIM (BIM Task Group, 2013). Areas addressed during the consultations include the following:

- How stakeholders in teaching, training and learning respond/react to the inception of BIM learning and training in HEIs.
- Unravelling areas of concern for HEIs in BIM adoption.
- Confirming indicators/elements for an updated assessment matrix of BIM readiness among individual HEI stakeholders.
- Identification of factors that influence attitudes, perception and behavioural inclinations inherent in HEIs (Clarke, 2008).

Participants in the consultation include the BAF, which is fully recognised by the UK Government, BIM Task Group, Construction Information Committee (CIC),
Constructing Excellence, etc. The forum includes professional and academic representations spread across over 35 UK universities.

THE QUESTIONNAIRE

The questionnaire was informed by data gathered from consultation processes analysed with the intent of identifying areas and issues of concern. As part of the evaluation process; a content analysis of the transcripts of workshop consultations was carried out. This resulted in a concept map comprised of the following thematic clusters and respective evaluation indicators of associated issues regarding BIM education in UK HE:

**Defining staff resource**
- BIM representation in the Built Environment

**State of BIM in HEI**
- Assessment of BIM Maturity Levels
- The need for Up-skilling in HEIs: BIM Representation Levels
- BIM Software adoption trends: Implications for CBL/CMC
- BIM Curriculum Incorporation
- Maturity levels of BIM delivery strategy/involvement
- Length of BIM inception: Impact on BIM Maturity Levels

**BIM adoption strategy**
- Perception of BIM components: Implication of Level of Experience with BIM
- External Engagement Assessment: Implication for BIM Maturity and BIM experience levels
- BIM Transition Strategy (BAF ILO)
- Competition and alternative education providers

**BIM awareness and associated issues**
- BIM Policy awareness
- BIM and institution accreditation in HEIs
- Understanding the relevance of BIM in overall construction policy development.
- BIM HEI transition strategy
**Generation implications**

- The recognition levels of the negative impact of premature and unrealistic ILO for BIM in HEIs.
- The recognition levels for more practical and ‘industry relevant’ BIM assessments, as against the theoretical approach.
- The recognition levels of the cost implications of discipline specific diversification/specialisation of BIM ILO as counter-productive to embedding BIM in HEI curriculum.
- Identification levels of the negative impact of lack of bespoke BIM ILO for different disciplines on employment readiness for industry specific roles.
- The level of understanding of the relevance of BIM in overall construction policy (future perception).

**THE SURVEY**

The questionnaire was sent electronically to academic and professional networks across the UK. Respondents were divided into three major groups; those with Academic, Industry and both Academic and Industry experience in BIM. For a more in-depth analytical and study focus purposes, the groupings were further sub-divided into other categories to develop a profile map of the respondents.

**ANALYSIS**

A random representation of the target databases was sought, irrespective of location. The questionnaire build up comprised simple and mixed format multiple choices and five point likert scale questions (mostly closed). The survey received a total of 98 responses (65 complete and 33 partial/incomplete). The survey constructs where then analysed with the SPSS software preceded with a measure of internal consistency. A Cronbach’s Alpha coefficient of (α=0.901) was obtained from the reliability test, which indicates a high level of internal consistency. Other major techniques adopted include Pearson’s Correlation and Multinomial Regression Analysis (MRA) to analyse patterns within study variables.

**DEFINING STAFF RESOURCE**

This section sets the stage for the data analysis by mapping the strategic profile of the survey responses. This plays a role in BIM strategy development in HEIs, hence help assess readiness, efficiency and upskilling potentials or needs.
Despite the survey receiving a total of 98 responses, 33 were incomplete. A quick analysis was carried out comparing the level of BIM experience existing within both categories. It was observed that 27.3% of respondents with grossly incomplete responses had no experience at all with BIM, compared to just 3.1% for those with complete responses. Therefore, it appears that the likelihood of completing the questionnaire was significantly impacted by the level of BIM experience of the respondent.

**BIM representation in the Built Environment**

Analysis of the respondents revealed that; 53.8% of the respondents had only academic experience of BIM; while 4.62% had only industry experience. However, 38.46% of the respondents had both academic and industry experience (Figure 1).

![Figure 1: Respondents’ BIM experience](image)

Furthermore, 20.0% of responses were researchers, 12.3% lecturers, 38.5% senior lecturers, 4.6% readers, and 20.0% professorial (Figure 2).

![Figure 2: Primary academic position/level](image)

A robust representative sample of respondents was also captured with 50.0% of the respondents being module leaders, 22.6% programme leaders, 6.5% head of directorates, 11.3% head of research centres, while 11.3% are not within these key academic categories.
To assess generation implications an intergenerational distribution of the respondents was also analysed. Interestingly, over 60% of the respondents fall within the 49-68 age categories (Figure 3).

**Figure 3:** Age Classification of respondents

In regards to BIM representation in the Built Environment, construction and architecture account for over 40% of BIM survey respondents; while Quantity Surveying, Civil Engineering, Building Services and Estate/Facilities Management related disciplines account for 13.6%, 10.6%, 7.6% and 6.1% of the respondents respectively. Other Built Environment related disciplines have a 12.1% representation, comprising disciplines such as Computer Engineering, Sustainability Systems, Planning and Urban Studies, the majority of which had
incomplete responses. Moreover, Electrical/Mechanical Engineering had no representation.

**STATE OF BIM IN HEI**

Findings from this section explored the perceptions of respondents on how they respond/react to BIM learning and training systems in HEIs. This study observed that over 80% of responses have come from individuals with some degree of management responsibilities within built environment disciplines (Figure 4).

![Figure 4: Positions with degrees of management responsibilities](image)

**Assessment of BIM Maturity Levels**

Perceptions from respondents on their (institutions/departments) BIM maturity levels revealed that the levels of development trends (Figure 5) in the following order; level 1: *Managed CAD in 2 or 3D format*, Level 0: *Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism and then Level 3: Fully open process and data integration enabled by IFC / IFD.*

![Figure 5: BIM maturity levels](image)
Responses revealed that 66.7% of respondents expressed average or less than average maturity for BIM Level 2: Managed 3D environment held in separate discipline “BIM” tools with attached data, with 36.7% expressing barely matured/not matured levels (Figure 5).

The need for up-skilling in HEIs: BIM representation levels

In order to evaluate built environment staff awareness and exposure to BIM the study measured the level of BIM interest gaps in built environment disciplines.

Figure 6: BIM representation levels according to disciplines.

Apart from architecture and construction related disciplines, analysis (Figure 6) indicated overall low levels of interest in BIM incorporation in teaching across built environment related disciplines. 64% and 47% of respondents indicated high levels of BIM representation for architecture and architecture Technology disciplines respectively. Construction, quantity surveying, Estate Management/Property related disciplines/programmes had considerable high interest levels of 55%, 36% and 16.7% respectively. Other built environment disciplines all had less than 20% BIM interest/representation.

BIM Software adoption trends: Implications for CBL/CMC

The study investigated BIM software adoption among respondents to explore CMC challenges in regards to software adoption (Kiviniemi et al, 2008; Woo, 2007). Findings show a 79% rate of adoption/use for Revit (Arch, struct, MEP), followed by both Autodesk Naviswork and Sketch Up with 45.6% and 42.1%, respectively (Figure 7).
Current Position and Associated Challenges of BIM Education in UK Higher Education

Figure 7: BIM software adoption

BIMMeasure, Causeway BIM Measure, ASTA.IES, CostX, IES, Grasshopper, White Frog training are some not so common platforms adopted for BIM teaching. They all account for about 21% of respondent adoption/use rate. Moreover, there was evidence that users of certain software products (Sychro Project Construct, VICO/Rapide 5D and Nemetschek Vectorworks) disagreed with the notion that the steep learning curves for (staff and students) impair BIM progression in HEIs. This is based upon their significant negative associations ($r (61) = -.308, p = .016$; $r (61) = -.279, p = .029$; and $r (61) = -.308, p = .016$, respectively) with the 'steep learning curves' statement.

BIM curriculum incorporation

An appraisal of the implementation/incorporation strategy for BIM in the HEI curricula is deemed crucial to addressing and understanding issues pertaining to risks that might be encountered when addressing implementation lapses (Forsythe, et al., 2013). It is therefore fundamental to measure BIM curriculum incorporation among individual disciplines.
Overall findings here indicated that 24% of programmes are yet to incorporate BIM; of this 6.9% are not considering incorporating BIM. Notably, 57% have incorporated BIM into particular modules. About 20% of programmes have developed standalone BIM modules, however only 13% have partially embedded BIM, while only 7% have fully embedded BIM in majority of their programmes.

**Maturity levels of BIM delivery strategy/involvement: Implications for CMC/CBL**

- Analysis carried out on the 'discipline specific BIM materials' (developed/delivered/involved) in a teaching capacity within respective education levels revealed that most activity occurred within (Figure 9):
  - Undergraduate Level 4 (NQF)/Level 8 (SCQF) (20% Lecture type delivery of BIM).
  - Undergraduate Level 5 (NQF)/Level 9 (SCQF) (31% Hands on teaching of BIM software in computer labs in addition to lecture type delivery materials).
Postgraduate Level 7 (NQF)/Level 11 (SCQF) (23% Lecture type delivery of BIM).

**Figure 9:** Maturity levels of BIM delivery strategy

At the cutting edge levels of BIM delivery, most of the activity is centred on ‘Undergraduate Level 6 (NQF) /Level 10 (SCQF)’ where 15% *Use BIM as a vehicle for teaching other aspects of the programme in addition to hands on teaching fully embedded in the curriculum*. Implications for CMC/CBL identified a significant negative correlation between the maturity level of individual BIM involvement at Postgraduate Level 7 (NQF)/Level 11 (SCQF) and the ‘steep learning curve barrier’ indicator, Pearson’s r (54) = -.302, p = .026. Therefore, at Postgraduate Level 7 (NQF)/Level 11 (SCQF), the ‘steep learning curve’ is likely to be perceived more as a barrier the less the maturity level of individuals’ involvement with BIM, and vice-versa.

**Length of BIM inception: Impact on BIM maturity levels**

Findings here revealed that about 53% of HEIs/departments have engaged BIM academically for up to 3 years. Moreover, 12% of HEIs have engaged BIM academically for at least 3 to 6 years, while 7% and 3% have been engaged with BIM in academic capacity for not less than 6 years and more than 10 years, respectively.

Implications on BIM development identified a significant positive correlation between the length of BIM inception and BIM Maturity Levels, particularly at Level
Therefore, the longer the length of time since BIM inception the more developed the maturity for levels 0 and 2.

BIM ADOPTION STRATEGY

In order to keep pace with the industry developments, Wong, et al (2011) suggested that the integrated approach is in line with industry requirements, hence suitable to stay abreast of recent developments. However, this will require inculcating avenues that cater to new developments in technology or new methods of project delivery to their students. Moreover, Forsythe et al (2013), suggested the active/regular collaborative design charrettes with industry, staff and students as a useful tool to facilitate up to date industry involvement. None of these will be possible without improved levels of external engagement and the general understanding of fundamental BIM components. These areas and more were further explored in the next section.

Perception of BIM components: Implication of Level of Experience with BIM

Results here (Figure 10) are generated mean of the perceived importance for each BIM component. The following mean scores were generated in descending order (Max: 5 and Min: 1); People (3.58); Information (3.25); Technology (3.19); Process (2.80). See (Figure 11) for distribution.

![Figure 10: Perception of BIM components](image)
Moreover, there were significant correlations between the level of BIM experience and the level of importance of the technological component of BIM, (Pearson’s r (57) = .262, p = .049). This correlation was not significant for the other components.

**Figure 11: BIM components distribution**

**External engagement assessment: Implication for BIM maturity and BIM experience levels**

The study measured HEI engagement levels with industry in the development and delivery of BIM related materials. Results indicated that there is a low level of engagement with industry either indirect or direct. 62% and 67% of respondents indicated less than high levels of industry direct and indirect external engagement in their BIM curriculum development, respectively (Figure 12). Moreover, there were significant positive correlations between the levels of direct and indirect external industry engagement and the level of development of BIM maturity levels:

- Direct External Engagement and Level 1 BIM, [Pearson’s r (57) = .318, p = .016].
- Direct External Engagement and Level 2 BIM, [Pearson’s r (57) = .541, p = .000].
- Direct External Engagement and Level 3 BIM, [Pearson’s r (57) = .322, p = .015].
- Indirect External Engagement and Level 1 BIM, [Pearson’s r (57) = .335, p = .011].
- Indirect External Engagement and Level 2 BIM, [Pearson’s r (57) = .489, p = .000].
Current Position and Associated Challenges of BIM Education in UK Higher Education

- Indirect External Engagement and Level 3 BIM, [Pearson’s r (57) = .263, p = .048].

![Figure 12: External engagement levels](image)

There were also significant positive correlations between direct and indirect external engagement and BIM inception duration, bearing in mind the following findings on the duration period BIM has been taught for and the corresponding percentage representations: 1 to 3 years, 53%; less than 1 year 19%; 3 to 6 years, 12%; 6 to 10 years, 7% and more than 10 years, about 3%. However, about 7% indicated that BIM is not taught all in their HEIs.

- Direct Engagement and BIM inception duration, [Pearson’s r (57) = .361, p = .006].
- Indirect Engagement and BIM inception duration, [Pearson’s r (57) = .345, p = .009].

Implications of these significant positive correlations show that the higher the levels of both direct and indirect external involvement with industry, the higher the level of perceived development of BIM levels 1, 2 and 3. Similarly, it appears that the longer the BIM inception, the higher the levels of both external and internal industry engagement/involvement in BIM curriculum development.

Also worth pointing out is the strong statistical relationship between external and internal industry engagement in curriculum development, [Pearson’s r (60) = .904, p = .000].
BIM transition strategy (BAF ILO)

In regards to the level of embedness achieved with key BAF ILO in curriculum development and delivery, results indicated a combined medium to very high adoption levels of 69% for the knowledge and understanding ILO (Figure 13).

This subsequently declines in the case of practical skills and transferable skills ILO; results indicated 47% and 37.5% medium to very high adoption levels respectively. 19%, 41% and 50% of respondents reported low levels of embedness for knowledge and understanding, practical skills and transferable skills, respectively. Notably, a significant 12.5% of respondents were not aware of the level of embedness for these key BAF ILO.

Generation influences investigated identified a significant weak positive correlation between generation classification and the perception of the level of BAF ILO incorporation into HEI curriculum development, Pearson’s r (32) = .374, p = .035.

Figure 13: BIM transition strategy: BAF ILO levels of adoption

Competition and alternative education providers

Results here indicated that a majority 66% of respondents agree that HEIs are failing to keep pace with BIM skill requirement and industry knowledge demands; hence are faced with the risk of alternative educational providers and/or ‘industry delivered in-house BIM education’ usurping their traditional roles in graduate skill development/training.
However, there was a significant negative correlation between generation classification and the level of agreement to the aforementioned notion, \( [\text{Pearson’s } r ](61) = -.296, p = .021 \). This might imply that that younger respondents are more likely to agree with this notion and vice versa.

**BIM AWARENESS AND ASSOCIATED ISSUES**

The first part of this section analysed the general level of awareness of BIM associated issues, whereas analysis carried out at the latter part focused on the respondents’ four adult generational classifications and their implications on research specific BIM perceptions.

**BIM Policy awareness: The role of BAF in BIM**

Despite BAF’s role as an academic networking platform for BIM, and the fact that 40% of the study’s respondents still consider themselves not adequately informed on BIM, 44% of respondents were unaware of BAF or its activities. Considering that the targeted sampling method employed by this study ensured robust representation of academics in HEI, only 56% of respondents considered themselves aware of BAF. Furthermore, awareness of BAF’s BIM ILO strategy was claimed by 44% of respondents. However, 80% see the role of BIM networks like BAF as crucial to informing professional bodies on strategic accreditation criteria for HEIs.

**BIM and institution accreditation in HEIs**

In regards to the impact of expediting the build up towards accrediting BIM courses in HEIs by key institution stakeholders, hence eliminating engagement barriers. Barriers investigated such as perceptions of the level of difficulty involved in engaging with professional institutions to help address new requirements and demands in discipline specific accreditation revealed that a majority (68%) of the respondents agree on the severity of these barriers, with a minority (15%) disagreeing.

On the issue of accreditation benefits to the overall BIM strategy in HEIs, a majority (80%) agree that BIM related accreditation criteria in academic institutions is important for improving overall student enrolment and graduate employability in the UK construction industry.
Understanding the relevance of BIM in overall construction policy development

Respondents were asked if ‘BIM is just a fad and at some period in the future will disappear’. Only 6% thought this, though a further 35% did not not view the future of BIM positively. A majority (65%) however, perceived BIM positively in regards to its present and future relevance.

Similarly, 60% of the respondents believe that embedding BIM into HEI curriculum would signify a paradigm shift in the way built environment education is delivered. Of the remaining 40% who disagreed with this, only 13% were in outright disagreement. Finally, 80% of respondents thought that embedding BIM in HEI built environment curriculum is crucial to attaining headline targets for the 2025 Government construction strategy. On the contrary, 21% of respondents disagreed.

BIM HEI transition strategy

The survey explored the transitional strategy that should be adopted by HEIs in response to industry demand for embedding BIM within the curriculum. Respondents were asked whether to follow and change reactively, track change with industry at equal pace or proactively push and lead change. At the Undergraduate level 4, 5, 6 (NQF)/Level 8, 9, 10 (SCQF), 27% would rather adopt a more cautious approach, that is follow and change reactively, while 29% chose to track change with industry at equal pace. Also, 44% would rather adopt a more aggressive/assertive approach; that is proactively push and lead change. For the Postgraduate level 7 (NQF)/Level 11 (SCQF), there was a 50/50 split among those that would rather adopt a more cautious approach, i.e. to follow and change reactively, or to track change with industry at equal pace, and those that will rather adopt a more aggressive/assertive approach that is proactively push and lead change.

GENERATION IMPLICATIONS

Multinomial Regression Analysis (MLA) was used to explore associations between the age of respondents and their perception of BIM strategic considerations. These include:

- The recognition levels of the respondent to the negative impact of premature and unrealistic ILO for BIM in HEIs
The recognition levels for more practical and ‘industry relevant’ BIM assessments, as against the theoretical approach.

The recognition levels of the cost implications of discipline specific diversification/specialisation of BIM ILO as counter-productive to embedding BIM in HEI curriculum.

Identification levels of the negative impact of lack of bespoke BIM ILO for different disciplines on employment readiness for industry specific roles.

The level of understanding the relevance of BIM in overall construction policy (future perception).

Results showed that higher levels of perception of the aforementioned BIM strategic considerations are likely to be associated with Generation X, Y or Baby Boomer categories than the Pre-war generation category.

See the other strategic considerations (BIM associated issues) (Table 1) for further reference to their importance as measured by the mean score of survey responses on a scale of 1 to 5.
## BIM ASSOCIATED ISSUES: STRATEGIC CONSIDERATIONS

<table>
<thead>
<tr>
<th>Issue</th>
<th>N</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance of BAF ILO targets to industry/professional institutions in regards to BIM accreditation criteria</td>
<td>57</td>
<td>3.75</td>
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<td>Difficulty involved in engaging with professional institutions towards discipline specific accreditation of BIM courses</td>
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<td>3.69</td>
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<td>Need for the prioritisation of tackling engagement difficulty with professional institutions</td>
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<td>3.90</td>
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<td>Importance of BIM networks such as the BAF- informing professional bodies on strategic accreditation criteria for HEIs</td>
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<td>4.03</td>
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<tr>
<td>BIM related accreditation criteria of courses and the improvement of overall student enrolment/graduate employability in the UK construction industry</td>
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<td>4.02</td>
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<tr>
<td>Difficulty accommodating adequate BIM learning contents due to already full curriculum contents</td>
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<td>2.98</td>
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<tr>
<td>Limited student study time and low level of receptivity to BIM learning</td>
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<td>3.39</td>
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<td>High financial implications associated with BIM software purchases and the need for extra investment</td>
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<td>3.23</td>
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<td>Impact of availability of free BIM software licences to students as a feasible and sustainable strategy in tackling cost implications</td>
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<td>3.80</td>
</tr>
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<td>Investment in bespoke/specific hands on BIM education for industry employees</td>
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<td>3.70</td>
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<td>Level of Prematurity- inculcating full BIM education in HEI curriculum</td>
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<td>2.85</td>
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<td>Channelling more resources into improving the curriculum of traditional disciplines rather than embedding BIM</td>
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<td>2.97</td>
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<td>Gradual funding transition based on necessity or practical industry needs/demand</td>
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<td>3.65</td>
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<td>Issue of ’steep learning curves’ for both academic staff and students presents behavioural barriers to BIM in HEI</td>
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<td>4.07</td>
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<tr>
<td>The relevance of BIM in particular area(s) of teaching</td>
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<td>Negative impact of premature and unrealistic Intended Learning Outcomes (ILO)</td>
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<td>The inconsistencies between a push towards software innovations and traditional software adopted in teaching is detrimental to BIM acceptability in HEI</td>
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<td>3.62</td>
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<td>More practical and ‘industry relevant’ BIM assessments, as against the theoretical approach</td>
<td>59</td>
<td>3.80</td>
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<tr>
<td>The regularisation of BIM curriculum and ILO in HEI across the Higher Education (HE) sector, through knowledge sharing platforms like the BAF</td>
<td>60</td>
<td>3.38</td>
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<td>Identifying low levels of understanding of BIM among staff as a barrier to embedding BIM in HEI curriculum</td>
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<td>4.25</td>
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<td>Contradictory relationship between traditional built environment education and embedding BIM into the curriculum</td>
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<td>3.50</td>
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<td>Recognising conflicting approaches and ILO requirements among different built environment disciplines as barriers to effective BIM transition in HEIs</td>
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<td>3.67</td>
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<td>The importance of core education component, multidisciplinary knowledge/requirements operational at every stage of an asset life cycle in embedding BIM into HEI curriculum</td>
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<td>4.14</td>
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<td>The need for collaboration and engagement among inter disciplinary staff is essential for enabling cohesion in built environment ILO and curriculum</td>
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<td>Identifying the negative impact of lack of bespoke BIM ILO for different disciplines on employment readiness for industry specific roles</td>
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<td>The need for potential availability of innovation research and consultancy funds as mitigating drivers/enablers for BIM ILO diversification/specialisation in HEIs</td>
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<td>The impact of existing political will and stakeholder efforts on the emergence of new/potential BIM inclined industry roles/jobs</td>
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<td>The impact of poor performance of HEIs in keeping pace with BIM skill requirement and the risk of alternative educational providers usurping traditional HEI roles.</td>
<td>61</td>
<td>3.72</td>
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</table>

Mean score. Min: 1 & Max: 5

### Table 1: Strategic considerations: BIM associated issues
DISCUSSION

BIM matrix: Strategic considerations

A BIM assessment matrix (Figure 14) was developed from the issues investigated in the study. This represents an update to the optimum requirements for BIM teaching among HEIs in the UK (Williams & Lees, 2009). Besides the teaching context, this update has also mapped additional crucial strategic considerations concerning BIM in HEIs. Building up from the study’s analysis implications for the findings were deductively interpreted then used to populate the matrix chart accordingly.

Defining staff resource

Considering the construction life cycle, an efficient BIM transition strategy in HEI can be improved with an integrated framework that encompasses every discipline in the built environment. This is crucial because it ensures consistency within HEIs/curriculum as an integral component of the construction value chain, hence improves collaborative networks throughout the construction life cycle. This consistency however, was not reflected in the response patterns because despite the survey receiving a total of 98 responses, 33 were incomplete. Therefore, it appears that the likelihood of completing the questionnaire was significantly impacted by the level of BIM experience of the respondent, which clearly was varied. This inconsistency appears to be manifest in the assessment of BIM Maturity Levels as indicators identified by this study in respect to HEIs contribution towards transforming the construction industry to operate at Level 2 BIM by 2016, which appears to be hampered. Therefore, there is clearly a significant disconnect between built environment disciplines. Despite “average/infused” to “high embedded” levels of appropriate BIM-related disciplines among respondents, this is not reflected on neither the BIM maturity levels, BIM policy awareness or the consistency expected for the appropriation of BIM components as shown in the BIM assessment matrix (Figure 14).
<table>
<thead>
<tr>
<th>BTIM</th>
<th>CURRENT POSITION OF BIM IN HEI ELEMENTS</th>
<th>ASSESSMENT PARAMETERS/ELEMENTS</th>
<th>Absent/Very Low</th>
<th>Aware/Low</th>
<th>Infused/Average</th>
<th>Embedded/High Very High</th>
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<td>BIM and institution accreditation</td>
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<td></td>
<td>Relevance of BIM in construction</td>
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<td>Need for upskilling</td>
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<td>Length of BIM inception</td>
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<td>State of BIM in HEI</td>
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<td>Built environment BIM representation</td>
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<td>Age classification</td>
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<td>Staff</td>
<td>Defining Staff Resource</td>
<td>Perception of BIM components (consistency)</td>
<td>X</td>
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<td></td>
<td>External engagement assessment</td>
<td>X</td>
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<td></td>
<td></td>
<td>BIM transition strategy (BAF ILO)</td>
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<td></td>
<td></td>
<td>Competition and alternative providers</td>
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<td>BIM Adoption Strategy</td>
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<td>The recognition levels of the impact of premature and unrealistic BIM ILO</td>
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<td></td>
<td>The recognition levels for more practical and ‘industry relevant’ BIM assessments</td>
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<td></td>
<td>The recognition levels of the cost implications of discipline specific specialisation of BIM ILO</td>
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<td></td>
<td></td>
<td>Identification levels of the negative impact of lack of bespoke BIM ILO on employment readiness</td>
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<td></td>
<td></td>
<td>The level of understanding the relevance of BIM in overall construction policy (future perception)</td>
<td>X</td>
<td></td>
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</tbody>
</table>

**Figure 14:** BIM assessment matrix: Strategic considerations
On the issue of software competency, while Sycho Project Construct, Nemetschek Vexterworks, VICO/Rapide 5D were found to have low rates of adoption, it appears that the relative ease of use by this group of respondents might have influenced their perceptions on the ‘steep learning curve impediment’ to embedding BIM in HEIs. Despite literature suggesting generation impact on CBL/CMC, this study found no correlation between software adoption and age of respondent (generation categories). While the implication for software vendors is not validated within this current study, factors other than generation category appear to have influenced software choice such as ‘ease of use’ as referenced earlier. Each particular BIM software has its unique set of pros and cons, e.g. effectiveness of available annotation plug-ins to address compatibility lapses. However, it is apparent that BIM software adoption in HEI is dominated by the trio of Autodesk’s Revit (Arch, struct, MEP) and Navisworks, and Trimble’s Sketch Up, with limited choice variability. This trend could be the result of the level of existing interoperability between software from different vendors, hence impeding software adoption choice among users along with competition and innovation among vendors.

**BIM Adoption strategy and the state of BIM in HEIs**

A breakdown of these statistics in line with individual disciplines revealed that the trio of architecture, construction and quantity surveying lead among those that have at least incorporated BIM into particular modules, although construction and architecture lead with larger margins, with construction holding a slight lead over architecture. However, at the cutting edge where BIM is fully embedded into majority of the programmes/modules, architecture maintains a significant edge over all others. Moreover, similar cutting edge levels of BIM delivery are most common at Undergraduate Level 6 (NQF) /Level 10 (SCQF). On taking the entire Built Environment disciplines into consideration there are low awareness levels for BIM maturity.

Implications for BIM level 2 targets show that the more inclined a respondent is to disagree with the notion that the steep learning curve for (staff and students) impairs BIM progression/development in HEIs then the more mature is their involvement in BIM delivery. Therefore, it is apparent that the more the exposure to actual practical BIM engagement, the more unlikely the steep learning curve for BIM is perceived as impairment. Hence, the need for training and upskilling particularly at matured levels becomes even more relevant to attaining Level 2 BIM targets for the UK by 2016.
It is important to point out that the length of duration of BIM inception in HEI does influence BIM maturity levels as reflected by the study findings. Therefore, the longer the time since BIM inception in a HEI, the more the likelihood of meeting Level 2 BIM HEI targets for the UK. This leaves HEIs with two options of either developing gradually with time, or intensifying the push towards an expedited strategy for those ranking low in BIM maturity levels. Perhaps in due time even low performing institutions will catch up. This will be dependent on the condition that issues raised by this study such as the lack of consistency in the understanding of the degree of BIM components required during adoption are remedied in a way that is not counterproductive to individual HEI goals.

On external engagement assessment and its implication for BIM Maturity and experience level, evidence suggests that, although broader industry awareness and appreciation of BIM is still largely in its infancy, larger leading contracting and consultancy firms have already embraced the benefits of BIM and most have a BIM strategy. For the smaller players, recent developments in this area include the BIM4SME group aimed at the Small and Medium Enterprises (SME) mainly found in tiers two and three in the supply chain (specialist contractors and sub-subcontractors). HEIs however are becoming less and less involved at these levels. The opportunities at these micro levels cannot be underestimated within the overall BIM network; however, how HEIs also respond here is most crucial. Unfortunately, this study found that HEIs are largely underperforming and have low levels of engagement with industry (see the BIM Matrix). This might have more severe consequence for the Level 2 BIM targets for 2016, as the study identified links between the low levels of both direct and indirect external involvement with industry and perceived low BIM maturity levels.

Regarding the issue of BAF’s role in ensuring Level 2 BIM targets for HEIs is centred on ILO developed to enhance and promote teaching and learning together with the research aspects of BIM. This study found that there are generation implications for perceptions of the BIM ILO in curriculum building particular for the ‘knowledge and understanding component’. The older the respondent the more the tendency to perceive higher levels of BAF ILO incorporation into the curriculum. This study did not however take into consideration individual contributions to BAF ILO incorporation. However, it is worth noting that 80% of respondents for this study occupy managerial positions in HEIs, (hence the high/embedded levels for academic position on the BIM matrix). Therefore, the more likely that they might
have been involved in some form of curriculum development and decision making that may have influenced this finding. Generation implications were also observable in regards to competition and alternative education providers. This might not absolutely imply a less competitive drive among older respondents, perhaps a little complacency? However, an overwhelming majority agree with this notion.

**BIM awareness, associated issues and generation implications**

Expectedly, the issue of accreditation benefits to the overall BIM strategy in HEIs was largely seen as positive. Despite an overwhelming level of support for the importance of BIM related accreditation criteria of courses in academic institutions, the level of conviction for actual change is however debateable. This is evidenced by the high degree of uncertainty/pessimism among respondents in regards to the prospect of BIM in the long term, as majority of respondents would rather adopt a more cautious approach that is follow and change reactively, as opposed to proactively pushing and leading change, hence the average/diffused levels on the BIM Matrix. With the rapidly evolving BIM policy landscape and the need for a more aggressive approach to leading change, it is important that HEIs and the industry workforce keep abreast with developments in the BIM sphere. Considering the high level of representation of academics among the respondents, about 40% still consider themselves not adequately informed on BIM and the UK government implementation strategy (see the BIM awareness element on the BIM Matrix). This high level of detachment remains a setback for embedding BIM. Mitigating this skill and information dearth would require improved level of awareness and access to information sources such as the BIM Task Group to facilitate the transmission of up to date knowledge on BIM policy, standards and processes. Moreover, consultations with BAF and BIM4SME working group can also help foster open innovation and collaboration with top performing HEIs and their respective local Regional BIM Hubs, and of course local SMEs and communities.

The multinomial logistic regression model developed provided sufficient evidence that the pattern of responses to certain BIM strategic considerations, particularly in the aspects concerning ambitious/proactive ILO, practical inclination of curriculum developments, cost implications and specialised ILO were closely associated with the age of respondent. Not surprisingly, the Pre-war generation category appeared to show more scepticism, perhaps restraint in their responses concerning the aforementioned considerations. This further confirms existing
studies on the impact of generational differences on beliefs/perceptions within the distinct generation cohorts in the academic workplace (Hannay & Fretwell, 2011; Murray, 2011). Apparently, this differential pattern would similarly apply to the dual categorisation of digital immigrants and natives (Underwood, 2014; Koutropoulos, 2011; Prensky, 2001).
REFERENCES


BAF. (2013). *Embedding Building Information Modelling (BIM) within the taught curriculum.* York: HEA.


### APPENDIX A: BIM ACADEMIC FORUM LEARNING OUTCOMES

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Undergraduate</th>
<th>Postgraduate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Knowledge &amp; Understanding</strong></td>
<td><strong>Collaborative working, BIM, information management and its application in the built environment.</strong></td>
</tr>
<tr>
<td></td>
<td>• Importance of collaboration.</td>
<td>• Commercial implications – contractual/legal, etc.</td>
</tr>
<tr>
<td></td>
<td>• The business of BIM.</td>
<td>• De-risking projects through BIM and risk management.</td>
</tr>
<tr>
<td></td>
<td>• BIM concepts – construction processes.</td>
<td>• Understanding nature of current industry practice.</td>
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<tr>
<td></td>
<td>• Stakeholders’ business drivers.</td>
<td>• Client value – soft landings.</td>
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<tr>
<td></td>
<td>• Supply chain integration.</td>
<td>• Business value – RoI/value proposition.</td>
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<tr>
<td></td>
<td>• BIM across the disciplines.</td>
<td>• Understanding supply chain management.</td>
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<tr>
<td></td>
<td>• Contractual and legal frameworks/regulation.</td>
<td>• Lifecycle management of BIM – asset, performance in use, etc.</td>
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<td></td>
<td>• People change management.</td>
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<td></td>
<td>• Demonstrate ability to adopt different platforms.</td>
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<td></td>
<td>• Critically judge/evaluate various BIM tools applications.</td>
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<td></td>
<td>• Protocols/interoperability/standards.</td>
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<td></td>
<td>• Capability evaluation.</td>
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<td></td>
<td>• Change in way projects are to be delivered.</td>
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<tr>
<td></td>
<td>• Visualisation of large data sets.</td>
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<td></td>
<td>• Lean principles and links to BIM.</td>
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<td></td>
<td>• Use of BIM enabled technology, e.g. palm devices.</td>
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<td></td>
<td>• BIM as a process/technology/people/policy.</td>
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<tr>
<td></td>
<td>• Value, lifecycle and sustainability.</td>
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<tr>
<td></td>
<td>• ‘Software-as-a-service’ platforms for projects.</td>
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<td></td>
<td>• Collaborative working.</td>
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<td></td>
<td>• Communication within interdisciplinary teams.</td>
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<tr>
<td></td>
<td>• Process/management.</td>
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<tr>
<td></td>
<td>• How to deliver projects using BIM.</td>
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<td></td>
<td>• Information and data flows.</td>
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<td></td>
<td>• BIM protocols/EIR.</td>
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<td></td>
<td>• Project level application.</td>
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<td></td>
<td>• Cross discipline and team working.</td>
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<tr>
<td></td>
<td>• Importance of effective communication and decision making – human interaction!</td>
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<tr>
<td></td>
<td>• Process mapping and BPR.</td>
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<tr>
<td></td>
<td>• Change management and cultural gap.</td>
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<tr>
<td></td>
<td>• Masters level thinking – strategic/technical/managerial.</td>
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<tr>
<td></td>
<td>• Ability to assess barriers to BIM at various levels, e.g. corporate/project</td>
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<tr>
<td>Knowledge &amp; Understanding</td>
<td><strong>Practical Skills</strong></td>
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<tr>
<td></td>
<td>• Introduction to technology used across disciplines.</td>
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<td></td>
<td>• Use of visual representations.</td>
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<tr>
<td></td>
<td>• BIM tools and applications.</td>
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<td></td>
<td>• Attributes of a BIM system.</td>
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<tr>
<td></td>
<td>• Technical know how.</td>
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<td></td>
<td>• Structures and materials.</td>
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<tr>
<td></td>
<td>• Sustainability.</td>
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<td></td>
<td>• BIM as a process/technology/people/policy.</td>
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<td>• Value, lifecycle and sustainability.</td>
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<td>• ‘Software-as-a-service’ platforms for projects.</td>
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<td>• How to deliver projects using BIM.</td>
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<td>• Information and data flows.</td>
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<td>• Project level application.</td>
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<td>• Cross discipline and team working.</td>
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<td>• Masters level thinking – strategic/technical/managerial.</td>
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<td></td>
<td>• Ability to assess barriers to BIM at various levels, e.g. corporate/project</td>
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### APPENDIX B: BIM TASK GROUP LEARNING OUTCOMES FRAMEWORK

<table>
<thead>
<tr>
<th>Understand what BIM is, the contextual requirement for BIM Level 2 and its connection to the Government Construction Strategy and Industrial Strategy 2025, including an understanding of:</th>
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<tbody>
<tr>
<td>1.01 * Background and the need for collaborative working (removing waste, errors and poor quality/incomplete information)</td>
</tr>
<tr>
<td>1.02 * The value of whole life and whole estate approach rather than capital-led and single asset</td>
</tr>
<tr>
<td>1.03 * The concept of Soft Landings / Government Soft Landings (GSL)</td>
</tr>
<tr>
<td>1.04 * Roles and responsibilities of the supply chain members and clients as part of BIM Level 2 delivery (cultural / behavioural)</td>
</tr>
<tr>
<td>1.05 * External context for BIM, global, national, standards and support communities</td>
</tr>
<tr>
<td>1.06 * Core and extended suite of standards, documents and deliverables describing BIM Level 2</td>
</tr>
<tr>
<td>1.07 * Barriers to successful adoption of BIM Level 2 and how to create the conditions for success</td>
</tr>
<tr>
<td>1.08 * The value of high quality data and the principles of data management</td>
</tr>
<tr>
<td>1.09 * The key vulnerability issues and nature of controls required to enable the trustworthiness and security of digitally built assets</td>
</tr>
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</table>

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<thead>
<tr>
<th>Understand the implications and value proposition of BIM within your organisation; including an understanding of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.01 * Implementation implications for the introduction of BIM Level 2 on your organisation and supply chain (e.g. training, management processes and systems)</td>
</tr>
<tr>
<td>2.02 * Organisational change management considerations in context of the introduction of BIM Level 2</td>
</tr>
<tr>
<td>2.03 * Assessment of capability of your organisation and your supply chain (e.g. standard methods of assessment PAS91 Table 8)</td>
</tr>
<tr>
<td>2.04 * Technical, technology and interoperability requirements of Level 2 BIM (Information Management / CDE, model-based design and analysis)</td>
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<tr>
<td>2.05 * The importance of Level 2 BIM as a driver for business process review and improvement</td>
</tr>
<tr>
<td>2.06 * Legal and commercial implementation implications for the introduction of BIM Level 2 on your organisation and supply chain (e.g. commercial stakeholders)</td>
</tr>
<tr>
<td>2.07 * The value, benefits and investment associated with BIM Level 2</td>
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<tr>
<td>2.08 * How BIM supports the relationship between Design &amp; Construction and Facilities &amp; Asset Management</td>
</tr>
<tr>
<td>2.09 * The potential security threats to built and information assets, and the need for the development of an appropriate and proportionate security risk management approach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Understand the requirement for the management and exchange of information between supply chain members and clients as described in the 1192 suite of standards and PAS55 / ISO 55000; including an understanding of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01 * The purposes for information in the capital and asset phase</td>
</tr>
<tr>
<td>3.02 * Requirements for the exchange of information between supply chain members in a collaborative manner as described in PAS1192-2: 2013 &amp; PAS1192.3: 2014 and provided in conjunction with BS1192:2007</td>
</tr>
<tr>
<td>3.03 * Roles and responsibilities of the supply chain members and clients of BIM Level 2 and the implications on Scopes of Services</td>
</tr>
<tr>
<td>3.05 * BIM Execution Plan (BEP) in context of PAS1192.2:2013 - the related concepts, purpose and implementation principles</td>
</tr>
<tr>
<td>3.06 * Digital delivery of information between supply chain members and with clients in context of BS1192-4:2014 (COBie), Digital Plan of Work (DPoW) and classification systems</td>
</tr>
<tr>
<td>3.07 * The Concept, purpose and implementation principles of Project Information Models (PIM) and Asset Information Models (AIM) and the relationship and interchange between them</td>
</tr>
<tr>
<td>3.08 * A Common Data Environment (CDE) as described in the 1192 suite of standards and BS1192:2007</td>
</tr>
<tr>
<td>3.09 * The implications of Level 2 BIM in relation to project team working methods as described in BS1192 :2007</td>
</tr>
<tr>
<td>3.10 * The way in which Level 2 BIM can be adopted to benefit decision-making for design management</td>
</tr>
<tr>
<td>3.11 * Technologies and methods for creating, using and maintaining structured information</td>
</tr>
<tr>
<td>3.12 * Contractual interventions required to support BIM Level 2 and the implications on existing forms of contract</td>
</tr>
<tr>
<td>3.13 * Organization of information and roles of supply chain members and clients in context of existing forms of contract</td>
</tr>
<tr>
<td>3.14 * Requirements for security-minded policies, processes and procedures which address threats of exploitation of critical information, including the exchange of sensitive information between supply chain members and clients</td>
</tr>
</tbody>
</table>

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* BIM Academic Forum
APPENDIX C: BIM ACADEMIC FORUM MEMBERS

Zulfiqar Adamu  
University of Loughborough

Abdullahi Ahmed  
Coventry University

Zeeshan Aziz  
University of Salford

Nooshin Akrami  
University of Bolton

Anas Bataw  
University of Manchester

Tim Bennett  
College of Estate Management

Mark Bew  
BIM Task Group

Avril Behan  
Dublin Institute of Technology

Paula Bleanch  
Northumbria University

Anne Boner  
Letterkenny Institute of Technology

Ezekiel Chinyio  
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David Comiskey  
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Nashwan Dawood  
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Eleanor Driver  
Letterkenny Institute of Technology

Ray Elysee  
Huddersfield University

John Forde  
University of Salford

Rob Garvey  
University of Westminster

Barry Gledson  
Northumbria University

Jack Goulding  
University of Central Lancashire

David Greenwood  
Northumbria University

Michael Greenwood  
University of Greenwich

Howard Griffin  
Kent University

John Harrington  
Leeds Metropolitan University

Peter George Haywood  
London South Bank University

David Heesom  
University of Wolverhampton

Aidan Hoggard  
University of Sheffield

Anthony Holeness  
Arts University Bournemouth

Georgios Kapoqiannis  
Coventry University

Mohamad Kassem  
Teesside University

Anthony Kelly  
University of Greenwich

Farzad Khosrowshahi  
Leeds Beckett University

Arto Kiviniemi  
University of Liverpool

Tahar Koudier  
Robert Gordon University

Bimal Kumar  
Glasgow Caledonian University

Richard Laing  
Robert Gordon University

Richard Lane  
BIM Task Group

Geoff Levermore  
University of Manchester
<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steve Lockley</td>
<td>Northumbria University</td>
</tr>
<tr>
<td>Priti Lodhia</td>
<td>The College of Estates Management (Reading)</td>
</tr>
<tr>
<td>Meenakshi Mandhar</td>
<td>University of Lincoln</td>
</tr>
<tr>
<td>Energy Maradza</td>
<td>University of Reading</td>
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<tr>
<td>Ramesh Marasini</td>
<td>Southampton Solent University</td>
</tr>
<tr>
<td>Diane Marsh</td>
<td>Liverpool John Moores</td>
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<tr>
<td>George Martin</td>
<td>University of Coventry</td>
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<tr>
<td>Malachy Mathews</td>
<td>Dublin Institute of Technology</td>
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<tr>
<td>Adam Matthews</td>
<td>Autodesk</td>
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<tr>
<td>Marie May</td>
<td>Sheffield Hallam University</td>
</tr>
<tr>
<td>Mark McKane</td>
<td>University of Ulster</td>
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<tr>
<td>Danny McGough</td>
<td>Coventry University</td>
</tr>
<tr>
<td>Benachir Medjdoub</td>
<td>Nottigham Trent University</td>
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<tr>
<td>Jim O’Connor</td>
<td>Galway Mayo Institute of Technology</td>
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<tr>
<td>Geoff Olner</td>
<td>Sheffield Hallam University</td>
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<tr>
<td>David Philp</td>
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<tr>
<td>Steve Pittard</td>
<td>London South Bank University</td>
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<tr>
<td>Andrew Platten</td>
<td>Leeds Metropolitan University</td>
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<tr>
<td>Milan Radosavljevic</td>
<td>University of Reading</td>
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<tr>
<td>Aimie Rimmington</td>
<td>Nottingham Trent University</td>
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<tr>
<td>Kirti Ruikkar</td>
<td>University of Loughborough</td>
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<tr>
<td>Noha Saleeb</td>
<td>Middlesex University</td>
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<tr>
<td>Mark Shelbourn</td>
<td>University of the West of England</td>
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<td>Bhavna Solanki</td>
<td>Nottingham Trent University</td>
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<td>Paul Stephenson</td>
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<tr>
<td>Josheph Tah</td>
<td>Oxford Brookes University</td>
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<td>Jim Tennant</td>
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<tr>
<td>Patrik Thornhill</td>
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<td>Ben Wallbank</td>
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<tr>
<td>Aled Williams</td>
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</tr>
<tr>
<td>Tom Workman</td>
<td>Blackpool &amp; The Fylde College</td>
</tr>
</tbody>
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The BIM Academic Forum aims to foster integrated collaborative working over the lifecycle of the asset through academic enhancement of BIM

A BAF survey of the current position and associated challenges of BIM education in UK Higher Education

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Appendix C: Higher Education Academy BIM Academic Forum report (2013)
Embedding Building Information Modelling (BIM) within the taught curriculum

Supporting BIM implementation and adoption through the development of learning outcomes within the UK academic context for built environment programmes

June 2013
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Supporting BIM implementation and adoption through the development of learning outcomes within the UK academic context for built environment programmes. June 2013
Foreword
This report has been produced by the BIM Academic Forum UK (BAF) core team comprising Doctor Jason Underwood, Senior Lecturer at University of Salford and Director of Construct IT For Business; Professor Farzad Khosrowshahi, Head of School of Built Environment at Leeds Metropolitan University; Steve Pittard of South Bank University; Professor David Greenwood of Northumbria University; and was authored by Tim Platts, Chair of BAF. The project was commissioned by Aled Williams, Discipline Lead (Built Environment) at the Higher Education Academy (HEA) and was carried out in late 2012.

Executive summary
This report considers the impact that building information modelling (BIM) is having on the learning needs of undergraduates and postgraduates; in particular those programmes within the built environment and architectural schools and faculties.

With Government strategy now gathering momentum, developing an informed and equipped workforce is a growing priority. Besides this is the requirement that all higher education institutions (HEIs) respond to changing needs across industry, and although many programmes have begun to recognise this, the need for guidance and consistency has also come into focus. BAF was established in late 2011 to respond to these needs and now includes the vast majority of HEIs with an interest in this area. The opportunity to build upon the original work of the group, particularly around articulating learning outcomes, and to share information was further enhanced by a HEA-funded interactive workshop at the University of Salford, November 2012.

The main purpose of the workshop was to:

a) provide opportunity for the candidates to hear the latest strategic developments from the Government BIM team from David Philp – Head of BIM Implementation for the Cabinet Office;
b) provide opportunity for the candidates to gain an insight into the work of the training and education task group and to consider the definition of outcomes of the National Occupational Standards (NOS);
c) work in peer groups to explore and determine definitions for learning outcomes at level 4, 5, 6 undergraduate and level 7 postgraduate programmes.

In addition, some key findings from the workshop evolved which fell into the following main categories, and from these this report considers its conclusions and recommendations:

- up-skilling of staff to support the delivery of the desired learning outcomes;
- student employability;
- framework for learning;
- keeping pace with the development of BIM.

“At this point in the evolution of the UK BIM strategy it is of increasing importance that our teaching institutions are equally well informed of the progress that is being made across those Government departments which are spearheading implementation on projects and across its asset base. The BAF has taken great steps by bringing together and providing a focus for UK academia. The agenda supports that of the BIM task group in promoting UK BIM adoption and leadership both home and abroad to ensure that the UK is at the vanguard on new, more efficient ways of working” Professor David Philp, Head of BIM at Mace, currently seconded in the Cabinet Office as Head of BIM Implementation
Introduction – background to the introduction of BIM

Over recent years, the attention that building information modelling (BIM) has been receiving has been steadily growing, and this has been substantially increased through the Government’s intervention, with its BIM Report and Government Construction Strategy (GCS) both published in 2011. The impact of these two documents on the industry has been significant and ultimately will lead to all public sector departmental spending being channelled through a supply chain which is BIM ‘level 2’ compliant. Indeed, the Government has mandated that all public procure projects are to be delivered through, by or with BIM by 2016. The ubiquitous Bew-Richards maturity diagram (noted in the reports mentioned above and included in this report at Appendix 2) defines ‘level 2’ as file-based collaboration and library management. The purpose behind the Government ‘push’ at this time is in order to derive significant improvements in cost, value and carbon performance, as has been cited by the industry for some time (see Latham (1994), Egan (1998), Wolstenholme (2009), Andrews, et al 2009). In addition to the challenge of up-skilling the current work force, this has significant implications for higher education in developing future built environment professionals with the necessary skills to work in new ways, beyond their traditional disciplines. Alongside this, it is recognised that there will be a need to work with the professional institutions in addressing new requirements in the accreditation of courses. Altogether this provides the construction industry with its greatest challenge and opportunity to revolutionise working practices with the aim of increasing productivity and efficiency. The GCS proposes that its recommendations, which include BIM alongside a call for greater collaboration and new contract formats, should lead to savings targeting 20% of both capital and operational budgets. Further information and reference sources are provided at the end of this report.

Currently there is very little regulation directly relating to the production and use of information relating to BIM in the UK. Much of the early momentum in respect of the approach, relevant standards and research has emanated from the US and is revealed in output such as that produced by the American Institute of Architects (AIA), ‘consensus docs’, Construction Operations Building Information Exchange (COBie) and the dominance of the world’s leading vendor for BIM authoring software, Autodesk. The effect of technology providers and software vendors is also a key matter in the formulation of BIM strategy and indeed learning, which needs careful consideration. The UK Government’s position in relation to these matters has been to be non-prescriptive and adopt a software neutral position, while its governance and guidance leaves the detail for delivering the outputs and outcomes it is demanding to the supply chain itself.

In 2011 the UK Government established its BIM Implementation team whose articulation of the process and promotion of the benefits of BIM within Government departments has had a great impact, and its influence continues to grow. From setting the agenda in the 2011 report, a number of task groups have been set up each of which seeks to address a specific area or topic related to the adoption and implementation of BIM. This includes the training and education task group which has had representation covering the HEIs, training organisations and bodies such as construction skills and Construction Industry Council (CIC).

As a result, the amount of information and data, and general progress being made in supporting BIM implementation in the UK is rapidly increasing with UK standards guides (e.g. Building Information Mode (BIM) Protocol, Standard Protocol for use in projects using Building Information Models, CIC 2013) either produced and available under free licence or imminent in release through the B/555 Technical Committee Roadmap. It is against this backdrop that BAF
has been established and seeks to provide a co-ordinated and integrated response from the higher education sector.

**BIM Academic Forum UK (BAF)**
The BIM Academic Forum (BAF) is a group of representatives from a large number of UK universities formed to promote the academic aspects of BIM. In particular, BAF is focused on the development of a ‘BIM academic framework’, the aim of which is to propose a roadmap towards a longer-term vision of embedding BIM learning at the appropriate levels within ‘discipline-specific’ undergraduate and postgraduate education. This would facilitate the development of professionals with the relevant BIM knowledge considered necessary. Moreover, BAF has begun to breakdown and establish the potential learning outcomes requirements at levels 4-7 of HEI education.

BAF has over 55 members from 30 teaching centres across the UK and includes representation from the Republic of Ireland. Formed in late 2011, it operates under the following values and principles:

**VISION**

*To foster integrated collaborative working on projects over the lifecycle of the asset through academic involvement and enhancement of BIM.*

**MISSION**

*To create a dynamic group to develop and promote the training, learning and research aspects of BIM through strong collaboration and co-operation.*

**OBJECTIVES**

- focus on and elevate the training and learning and research aspects of BIM;
- collective promotion of BIM (expand wider market not extend own market);
- establish open medium for communication thus sharing knowledge, experience, case studies, views, etc.;
- collaboration for joint activities and research projects;
- collective voice in both teaching and learning and research matters, so to contribute to policy issues, funding priorities and agenda setting;
- attempt to minimise duplication and create standard practices while celebrating diversity.

BAF has met on several occasions and held meetings to formulate and develop the BIM academic framework UK (see Appendix 1) which seeks to provide a graphical presentation of the requirements at undergraduate and postgraduate level along with the relationship to the vocational training being led by the Government’s BIM task group on training and education and the professional institutions, e.g. including Royal Institute of British Architects (RIBA), Chartered Institute of Building (CIOB) and Royal Institution of Chartered Surveyors (RICS). This approach has been interrogated by the group and has stood up to the tests applied to it to date. It is therefore considered a robust articulation of the needs for and purpose of BAF.

The BAF membership is noted in Appendix 4
Development workshop

Discussions with HEA led to the proposal for a funded workshop whose focus it was to present the initial work of BAF in terms of the BIM academic framework and the initial outcomes of previous working group sessions (e.g. Loughborough, June 2012) to a wider audience and also to facilitate further development of the framework and the associated learning outcomes. Representatives from some 20 HEIs, noted below, participated in the workshop held at University of Salford, 26 November 2012.

Figure 1: Location of partner institutions across UK

By bringing together interested academics from across the UK, the opportunity to brief delegates on Government strategy was achieved through the involvement and contribution at the event from Cabinet Office representatives and the BIM task group for training and education. The initial sessions were delivered by David Philp, Head of BIM Implementation and David Cracknell, Director of Skills & Lifelong Learning, Construction Industry Council.

Key Messages from the Presentations

Together, David Philp and David Cracknell provided the group with a complete and up-to-date overview of current policy and how this is evolving, in particular and of significance was the statement that UK construction industry now ranks second behind Finland in leading the implementation of BIM in terms of infrastructure spend. Other aspects of the presentations that are useful to include and note in summary in this report are:

- function of the Cabinet Office is to set BIM policy; Department of Business, Innovation, and Skills (BIS) to support BIM growth; and CIC to ensure engagement;
- role is to create the 'intelligent client' thus establishing the 'pull' equals purpose driven BIM, through defining the data it wants to buy;
• part of the journey necessitates behavioural change, thus engaging the social sciences;
• traditionally, customers not getting the outcomes they needed/wanted; BIM is able to deliver performance predictability for the client, and for the supply side to attain new efficiencies;
• BIM ‘supply side’ group established with this focus alongside other working groups targeting retail, private sector, rail and small, medium sized enterprises (SMEs);
• project life cycle now being articulated through ‘data drops’ using COBie as its common language;
• the introduction of employer information requirements is seen as key a part of the processes that are to be defined in the burgeoning output from Government relating to standards, protocols, definitions and contracts;
• the role of the information manager is now evolving;
• all aimed at securing the right amount of data at the right time.

Initial BIM learning outcomes framework – David Cracknell:

“The framework covers three levels of need: strategic, management and technical… the framework endeavours to interpret broad outline headings (resulting from the initial review of BIM learning needs for Government departments) into learning outcomes. These consist of a stem statement followed by a series of more detailed outcomes taken from the titles of relevant current sector National Occupational Standards. This will hopefully help to give substance to each area and focus on the various functional contexts in which the learning can be applied.

At the moment the term ‘understand’ is used in each of the learning outcome stems. This is partly because what is proposed is a short course that may not allow for going beyond basic understanding. However, it is quite possible to alter this stem learning verb to indicate a different depth of learning or different emphasis e.g. ‘apply’ ‘evaluate’ etc. Each of the three level frameworks incorporates the overarching BIM introduction learning outcome”

An extract from the framework is included in Appendix 5 for illustration purposes. This will be available from the BIM task group website (http://www.bimtaskgroup.org/education-and-training/).

Teaching possibilities

The way in which BIM can be taught and the impact BIM could have on teaching was considered by Aled Williams in his presentation. Clearly there is a broad spectrum of possibilities covering the following aspects:

• the technology;
• language used;
• approach adopted;
• pedagogy.

Each HEI will need to consider its own approach in light of a number of factors, not least how far BIM is currently embedded within its curricula. Where HEIs are considering implementing BIM in their modules, the BIM teaching impact matrix noted below can be used as an aid to determining the optimum requirements
### Figure 2: BIM teaching impact matrix

<table>
<thead>
<tr>
<th>BIM Level:</th>
<th>Absent</th>
<th>Aware</th>
<th>Infused</th>
<th>Embedded</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM descriptor</td>
<td>BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.</td>
<td>BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.</td>
<td>Students should understand how BIM will affect their future and have chance to learn BIM in a discipline &amp; multi-disciplinary context.</td>
<td>BIM is so important it should become the ‘vehicle’ for our students’ learning experience. Teaching should enabled by the BIM model.</td>
</tr>
<tr>
<td>Curriculum</td>
<td>No change</td>
<td>Key modules are identified and BIM knowledge incorporated.</td>
<td>Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.</td>
<td>Full curriculum review to allow every module to identify changes required for delivery through a BIM model.</td>
</tr>
<tr>
<td>Structure</td>
<td>No change</td>
<td>No change</td>
<td>Structural review needed but impact on current structure likely to be minimal.</td>
<td>A complete review of structure to enable the BIM model to be the driver/vehicle for learning.</td>
</tr>
<tr>
<td>Staff</td>
<td>No change</td>
<td>Staff in the key modules will need an understanding of BIM and how it impacts industry.</td>
<td>All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.</td>
<td>All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>No change</td>
<td>No change</td>
<td>Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.</td>
<td>Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.</td>
</tr>
<tr>
<td>Curriculum - Research gap</td>
<td>Can be large</td>
<td>No change</td>
<td>Has to be small in some areas but with some flexibility.</td>
<td>Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery.</td>
</tr>
</tbody>
</table>

(Williams and Lees, 2009)
Group work

The remainder of the workshop focused on the delegates views and opinions of the necessary learning outcomes required at levels 4, 5, 6 (undergraduate) and 7 (postgraduate) programmes of higher education in the built environment. This covered the following disciplines represented by the various HEIs attending the workshop:

- construction management and construction project/design management;
- architectural technician/technologist;
- building services engineering;
- quantity surveying;
- architecture;
- civil engineering;
- BIM Masters programmes (i.e. at Salford and Northumbria).

Following the breakout sessions, each workgroup presented their results to the whole workshop which are covered below:
**Figure 3: Presentation of learning outcomes from workshop group sessions**

<table>
<thead>
<tr>
<th>Level</th>
<th>Knowledge and understanding</th>
<th>Practical skills</th>
<th>Transferable skills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Undergraduate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>• importance of collaboration</td>
<td>Introduction to technology used across disciplines</td>
<td>BIM as a process/technology/people/policy</td>
</tr>
<tr>
<td></td>
<td>• the business of BIM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>• BIM concepts – construction processes</td>
<td>• use of visual representations</td>
<td>• value, lifecycle and sustainability</td>
</tr>
<tr>
<td></td>
<td>• stakeholders' business drivers</td>
<td>• BIM tools and applications</td>
<td>• ‘software as service’ platforms for projects</td>
</tr>
<tr>
<td></td>
<td>• supply chain integration</td>
<td>• attributes of a BIM system</td>
<td>• collaborative working</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• communication within inter-disciplinary teams</td>
</tr>
<tr>
<td>6</td>
<td>• BIM across the disciplines</td>
<td>Technical know how:</td>
<td>Process/management:</td>
</tr>
<tr>
<td></td>
<td>• contractual and legal frameworks/regulation</td>
<td>• structures and materials</td>
<td>• how to deliver projects using BIM</td>
</tr>
<tr>
<td></td>
<td>• people/change management</td>
<td>• sustainability</td>
<td>• information and data flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• BIM protocols/EIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Postgraduate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>• collaborative working, BIM, information management and its application in the built environment</td>
<td>• demonstrate ability to adopt different platforms</td>
<td>• project level application</td>
</tr>
<tr>
<td></td>
<td>• commercial implications – contractual/legal etc</td>
<td>• critically judge/evaluate various BIM tools/applications</td>
<td>• cross discipline and team working</td>
</tr>
<tr>
<td></td>
<td>• de-risking projects through BIM and risk management</td>
<td>• protocols/inter-operability/standards</td>
<td>• importance of effective communication and decision making – human interaction!</td>
</tr>
<tr>
<td></td>
<td>• understanding nature of current industry practice</td>
<td>• capability evaluation</td>
<td>• process mapping and BPR</td>
</tr>
<tr>
<td></td>
<td>• client value – soft landings</td>
<td>• change in way projects are to be delivered</td>
<td>• change management and cultural gap</td>
</tr>
<tr>
<td></td>
<td>• business value – RoI/ value proposition</td>
<td>• visualisation of large data sets</td>
<td>• masters level thinking – strategic/technical/managerial</td>
</tr>
<tr>
<td></td>
<td>• understanding supply chain management</td>
<td>• lean principles and links to BIM</td>
<td>• ability to assess barriers to BIM at various levels e.g. corporate/project</td>
</tr>
<tr>
<td></td>
<td>• lifecycle management of BIM – asset, performance in use etc</td>
<td>• use of BIM enabled technology e.g. palm devices</td>
<td></td>
</tr>
</tbody>
</table>
Summary

Level 4 (year one of undergraduate study): essentially, the key learning outcomes at this stage are to provide the context and background to the industry, and why the need for significant productivity improvements exists, set against the historical and traditional working arrangements which have prevailed. This will cover an appreciation of how the industry works, the key roles and disciplines involved in delivering projects and identify the nature and role of the various stakeholders. It should also include an introduction to the way in which information is prepared, shared and issued and also to the technologies being employed to support BIM and promote collaborative working.

Level 5 (year two): outcomes here aim to develop the knowledge and understanding of the role of BIM as a business driver for collaborative working within an integrated supply chain, considering the roles and responsibilities of each within a BIM approach. Students should be able to investigate and articulate the value proposition for BIM from the perspective of each party and consider the impact of BIM in terms of life cycle and whole life cost on projects.

Level 6 (year three and potentially after year out in industry): at this level there should be a greater focus on building competence and knowledge around the people, systems and process which are required for BIM to be delivered successfully on projects. This should include the ability to fully articulate the benefits of BIM. There should be awareness and appreciation of the cultural and organisational impacts of change necessary for the adoption of BIM both people issues and practical issues; awareness required of the practical measures necessary for BIM implementation including understanding of available technologies, means for exchanging data, standards and protocols; and appreciation of new ways of working in groups/projects—integrated project team work and collaborative working environments to support BIM delivery.
Key findings
Beyond the core learning outcomes in relation to knowledge and understanding, practical skills and transferable skills, key findings from the workshop note the need for up-skilling of staff, student employability, and a framework for learning.

Up-skilling of staff

While the industry itself is faced with a substantial steep learning and training programme, the HEIs need also to contemplate how they can ready themselves to deliver a programme of learning and study that is BIM aware, BIM focused and BIM enabled. To date most HEIs have relied on basic training of the technology and its functionality, which at best represents only the most fundamental aspects of BIM, and does not, in itself, support the knowledge and understanding (as noted below) required by the push for BIM adoption and in particular the recommendations of the Government Construction Strategy (2011). This matter, therefore, obscures the need for greater staff awareness and exposure to BIM methodologies so as to be able to articulate the changes clearly needed and acknowledged by industry in order for BIM adoption and implementation to succeed. A crucial factor to this up-skilling requirement is greater collaboration, contribution from, and participation of industry with academia. Some great examples of such knowledge exchange forums already exist, e.g. BIM Academy at Northumbria University, thinkBIM at Leeds Metropolitan University, and The Learning Xchange at the University of Salford. The opportunities presented by the formulation of the CIC sponsored regional BIM hubs is to be noted and not to be underestimated. CIC has been tasked with setting up a network of BIM regional hubs to help ensure that the most up-to-date and consistent information on the UK Government level 2 BIM programme is disseminated across the UK and allowing for a local feedback mechanism to the Government BIM task group at a grass roots level.

Student employability

HEIs are already experiencing the demands from industry for BIM-ready graduates, i.e. those capable of articulating the benefits of BIM; able to use aspects of the technology relevant to their discipline; aware of the challenges imposed by existing methodologies; and capable of delivering change. The increasing awareness of BIM across industry will drive this demand exponentially and the response from academia will be tested. While the broader industry awareness and appreciation of BIM is still largely in its infancy, the larger firms both in contracting and consultancy have already embraced the benefits of BIM and most have a BIM strategy at the heart of their operations. The introduction of a specific BIM4SME group aimed at the small and medium enterprises mainly found in tiers two and three in the supply chain (those specialist sub-contractors and subcontractors). This heralds the championing of this sector of the industry and their important and crucial role in fully embedding BIM throughout the process. This will include not only the smaller contractors and consultants, but also manufacturers and specialist suppliers/contractors. Hence, the reach of BIM and the need for this to be reflected in the graduating cohorts’ innate skill sets is likely to become critical within the next few years. Most software vendors provide free student licences, although hardware demands may be a factor is ensuring there is provision at the necessary level. The opportunity provided by the relationship already formed between BAF and the BIM task group, alongside the growing involvement of CIC should allow a seamless and quick integration of the necessary steps and guidance, to ensure such provision is made widely available.
**Framework for learning**

A framework for learning which provides a non-prescriptive yet overarching template that can be configured and adopted for a wide variety of purposes will allow HEIs to move forward quickly and confidently. This will rely upon the early adopters of BIM sharing some of their knowledge for the benefit of the many – and the pay back must have to be greater collaboration between the HEIs themselves leading to benefits in terms of networking, knowledge exchange, reciprocation and joint research. Further analysis of the needs at each learning stage covered includes:

- providing wider industry context and background relating to the introduction and implementation of BIM in the first stages of study;
- greater collaboration across the disciplines; use and adoption of the technology;
- realising the impact on project/business structures, communications and behaviours.

Within the detail of the response to learning outcomes at each stage it became apparent that the best way to approach the learning requirements would be to categorise these by/as:

- knowledge and understanding;
- practical skills;
- transferable skills.

The presentation of material for each level resulting from the working groups has therefore been represented in this way, leaving only those residual issues that need to be considered by each provider, and which is likely formulate the ongoing agenda for BAF.

**Keeping pace with BIM development in IT and industry**

The increasing volume of output and information relating to BIM in industry and academia will lead to an additional challenge for the HEIs and in response to this given the feedback provided by delegates at the workshop, the need for greater communication and collaboration between academics needs to be recognised. This provides BAF with an ongoing mandate to act on behalf of the stakeholders and to improve its offer through a more regular agenda, planned events, communication platform and sharing of knowledge and information, thereby meeting its aims and objectives as noted in its terms of reference (see the section headed BAF above). The construction industry is not the only sector undergoing change and challenge, nor is the technology surrounding BIM of any great significance beyond providing highly functional and efficient tools, but the need to reflect on the impact in other areas such as business, engineering and IT has been identified by this study group.

As mentioned earlier in the report the relationships fostered throughout 2012 with the BIM Implementation team leaders and the training and education task group in particular, along with the need to ensure full and proper representation with CIC, is a fundamental requirement in moving forward with the higher education agenda. Given the broad representation of the current group, the robust testing and interrogation of the BIM academic framework, and the emerging articulation of learning outcomes, it is now necessary to alert the professional institutions to the work and effort that has been undertaken and to seek closer collaboration in 2013 to ensure that such effort is not duplicated.
Conclusions
The workshop and group work at the event facilitated by HEA with University of Salford has provided an important step in the evolution of determining the learning outcomes at various levels within the undergraduate and postgraduate related programmes, alongside the broader dissemination of information within a larger representative group. This builds the resilience of the BIM academic framework process, and provides opportunity for this to be shared with a larger audience and broader stakeholder groups.

The information prepared by BAF and developed through 2012 alongside the workshop output, which articulates the high-level learning outcomes at each stage within the relevant programmes, provides the basis for each institution to begin to map its own content.

This report should provide a firm basis for understanding the impact of BIM and the opportunities this presents to those in higher education, together with an understanding of why this needs to be undertaken and how this can be done.

It further establishes the work of BAF and the need for this to continue against the original doctrine, as well as endorsing the work and output to date. The ability for BAF to act as hub to receive, co-ordinate and act upon information and suggestions from its member/member institutions should be well noted, and its growing importance respected. Hence the continued growth and development of its work and membership is seen as both necessary and worthy.

As a result of the workshop, and the output from it, a report has been prepared for wider dissemination, in particular aimed at the professional institutions, which for now have been targeted through the CIC BIM forum (see Appendix 3).

Recommendations
Head of BIM Implementation for the Government and speaker at the workshop David Philp, offered BAF the use of a page on its website to be dedicated to BAF. This would not only provide a valuable communication and information tool but also ensure that anyone searching for BAF is able to view and access the wealth of other information that exists on the website which is expanding all the time. It is also to be noted that a large proportion of ‘hits’ to the website are international. It is recommended that this offer be accepted and the webpage be developed.

The level of output and work produced as a result of the workshop funded by HEA with University of Salford establishes some key outcomes which are sufficiently developed to be shared with other key stakeholders, in particular, the main professional institutions associated with this sector including RIBA, CIOB, RICS, Institution of Civil Engineers (ICE) and Chartered Institute of Architectural Technologists (CIAT). The purpose of the approach at this stage is to ensure that the institutions are aware of BAF and its purpose and, through close collaboration and co-operation, future thought processes and work in this area can be aligned for mutual understanding and benefit.

Further work is required to develop the high-level outcomes identified by this workgroup and to add necessary detail. Such detail is indicated in the forthcoming publication of the BIM training and education task group’s initial BIM learning outcomes framework. Further HEA funding should be considered in order to release this level of detail and to ensure that, via BAF, the sharing of this knowledge is achieved across UK academia.
References


Web links

HM Government BIM Task Group main website http://www.bimtaskgroup.org/

AEC UK CAD and BIM Standards Site - http://aecuk.wordpress.com/

American Institute of Architects - http://www.aia.org/

Construction Industry Council website http://cic.org.uk/
1. The purpose of the BIM academic framework (depicted) is to propose a roadmap towards a longer-term vision of incorporating BIM learning at the appropriate levels within ‘discipline-specific’ undergraduate and postgraduate education that facilitates the development of professionals with the relevant BIM knowledge considered necessary.

2. In the first instance, the framework depicts the process of translating the work being undertaken by the Government BIM training and education task group to develop a skills capability/competence matrix into establishing consistent and comprehensive BIM-related learning outcomes at the various levels of undergraduate and postgraduate discipline-specific programmes. In this way, it is proposed that BIM-related knowledge is progressively developed at an appropriate level and in line with the discipline-specific knowledge development within programmes. Furthermore, these BIM-related learning outcomes, and individual institutionally developed course materials, can also be informed through their research activities.

3. It is proposed that such BIM-related outcomes described above should also facilitate informing the relevant industry professional institutions towards establishing the required BIM-related accreditation criteria and therefore the accreditation requirements for undergraduate/postgraduate programmes.

4. From the professional development perspective, the work being undertaken by the Government BIM training and education task group will inform the CPD aspect of the professional bodies, which in turn, informs their accreditation criteria.
Appendix 2: Bew-Richards maturity diagram
Appendix 3: Briefing note to professional institutions

From BIM Academic Forum December 2012

Key points
- BIM Academic Forum UK formed in 2011 to promote collaboration and co-operation across higher education institutions;
- academic framework evolved in 2012 and articulation of learning outcomes being developed;
- 60 members from 29 institutions;
- HEA funded workshop and report due June 2013;
- Need identified for communication and alignment with professional institutions.

Background
The surge of interest in BIM, in particular the commitment shown by Government, highlights the need to visit BIM concepts within the taught curriculum in undergraduate and postgraduate programmes across UK academia. In December 2011 representatives from eight UK universities and a technology organisation formed the BIM Academic Forum (BAF) to promote the academic aspects of BIM. From inception the forum enjoyed a high degree of commonality in terms of thinking and approach. It was also agreed that the focus of the group would be on issues pertaining to teaching and learning as well as research. While it was recognised that the work of the forum would be inspired by the needs of the industry, the aspiration of the group would be focused on developing student competence in BIM concepts as well as generating BIM-related new knowledge through research.

It is recognised that the research aspects are themselves governed by the nature of the funding opportunities many of which may fall under applied areas. It is also recognised that BIM issues may appeal to academic disciplines peripheral or outside built environment.

The terms of reference are identified as follows:

Vision
To foster integrated collaborative working over the lifecycle of the asset through academic enhancement of BIM.

Mission
To create a dynamic collaborative group to enhance and promote the teaching, learning and research aspects of BIM.

Objectives
- focus on and elevate the training and learning and research aspects of BIM;
- collective promotion of BIM;
- establish open medium for communication and sharing knowledge, experience, case studies, etc.;
- collaboration for joint activities and research projects both in UK and international;
- collective voice in both training and learning and research matters, so to contribute to policy issues, funding priorities and agenda setting;
- attempt to minimise duplication of effort, and create standard practices but celebrate diversity.
Since these principles have been established and enshrined in the BAF terms of reference document, which each institution endorses, the forum has met on a number of occasions. Meetings held in Leeds, Salford and Loughborough were held throughout 2012 to drive collaboration and co-operation between organisations. This included sharing the BIM academic model formulated originally between Salford, Leeds Metropolitan and South Bank universities as noted in Appendix 1, and to begin identifying common learning outcomes at the various learning stages and levels on related programmes.

Most recently the group, which now numbers 60 members and covers the centres detailed on the map in Figure 1, obtained HEA funding to host and run a workshop to expand on this work and capture the data and information in a formal report. This was held at the end of November 2012 at Salford and included presentations from BIM Implementation task group (David Philp) and Training and Education working group (David Cracknell/CIC), followed by structured working sessions focusing on the learning outcomes for each stage of learning. The delegates attending the event represented programmes in the ‘built environment’ field including quantity surveying, construction management, architecture, architectural technology and project management at undergraduate and postgraduate level. Currently the BAF leadership team comprises

- Professor Farzad Khosrowshahi, Leeds Metropolitan University;
- Steve Pittard, South Bank University;
- Tim Platts (Chair);
- Professor Jason Underwood, University of Salford;
- Professor David Greenwood, Northumbria University.

Figure 1 – BAF member institutions
Outcome of workshop

One of the initial key outcomes from the HEA Salford workshop has been the identification of high-level learning outcomes at each level within university provision. The resulting report will also identify further key points from the discussion and debate on the day and will be available from June 2013.

Next steps

The BAF leadership team wish to see engagement between the activities of BAF and the educational teams within each of the professional institutions including, but not limited, to RICS, CIOB, RIBA, CIAT, Chartered Institution of Building Services Engineers (CIBSE), etc. The aim is to be able to create a direct link between the organisations in order initially to secure:

- clear lines of communication to ensure that activity is co-ordinated and duplication of effort avoided;
- provide a suitable platform to share information, inputs and outputs which augment the effort and activity currently being undertaken and envisaged in the future;
- promote collaboration to see that all parties benefit from the most informed and up to date information and thinking with regard to BIM;
- engender close co-operation and appropriate use of resources to be able to make substantial gains in the shortest possible timeframe.

The purpose of this briefing note is to communicate the existence and work of BAF and to begin the collaborative effort necessary to prepare an integrated and co-ordinated plan for the delivery BIM across the relevant programmes of study.
## Appendix 4: List of members

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nooshin Akrami</td>
<td>University of Bolton</td>
<td>Energy Maradza</td>
<td>University of Reading</td>
</tr>
<tr>
<td>Anas Bataw</td>
<td>University of Manchester</td>
<td>Ramesh Marasini</td>
<td>Solent University</td>
</tr>
<tr>
<td>Mark Bew</td>
<td>BIS</td>
<td>Diane Marsh</td>
<td>Liverpool John Moores University</td>
</tr>
<tr>
<td>Paula Bleanch</td>
<td>Northumbria University</td>
<td>George Martin</td>
<td>Coventry University</td>
</tr>
<tr>
<td>Claire Bowles</td>
<td>Leeds Metropolitan University</td>
<td>Malachy Mathews</td>
<td>Dublin Institute of Technology</td>
</tr>
<tr>
<td>Ezekiel Chinyio</td>
<td>University of Wolverhampton</td>
<td>Adam Matthews</td>
<td>Autodesk</td>
</tr>
<tr>
<td>David Cracknell</td>
<td>CIC</td>
<td>George Mokhtar</td>
<td>BIM Academy</td>
</tr>
<tr>
<td>Nashwan Dawood</td>
<td>Teesside University</td>
<td>Jim O'Connor</td>
<td>Galway Institute of Technology</td>
</tr>
<tr>
<td>Peter Demian</td>
<td>Loughborough University</td>
<td>David Philip</td>
<td>BIS/Cabinet Office</td>
</tr>
<tr>
<td>Ray Elysee</td>
<td>University of Huddersfield</td>
<td>Steve Pittard</td>
<td>London South Bank University</td>
</tr>
<tr>
<td>John Forde</td>
<td>University of Salford</td>
<td>Andrew Platten</td>
<td>Leeds Metropolitan University</td>
</tr>
<tr>
<td>Rob Garvey</td>
<td>University of Westminster</td>
<td>Tim Platts</td>
<td>Leeds Metropolitan University</td>
</tr>
<tr>
<td>Barry Gledson</td>
<td>Northumbria University</td>
<td>Milan Radosavljevic</td>
<td>University of Reading</td>
</tr>
<tr>
<td>David Greenwood</td>
<td>Northumbria University</td>
<td>Aimie Rimmington</td>
<td>Nottingham Trent University</td>
</tr>
<tr>
<td>Michael Greenwood</td>
<td>University of Greenwich</td>
<td>Kirti Ruilkar</td>
<td>Loughborough University</td>
</tr>
<tr>
<td>Peter Haywood</td>
<td>London South Bank University</td>
<td>Paul Stephenson</td>
<td>Sheffield Hallam University</td>
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<tr>
<td>David Heesom</td>
<td>University of Wolverhampton</td>
<td>Joseph Tah</td>
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<tr>
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<td>Jim Tennant</td>
<td>Leeds Metropolitan University</td>
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<td>Anthony Kelly</td>
<td>University of Greenwich</td>
<td>Patrick Thornhill</td>
<td>University of the West of England</td>
</tr>
<tr>
<td>Farzad Khosrowshahi</td>
<td>Leeds Metropolitan University</td>
<td>Antony Thorpe</td>
<td>Loughborough University</td>
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<tr>
<td>Arto Kiviniemi</td>
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<td>Jason Underwood</td>
<td>University of Salford</td>
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<tr>
<td>Tahar Koudier</td>
<td>Robert Gordon University</td>
<td>Jennifer Whyte</td>
<td>University of Reading</td>
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<tr>
<td>Richard Laing</td>
<td>Robert Gordon University</td>
<td>Aled Williams</td>
<td>HEA</td>
</tr>
<tr>
<td>Geoff Levermore</td>
<td>University of Manchester</td>
<td>Bimal Kumar</td>
<td>Glasgow Caledonian University</td>
</tr>
<tr>
<td>Steve Lockley</td>
<td>Northumbria University</td>
<td>David Boyd</td>
<td>Birmingham City University</td>
</tr>
<tr>
<td>Priti Lodhia</td>
<td>The College of Estate Management</td>
<td>Poorang Piroozfar</td>
<td>University of Brighton</td>
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</tbody>
</table>
### Appendix 5: Initial BIM Learning Outcomes Framework

**Extract for illustration purposes only**

<table>
<thead>
<tr>
<th>STRATEGIC</th>
<th>Overview</th>
<th>In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>O1</strong> What is BIM</td>
<td>Understand the principles of Building Information Modelling and its application to the whole life inter-disciplinary design, construction and use of building and infrastructure developments</td>
</tr>
<tr>
<td></td>
<td><strong>O2</strong> BIM value proposition (context relevant e.g., client and contractor)</td>
<td>Understand the value proposition that BIM offers enabling adopters to more efficiently: Identify and evaluate stakeholder, user, community and sustainability project requirements Prepare project briefs and development programmes Assess and manage project risks and opportunities Prepare and present project design recommendations Assess, plan, estimate and control proposed development energy, whole life and capital costs etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MANAGEMENT</th>
<th>Overview</th>
<th>In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquiring internal resources</td>
<td><strong>A1</strong> Developing the business case, investment and return model</td>
<td>Understand the business case, investment and return model for BIM in order to be able to: Evaluate the benefits and risks of partnership and strategic sourcing Identify and resource the research and development of new products and services to meet market needs Identify opportunities to maintain and increase revenue Establish, implement and improve a business plan Allocate organisational budgets for projects Manage physical resources Manage business processes and improve performance</td>
</tr>
<tr>
<td></td>
<td><strong>A2</strong> Organisation and Project applications, and benefits of BIM</td>
<td>Understand the organisational and project applications and benefits of BIM in order to be able to: Identify and evaluate stakeholder, user, community and sustainability project requirements Confirm project energy efficiency and carbon minimisation requirements and strategies Establish arrangements for procurement and management of sustainable projects Prepare project briefs and development programmes</td>
</tr>
</tbody>
</table>
Overview

In relation to each of the learning outcomes below, as a result of following this course, individuals will be expected to:

O1 What is BIM
Understand the principles of building information modelling and its application to the whole life inter-disciplinary design, construction and use of building and infrastructure developments

Tech 1 Identifying project requirements
Understand how to gather, maintain and use BIM data in order to be able to:
Identify and evaluate stakeholder, user, community and sustainability project requirements

Tech 2 Assessing contextual data affecting potential developments
Understand how to gather, maintain and use BIM data in order to be able to:
Investigate and assess contextual factors affecting potential project developments
Identify, assess and take account of resource factors… etc
Investigate and assess regulatory and legal factors affecting potential developments

Tech 3 Developing design solutions
Understand how to gather, maintain and use BIM data in order to be able to:
Assess and develop sustainable project design options
Prepare and advise on project design recommendations
Assess, plan, estimate and control proposed development energy, whole life and capital costs
Plan and agree detailed project designs
Analyse and model environmentally sustainable project design solutions
Analyse, advise on and support sustainable solutions for historic and heritage assets
Manage health and safety in design
Investigate, develop and integrate detailed design solutions
Prepare applications and appeals to secure statutory consent
BAF aims to foster integrated collaborative working on projects over the lifecycle of the asset through academic involvement and the enhancement of BIM

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There has been a significant progress in the use of Building Information Modelling (BIM) around the world, especially in the last decade. In several countries, BIM has been employed into practice. However, the United Kingdom (UK) has not yet made noticeable use of BIM, although there are strong government policies in place to ensure the adoption of Level 2 BIM by 2016 on all UK public projects. Since the UK government is leading the implementation of BIM strategies, the higher education sector has become interested in developing new ways in teaching BIM process. Though, educational institutions in the UK are facing many difficulties, partly due to the novelty of the technology and the dilemma of current methods of teaching. Although, some educational institutions within the UK have begun examining the importance of preparing their students for a career in a BIM-enabled work environment. Yet, educators in universities are facing the same problems as many professionals within industry such as the misconceptions of the reality of BIM and the lack of understanding on how to implement the concepts of BIM. Preliminary research findings derived from an investigation of the current teaching methods is outlined to better understand and evaluate the contribution of BIM to the educational experience of students in construction degrees. Fundamentally focusing on balancing the students’ requirements and the industry’s desires to propose “best practice for teaching BIM within the UK”, in order to assist educational institutions on developing their teaching approaches to suit the evolution of BIM while maintaining the underlying principles of teaching construction degrees.

Keywords: BIM Education and training, BIM in curriculum, BIM in Construction courses, BIM in UK Education, BIM in Academia.

INTRODUCTION

Building Information Modeling (BIM) is seen as a fundamental change to the industry and all professionals serving it. The policy of implementing BIM within the UK by 2016 has indicating that the government is aware and interested in BIM benefits to enhance the control of time, cost and quality that BIM is proposed to offer to everyone involved including clients, designers, contractors, suppliers and facilities managers. Subsequently, many stakeholders have shown a slow but definite approach towards using BIM. However, according to Young, et al. (2008) and Bataw, et al. (2014), the lack of BIM knowledge and skills in the UK created great constraints delaying the use of BIM and generated great concerns for many professionals working within the industry and students undertaking construction degrees at university levels.
BIM IN EDUCATION

A number of researchers have examined whether BIM concepts and tools should be taught to students at university levels. Dean (2007) concluded in overall that educational institutions should teach BIM to their students, stating that graduates with BIM skills have an advantage over graduates who lack BIM knowledge.

Correspondingly, some of the UK’s largest graduates employers are concerned that their newly hired graduates will lack BIM knowledge, advanced computer skills and most importantly will lack the communication and team working skills that many graduates miss out as a result of studying construction degrees via the traditional methods (Dean, 2007). According to Fox and Hietanen (2007) students and graduates with BIM knowledge and skills are important individuals that can contribute to the use of BIM within their organisations.

In regards to construction students in the UK, recent study by Wesley (2013) indicated that only one Russell group University stated that BIM activities were introduced within their programmes with very little implications suggesting that undergraduate students were studying or even being made aware of BIM. This suggesting that many construction students would not be capable of working on projects using BIM once they graduate, which is generating a significant gap of knowledge that graduates and recruiting companies will face in the upcoming future.

Education at undergraduate levels in the UK will always be lagging behind the research being done at postgraduate level. In the case of BIM, it has been a subject researched for a number of years at postgraduate level. However, it was never introduced to the curriculum of the majority of educational establishments across the UK. This was due to the complexity of BIM theory and also the difficulty of the educational sector to introduce new technologies.

Approaches of teaching BIM

Through a literature review it was possible to identify how 125 schools are currently incorporating BIM into their curriculum; 97 schools are based in the United States and 28 in other countries (none in the UK). These schools taught BIM differently, 70% of these schools have taught BIM within existing courses either by integrating BIM within existing modules or as an individual module, while 30% have generated a new course to teach BIM. The emerged three approaches were as following:

1. BIM integrated into existing modules
   In simple terms, BIM tools, techniques and concepts were included within existing modules; this is usually done by developing the existing curriculum of each module to suit BIM practices. This structure appears to be the most preferred method used by the schools. However, it is the most complex approach and requires renovation of the existing modules.

2. BIM as an Individual Module
   BIM tools, techniques and practices were also integrated within the course as a new single module usually named BIM, but not isolated from the evolved course discipline.
3. BIM as an Individual course
Some universities found it more functional to develop a course that contains all BIM tools, techniques, theories and practices. This teaching method was rarely used but seem to be very popular to students especially in postgraduate levels.

The used term “Module” is referred to each set of standardised parts or independent units that can be taught within a course. While the term “Course” is referred to the whole program of study.

These approaches were designed in the initial steps of adopting BIM and were used by many construction courses around the world. However, universities in the UK are still uncertain which approach is most appropriate to adopt and therefore are behind with teaching BIM to construction students in all university levels. Hence, this research will focus on determining the most suitable approach to incorporate BIM within construction courses in the UK from the student`s perspectives and preferences.

As the case with any corporation, the customers must be considered and consulted when developing new services. In the case of the university courses, the customers are both industrial employers and students. As explained above, the industrial employers are concerned with BIM and are already seeking to employ graduates with BIM knowledge. Therefore, a survey was required to better understand the student`s requirements to raise their aspirations and educate them to become more discerning and competitive in the construction industry. Therefore, asking the students to take part in identifying the most suitable form of education is essential.

**QUESTIONNAIRE SURVEY**

An online survey was developed to outline the requirements and understanding of current construction students on teaching BIM within construction courses in the UK, sent to students undertaking construction courses in the UK from all university levels in the academic year 2013-2014. The survey collected data from students regarding their views on BIM and best practices of teaching BIM. The survey also inquired about the students’ expectations of BIM knowledge upon graduation and who they believe is reliable to provide and teach this knowledge.

An online link to the survey was emailed on three occasions to the sampled students within three-months period, between the months of January and April 2014. Responses were received from 1856 construction students from different programmes and academic levels, generating a response rate from 26 Universities in the UK teaching construction courses.

**Sampling approach**

The probability sampling technique was used to select the samples of construction courses to carry out this questionnaire survey. However, the student’s population in the sampled construction courses was too large and was almost impossible and time consuming to identify every student of the population to choose a specific sample for this questionnaire survey. Therefore, the non-probability sampling technique was the most appropriate to generate the best possible samples of students from the sampled courses.
The simple random sampling technique was used to increases sample's representativeness of the population to generate statistical inferences and allow for generalisation, where every construction course had greater chance and equal opportunity for selection. While sampling errors and sampling bias were minimised

However, the snowball sampling technique was used in the later stage due to the difficulty of accessing information on each and every student in the sampled courses. Where the snowball sampling technique was much easier, quicker and cheaper than probability sampling techniques to produce sufficient data.

The process started by breaking down the list of each construction course to the academic years. Then each academic year was assembled separately where similar academic years were gathered in one table, this process was carried out with every academic year. Once all the academic years were assembled and the population was distinct, the researcher used the simple random sampling technique to randomly select 25 of each year i.e. (25 x 1st year programmes, 25 x 2nd year programmes, 25 x and 3rd year programmes) adding up to construction courses from 29 different Universities in the UK. The simple random sampling technique was used for this stage to guarantee equal chance (probability) for each university and each academic year to be selected for inclusion in the sample.

Once the samples of the universities and academic years were selected, it was easier to identify and contact academics teaching members in these universities rather then the students, hence the Snowballing sampling technique was adapted as it is the most suitable and usable technique for sampling such a large amount of students, where the teaching academics were initially contacted to identify further suitable members (Students). According to Hussey (1997) and Saunders et al., (2003) snowball sampling technique can identify the only possibility when populations are difficult to identify.

RESULTS AND SUMMARY

The students were asked, “Has/ will BIM be taught in your current course?” with one option to choose from “Yes”, “No”, “Not sure” and “if yes (please describe)”. 27% (N= 501) responded “Yes”, 54% (N= 1002) responded “No”, while 19% (N= 353) responded with “Not sure”.

The 54% (N= 1002) who responded with “ No” were students from 18 different universities, indicating that at least 18 construction courses in the UK do not teach BIM to their students at university levels. However, students undertaking these construction courses will soon be graduates seeking for work within the industry but without any BIM knowledge, BIM qualifications or BIM experience.

The 27% who responded with “ Yes” were students from 6 different construction courses, at the beginning it seemed like a good number of universities are teaching BIM. However, when theses students were asked “If yes, please explain”, most of descriptions indicated that students were referring to CAD rather than BIM.
Also students were asked “which way do you prefer to learn BIM?” the respondents were asked to select “all that apply” when answering this question. 69% (N= 1281) Prefer to learn BIM integrated within their existing courses, 13% (N= 241) prefer to learn BIM (ONLY) within multidiscipline modules, combining different disciplines together, while 29% (N= 538) prefer the combination of the above i.e. learn BIM within the existing courses and within multidiscipline modules (combining different disciplines together). However, 9% (N= 167) prefer a dedicated BIM degree and 7% (N= 130) prefer to learn BIM in an Independent BIM training courses.

These results indicated that 1281 current construction students prefer to learn BIM integrated within their existing courses, which means that this method is the most preferred by the construction students in the UK. Furthermore, out of the 1281 students 538 also prefer to learn BIM within multidiscipline modules, combining different disciplines together.
In the last but not least question of the survey, the students were asked “Who should have the most responsibility in preparing Students/ Graduates to work with BIM?”. 80% (N= 1485) of the students suggested that universities should be responsible for preparing students with BIM knowledge, while 17% (N= 316) of the students suggested that the employers should prepare the students/ graduates toward working with BIM and only 3% (N= 56) of the students suggested that the software companies should be responsible in preparing students/ graduates to work with BIM.

This demonstrates that the majority of construction students mostly rely on their universities to prepare them for the industry. Indicating that Universities are required to rearrange some of the current programmes to better equip students for the growing demand of BIM. Therefore, universities should prepare their construction courses with the support of the major employers and software companies, to provide a theoretical understanding to their students with practical experiences and approaches in unison with the Software Companies to give practical examples of how it is intended to work.

![Figure 3. Responsibility in preparing students/ graduates to work with BIM? (N=1856)](image)

**DISCUSSION**

It is essential to comment on the response rates for this questionnaire survey. Responses were received from 1856 construction students in 26 different universities. This was encouraging for the authors and will also be encouraging to academics and professionals supporting the involvement of BIM within construction courses. The survey results concluded the following:

- The positive response rates indicate that students are taking an interest in learning BIM.
- In terms of teaching BIM, none of the results indicates real implementation of BIM within construction programmes in the UK.
- Construction students from 18 different universities in the UK have indicated that BIM was not even introduced within their courses, which means that these students will soon be graduates seeking work within the industry but without any BIM knowledge, BIM qualifications or BIM experience.
• Even though it wasn’t specifically inquired in the questionnaire, the majority of the respondents stated that they are currently undertaking Autodesk Revit within their courses, which indicates that universities are capable of teaching such technologies and the students are capable of learning these technologies.

• Construction students in their final year have indicated that BIM research topics have been introduced as one of the options for the dissertation themes to undertake in their final year as part of completing their construction course.

• None of the respondents stated or implied that they did not feel that BIM was important for their learning curve.

• As the interest of implementing BIM is growing, construction courses across the UK must be rearranged to better equip the students for the growing demand of BIM knowledge within the construction sector.

**CONCLUSIONS AND RECOMMENDATION**

The majority of the responding students indicated that the preferred method of learning BIM is by fully integrating BIM within the current construction courses. While more than the third also prefer to learn BIM within multidiscipline modules by combining different disciplines together.

The integration of BIM principles within the construction courses in the UK indicates that the core standards of the current taught construction courses will not change. Rather, BIM standards and capabilities can be introduced within the current curriculum to assist the students with understanding construction disciplines and concepts and to enhance the students' practical abilities and problem solving.

In Recommendation, educators should not commit to narrowing down the existing construction courses to a certain topic such as BIM even if it is currently dominating the industry. BIM is an idea that might fade in the near or distant future but the construction disciplines are professions that have existed for generations and will continue to do so, embracing the same knowledge and practices. However, it requires improvements to fit with the 21st century. The essential aspect of teaching BIM is technology and working in a collaborative environment, and that is what the educators should concentrate on. Whether BIM ideology and tools can be taught within the construction courses in the UK, construction will always be taught.

**REFERENCES**


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Appendix E: CONVR2014 Proceedings
THE CHALLENGES OF ADOPTING BUILDING INFORMATION MODELLING (BIM) PRINCIPLES WITHIN SMALL TO MEDIUM SIZED ENTERPRISES (SMEs)

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ABSTRACT: Building Information Modelling (BIM) has recently attained widespread attention within the Architectural, Engineering and Construction (AEC) industry involving the Government, institutions and the private sector. The new ‘evolution’ of BIM represents the development of the “virtual buildings” concept through the use of computer-generated n-dimensional (n-D) models, to help architects, engineers, constructors, clients and Facility managers to simulate, plan, design, construct and operate the facility throughout its whole life cycle. This evolution is aimed to provide an increase in construction productivity while also resulting in improved profit margins and sustainability, with the growing focus on a low carbon future. However, It is not known if there is a true understanding of BIM or a clear plan to help the implementation of BIM within UK’s industry specially for the small and medium enterprises (SMEs). In this paper, the possible use of BIM and future challenges for SMEs are discussed. First presented is the key concept of what BIM actually is including its advantages and disadvantages, highlighting the challenges to implementing BIM and why it is important for SMEs to understand these challenges especially within the current timeline of the UK BIM strategy. This research is based on the results of two recent questionnaire surveys along with case studies to present a quantitatively illustration of the potential benefits to SMEs implementing BIM.

KEYWORDS: Building Information Modelling (BIM), Small and Medium Enterprises (SME), BIM Implementation, BIM for SMEs, BIM Execution plan, BIM SME challenges.

INTRODUCTION

Since the UK government made a proposal in 2011 to implement BIM and required for all public projects to be formed using BIM level 2 by 2016, there have been a great growth of interest in BIM. However, this growth is mainly dominated by the large enterprises while most of the Small and Medium enterprises are left almost abandoned in this sensational evolution.

The intention of this paper is to investigate whether SMEs require support to reach the implementation requirement of BIM level 2, and to identify and present evidence of what challenges SMEs face when adopting BIM in their organisations. Since the UK Government is aiming to be number one BIM user in Europe over the next few years, a considerable amount of focus is therefore required to be given to the SMEs who dominate UK’s construction industry and highly involved in a great percentage of UK public projects. However, no research has been carried out to outline the current position of SMEs in the UK and summarise their requirements to be part of this evolution. Therefore, practical research is essentially required to asses the current position of SMEs and the challenges that they are facing while trying to implement BIM in order to provide solutions to BIM implementation from the SMEs prospective.
Why BIM

As gathered from the UK governmental reports such as the National Audit Office NAO reports illustrates that the industry is currently suffering from many common problems from using the traditional fragmented way of working due to projects complexity, health and safety control, lack of communication and difficulty of time, cost and quality control (J.W. Hinze, J. and Teizer 2011). However, the implementation of BIM could help reducing these inefficiencies within the industry (Henrik C. J. Linderoth 2010).

The Journal of Building Information Modeling (JBIM) have published in 2009, 2010 and 2011 a series of pilot studies and case studies on projects using BIM in the US, demonstrating how BIM operates as a bridge to communicate regular and reliable information across the scope of the project offering a successful and a clear understanding between the architects, engineers, construction professionals, facility managers and building owners; enabling these professional members to stay synchronized to improve accuracy and make knowledgeable decisions in advance, which reduces waste and helps to ensure the project’s success with a better control of cost, time and quality.

BIM is also considered to be a positive transition for designers, where they are supported by new means of technological tools that makes their work easier, smoother and faster while enhancing the quality of designs. Similarly, contractors can visually create models for estimating, fabricating and construction sequence within a shared collaborative model.

The design team and construction team feed information into the BIM platform. Once all required data information are placed within the BIM model, it can automatically present itself in floor plans, elevations, specifications, work sequences, quantity takeoff, etc. where all users can be able to access it and operate on it, instead of working from detached drawings and schedules in the form of countless separate paper documents.

Information within BIM can also automatically adapt when changes occurs to a set of data, along with a clash detection tool if changes are unsuitable. This is different to the traditional fragmented practice of numerous individual sets of drawings, where design and construction teams have to go back and manually change each set of drawings, elevation, specification, work sequence and quantity takeoff etc. According to case studies by Kaner et al. (2008) and Eastman et al. (2011), the use of BIM on projects reduced the number of information requests and order changes; it also improved the productivity and efficiency, especially in the design stages.

Issues of BIM

As mentioned above, JBIM series has demonstrated how BIM can be of extreme benefit to the industry and could assist in improving the industry; however, the authors don’t completely agree, as the use of BIM could also raise a vast number of issues that deserve serious consideration. Many clients in the UK are still hesitant toward the implementation of BIM as they are still uncertain and puzzled on what BIM really is. This is due to the nature of all participants within the industry and the high costs of BIM implementation owing to the required extensive training of all involved professionals, the cost of technical expertise, the costs of organising protocols and managing a network server to store and access the model.

Other issues stopping the Implementation of BIM are the Legal barriers surrounding liability, uncertainties to the Intellectual Property Rights, digital information exchange and ownership of the program, which could all be resolved in time.

BIM IMPLEMENTATION BARRIERS

As most of the above mentioned issues only occur during the implementation of BIM. The UK Government has adopted the BIM maturity Diagram approach developed by Mervyn Richard and Mark Bew in 2008 (BIM Industry Working Group, 2011) shown in (Figure 1). This approach has helped breaking down the implementation strategy of BIM in the UK into different levels. BIM level 1 is the use of design software features only within the design stage; this level is currently being used and widespread within the industry without any major implementation issues. On the other hand, BIM level 2 is an advanced method in using software technologies within separate disciplines. However, few things need to be considered and improved before the implementation of BIM Level 2 could take place within projects in the UK, as follow:

- The great need of intense awareness campaigns and training courses throughout the industry to clear the doubts and debates surrounding BIM.

- Likewise, full training is required for all professionals to get them equipped with their new responsibilities and roles throughout the use of BIM level 2.
Contractual amendments and software measures to be arranged to protect from data corruption and software tool failures especially when different stakeholders using different tools.

Figure 1: BIM Maturity Diagram (BIM Industry Working Group, 2011)

BIM Level 3 is the complete implementation of all BIM tools in a network-based integrated system. In this, all key members work in an integrated and collaborated manner using 3D design tools, 4D construction sequencing, 5D cost information and 6D project lifecycle management information. All of these tools are managed and sequenced by Industry Foundation Class (IFC) web services and standards. However BIM Level 3 implementation is not only a step up from BIM level 2 in terms of using software tools; it is also an elevation to a new way of working. BIM level 3 will require using 3D, 4D, 5D and 6D tools within one collaborative platform; this will also require amendments and considerations in order to make the industry ready for this evolution. Questionnaire surveys and interviews with professionals and UK Government officials for a PhD research carried out by Bataw, A in 2014 have generated the following BIM level 3 Implementation concerns:

- Costs – BIM level 3 will require significant investment from those across the industry. Taking into account the costs of BIM’s software and hardware as well as other costs, such as the extensive training of the different professionals, cost of technical expertise, costs of organising protocols and organising a network server to store and access the model. These costs raise the concerns of many small/medium enterprises within the industry, failure of these enterprises in fulfilling the cost requirements will generate a large gap between them and other “BIM-Ready” enterprises in terms of work quality, winning tenders, saving time and money etc.

- Industry mind-set - The current traditional way of working will not easily adjust to the high-tech collaborative way of working that BIM can bring into the industry. BIM level 3 will completely change the way that professionals approach their day-to-day duties, from the fragmented paper method to having to work within an informational collaborative model that requires regular communication between different participants from early stages. Therefore, duties should be considered and drafted within the contractual documents to ensure that all tasks are carried out according to the collaborative nature of BIM.

- Information control - BIM level 3 relies considerably on Information Technology and software systems, this reliance raises many concerns as to the need of various control procedures in order to record and control access and inputs. Also Data protection firewall systems and data backup features can be vital to eliminate and control data corruption and data loss. The BIM model is the core data platform of the project, one error within the model can be very costly and time wasting.

- BIM within contractual documents – BIM level 3 offers new roles and responsibilities for existing and new professions such as BIM managers and Architects and Draftsmen. Therefore, all projects should include a description of these roles and outline the duties of each professional role. Also contractual documents to include Model Ownership, Liability exposure and insurance policies.
We can now understand that enterprises operating on BIM can be more advanced than those who aren’t using BIM or behind with BIM levels. Yet, in the UK there is noticeable gap between the large enterprises and the small to medium enterprises; where larger enterprises seem to grasp the idea of BIM and are moving forward whilst SMEs are still mystified. This study is concerned with understanding the current position of SMEs within the BIM implementation process in the UK and their concerns on BIM.

RESEARCH METHODOLOGY

A questionnaire survey was formed to produce a view towards the population being studied. A combination of the snowball method and the purposive method was chosen to conduct this research due to the ideas of sampling involved. It was thought that this combination was best suited because the purposive method allowed for targeting a specific population of SMEs in civil engineering who were currently involved in BIM, either by using it or by trying to adopt it. The national BIM conference, RICS 2013 in London witnessed 23 SMEs that were interested in BIM. All attended SMEs were contacted about project involvement and to undertake the survey, they were also asked to pass on the survey to other professionals and SMEs in the industry that were interested in BIM or had involvement in BIM, which generated 14 more SMEs. However, Only 20 professionals out of the invited 37 completed the SME survey, whilst the rest of SMEs did not feel they had sufficient knowledge of BIM to complete the survey.

FINDINGS AND DISCUSSION

SMEs were asked the question, “Which definition closely matches your understanding of BIM”? The results are shown in Figure 2 below. The overwhelming choice was that Revit was the definition that best represented BIM and that it is simply 3D modelling software. This shows that many of the SMEs who are involved in BIM or interested in BIM misunderstand BIM to be just Revit and restricts in computer modelling software.

However, when participants were asked “Is your organisation currently adopting principals of BIM?” the results shown below in Figure 3. 50% of the participants (10) said yes, although when these participants were questioned on what they class as BIM adoption, 6 out of the 10 classed it as working with Revit. This shows that the majority are not actually using BIM and so the results for this question may have been affected by their own definition of BIM.
A major question was raised to the SMEs on what they thought was the biggest challenge with regards to BIM adoption. From the results shown in Figure 4, SMEs ranked the lack of government help as the biggest challenge to BIM adoption. Hence it is clear that the Government needs to do something to ease the pressure and provide some sort of a road map to guide SMEs through the implementation of BIM. The next two ranked challenges come under a similar topic that continues to remain year on year: the fact that there is a total lack of knowledge on what BIM actually is, not only for the engineers and designers but also for the clients means that the process of work will be fragmented when adopting BIM on a project.

Figure 4: SME ranked challenges to BIM adoption

Only 2 of the SMEs questioned had received help from the professional institutions. Other SMEs that had not received help or advice have left comments on the lack of help and advice from professional institutions. The most appropriate comments are as following:

- The professional institutions are informed and poorly educated on BIM.
- We need support and encouragement to help push BIM forward within the SMEs.
- We need lots of support from all the institutions involved.
- Advice received about BIM was very misinforming and confusing.
- The professional institutions do not really understand BIM fully so cannot provide useful advice.

However, almost all of the SMEs questioned have not received any help from the Government in regards to BIM implementation. The following comments were given by the SMEs on governmental advice and guidance:

- Government seems to leave it down to us to either get moving with BIM or get left behind.
- Any information they do provide seems to only relate to their own work and the much larger companies
  “When we asked for assistance with BIM adoption, we get no response”
- They just seem to pass the baton and no real ‘how to do’ information is forthcoming.
- They seem to be introducing more ideas to add to BIM before we can even catch up to understand BIM at first.
- I get the feeling implementation will be left down to us.
- Big concerns that the people pushing BIM do not have time to slow down and help us out.
- They just seem to point the way towards the recently set up BIM4SME group to have all the answers and deflect the questions.
- They seem more focused too much on the major public projects, adding more inclusions to BIM before getting it right and achieving mass implementation first.

All of the above comments lead to the same suggestions that the Government is leaving it up to the SMEs to implement BIM. There is a belief that the government is ploughing forward with BIM when everyone else has no idea what they are doing and again just left to get on and catch up. The only positive discovery is that the government point to a group set up by the BIM TASK group called BIM4SMEs. The group has regular meetings to solve problems and directly help SMEs with BIM so that everyone is ready before 2016. The BIM4SMEs task group meets all across the UK at the BIM regional HUBS. This is where all issues are raised and should be
attended by professionals from SMEs to overtake the lack BIM knowledge and have their concerns quelled and discussed. The BIM4SME group is supposed to help SMEs resolve all their problems and get them up and running with BIM while also helping to fully understand BIM.

To understand the perception of BIM within SMEs and what the current BIM knowledge is, the question was put forward to the SMEs involved was “What do they feel is the most important benefit of BIM?” The results from this question would provide information on what SMEs expect to get or gain from implementing BIM. From the results shown in Figure 5, there is an overwhelming response that the collaborative working involved in BIM is the major benefit. Collaborative working runs right through the BIM process. Selecting a benefit relating to the actual process, rather than a product of the process, could suggest that SMEs understand the major benefits of what BIM’s collaborative way of working could bring to the industry.

![Figure 5: SMEs perceived most important benefit of BIM implementation](image)

**CONCLUSION**

To conclude on the study, the SMEs and BIM survey suggests that there is still a significant lack of knowledge to what BIM actually is. This continues to follow the pattern of previous studies in 2010, 2011 and 2012 (NBS, 2012) and (NFB, 2012). Even though an increasing number of organisations are becoming more and more involved with BIM and its adoption process, in 2013 there is still evidence to suggest that SMEs do not fully understand BIM. In the conducted survey, the majority of the SMEs stated that the definition of BIM was best represented by being defined as just 3D modelling software such as Revit. However, as stated in the BIM definitions, BIM is a process and a way of working with the use of software tools rather than just software. Therefore, the results suggest that SMEs do not really understand what BIM actually is and the 50% of the participants stating that they were currently using BIM, may not actually be using the BIM process rather they are just using software.

The top ranked concerns to BIM adoption from SMEs perspective were the lack of government assistance and the lack of education, which is not only within their organisation but also with the clients they work with. It was also stated that only three of the SMEs involved in the survey had received help from professional institutions and only two SMEs received assistance from the government. However, this assistance was only in the form of financial help.

SMEs stated that they wanted more assistance from the government. There was a strong belief from the survey results suggesting that the government tends to avoid questions and enquiries asked by SMEs in regards to BIM and simply pass the baton on to another group to answer the questions. Also participants stated that concerns of the SMEs were mentioned by them at many BIM related conferences but seem to be avoided and responses were such as “everything will be fine, SMEs are at an advantage, it will all fall in place”; However, this frustrated the SMEs more and does nothing but increase the fears of BIM adoption.

There was also a strong feeling that SMEs are left on their own to sort out BIM for themselves and produce their own implementation strategy, a very bad idea considering the lack of BIM knowledge throughout SMEs and the industry in general. One of the participants commented on this option by saying “How can an organisation produce their own successful BIM implementation plan when they are severely lacking in knowledge in the topic?” There was a major feeling within the SMEs that the government continues to add extras to BIM requirements, before they have even successfully implemented basic BIM knowledge throughout the industry. The government wants to become the number 1 nation in BIM over the next few years (Cabinet office 2011). This cannot be possible if the rest of the organisations in the UK have no idea on what is going on and what is
involved. The BIM knowledge and implementation strategy needs to be implemented from the bottom up, starting with education at universities before moving on to smaller companies, medium size companies, and finally the large companies. This approach will enable the small “bugs” and problems in the process to be resolved before they get to the biggest scale and the biggest projects, thereby preventing the reputation of BIM from being damaged or misread.

Based on the conclusions, the recommendations to take forward from the findings would be to:

- Produce a set of BIM standards to attain BIM compliance within SMEs.
- Introduce accredited and certificated BIM training courses
- Provide opportunities for SMEs to work with larger BIM compliant companies to gain experience
- Suggest that the SMEs attend the BIM4SMEs group to help with BIM adoption
- Suggest that universities introduce BIM learning, with the opportunity to provide BIM learning to both students and professionals

The interest in a set of BIM standards to follow was common with all the SMEs. The SMEs indicated that a set of standards to follow would be very beneficial to them, not only for the 2016 implementation date but also beyond that date. The SMEs believe they will be able to check their internal process with the BIM standards set process and be confident in the level of BIM compliance they have to offer.

Based on the survey questions relating to the requirement of BIM training, the responses suggest a very high interest in undertaking BIM training courses. The highest interest related to full accredited courses, either provided by the professional institutions or by universities. Having such a high interest in BIM educational courses from professionals in the industry triggers the need for universities to take part in the implementation strategy of BIM.

The study also suggested that SMEs would be interested in the idea of working with the much larger BIM compliant companies to gain experience and learn from organisations that are currently operating BIM processes. Furthermore, if rentable access is provided to SMEs for BIM software, it would quell the BIM adoption problems of the expenses involved and the financial implications with regards to implementation. The biggest offset cost of providing training, purchasing full software and managing regular updates of BIM software will be replaced by working freely alongside BIM compliant companies. This solution would resolve two of the main problems in BIM adoption: costs and training.

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NBS, 2012; NFB, 2012; open BIM Network, 2012)


Appendix F: ARCOM 2013 Proceedings
MAKING BIM A REALISTIC PARADIGM RATHER THAN JUST ANOTHER FAD

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There has certainly been progress in the use of Building Information Modelling (BIM) around the world, especially in the last decade. In several countries BIM have been put into practice and employed. The UK industry has not yet fully implemented or made use of BIM but there is a strong drive from the government to adopt BIM Level 2 on all UK public projects by 2016. However, there is as yet no clear roadmap to ensure the adopting of BIM is accepted and progressed in the correct methods. The complexity and nature of BIM needs to be addressed and outlined to ensure all participants are “BIM ready” before 2016. The aim of this paper is to outline a clear understanding of the barriers and hazards surrounding the use of BIM to give comfortable consideration on the implementation of BIM. First, the current implementation of BIM around the world is explored to outline the process of BIM across different countries and understand their practices. Then the key concept of BIM including advantages and disadvantages within the current AEC industries is investigated. Followed by a comprehensive research on the challenges of implementing BIM and why it is important for all participants to understand these challenges especially within the current timeline of the UK BIM strategy. This research is based on broad literature reviews, along with results of two recent questionnaire and Interviews to present a qualitative illustration of the current situation and the concerns of implementing BIM within the UK.

Keywords: Building Information Model (BIM), Virtual Design and Construction (VDC), n-Dimensional Modelling, Parametric Modelling, Facilities Management (FM).
INTRODUCTION

Technology was first introduced into the industry in the early 1980s under the Virtual Building concept by Graphisoft’s ArchiCAD now known as ArchiCAD. This was the start of the software revolution that allowed architects to create virtual, three dimensional (3D) designs of their project instead of the standard two dimensional (2D). Since then, new technologies and updated software were developed and used. However, this use of technology was only limited to the design stage, until the concept of Building Information Modelling (BIM) was introduced. This advanced system was established to assist architects, engineers and construction professionals in storing and communicating all the amounts of datasets such as the building geometry and spatial data as well as the properties and quantities right from the inception of early stages throughout to demolition.

The use of BIM is aimed for much more than just performing a model to see what the building should look like; BIM intend to create a model that contains all kinds of information, from spaces and geometry, to costs, personnel, programming, quantities, specifications, suppliers and other information types. To be well-managed and qualitative this information is contained in such a model where it is all related and built on each other to provide the best solution, enhance decision making, improve production to high level of quality, enhance prediction of building performance, major time saviour, and control the budget in a safer environment within an organised collaborated way of working.

In the last decade BIM stood out as a very beneficial process due to the excellent benefits and the successful use around the world; therefore, later in 2011 the UK government proposed to implement BIM by 2016 to eradicate many inefficiencies within the industry and to bring in a modern way of working to make it a pleasant working atmosphere as well as making shared information easy to visualise and understand, providing greater efficiency and quality. However, this technology on its own cannot provide the final solution as the industry has always been managed by the current “Fragmented” way of working. Therefore, it is essential to initially change the current way of working in order to adapt with the use of BIM. The UK Government has published a BIM strategy plan in March 2011, which outlined the importance of BIM use and implementation contents. However, this strategy cannot be used for implementation guidance. The need for an implementation plan is not only required for the sake of giving a clear roadmap for the industry but also to give viable information on what to be considered before using BIM.

“Change without a plan ultimately ends in chaos. If we fail to plan, we will have squandered the tremendous opportunity that is available to our industry.”

(Henry, I. JBIM. 2009)
CURRENT PRACTICES OF ADOPTING BIM AROUND THE WORLD

BIM have rapidly spread around the world. Many countries around the world have exposed great interest towards implementing BIM within the construction industry but each country has its own arrangements and progressed differently.

BIM in the USA

The USA was the earliest initiator of BIM especially within the public sector. In late 2006 the US General Services Administration (GSA) issued a BIM-guideline outlining an implementation plan to accompany the integration of BIM use within the US AEC sector in general and the Public Building Service (PBS) in particular. Following that, in 2007 the US GSA issued a mandate to obligate all planners to use BIM while applying for GSA’s funding schemes (GSA, 14).

In addition to the widely recognised benefits of BIM that the public sector was mainly profiting from, the US AEC sector established BIM’s policies by addressing the allocation of risks associated with the implementation of BIM, outlining the roles and responsibilities of each participating party while avoiding any conflicts with the existing construction contracts policies. This has encouraged many stakeholders to use BIM as proved by the American Institute of Architects’ report on the Business of Architecture (2010), confirming that 60% of US architects are using BIM throughout their projects.

BIM in Finland

The Implementation of BIM within Europe was initiated later than the USA but showed a faster and wider improvement within the industry especially in Finland (as shown in Figure 1). According to the Finnish ICT Barometer for all architects in Finland (2007), 93% of architects are using BIM in current projects with 33% of that usage at BIM level 3. In the same survey it was observed that nearly 60% of Finland’s engineers are using BIM in both the public and private sectors (Kiviniemi, 2007).

This spectacular spread of BIM use within Finland is due to increased interest by the Architectural Engineering and Construction (AEC) and Facilities Management (FM) companies in profiting from the benefits of BIM. Starting from 1st October 2007, they focused on using BIM’s model technology within common project works. In 2009, they established detailed modelling guidelines to assist the use of BIM during the design stages. This was used by the governing body of public properties to run several pilot projects, showed a great impact in making decisions for Senate Properties’ investment processes and enhanced developments within the private sector (VTT, 2007).
BIM did not only reach the public sector but also the private sector, where several major companies such as ‘Skanska Oy’ and ‘Tekes’ have taken the lead in working with BIM (Kiviniemi, 2009). Numerous researches with local Universities such as Tampere University of Technology were also highly involved in investigating the benefits and outcomes of BIM practice within the industry to promote the potential implementation of BIM, developing technical tools and investigating the potential of BIM in providing solutions sustainability within the industry. (Leicht et al. 2007) (Huovila, 2008).

**BIM in Singapore**

BIM concept was first introduced in Singapore in early 1995 by Singapore's Ministry of National. This gave organisations such as ‘Development Construction and Real Estate Network’ (CORENET) an early involvement to develop and implement BIM within government projects.

Singapore’s government was successful in pushing for BIM implementation and BIM standards on various kinds of projects in the public and private sectors with the help of CORENET’s BIM Guideline “Integrated plan checking” (Khemlani, 2005). This has noticeably enhanced the number of public-private initiatives to encourage the use of BIM in a number of large pilot projects.

**BIM in India**

India’s fast growth of population and economy has generated a boost in the building environment which provided the perfect platform to implement BIM. India has a strong workforce of Qualified, Trained and experienced BIM specialists who are not only implementing BIM technology in India’s Construction Projects but also assisting on the implementation of BIM in Canada, USA, UK, Singapore and Middle East regions.

**BIM in Canada**

The Institution of BIM in Canada (IBC) has taken the responsibility to lead and facilitate the full Implementation of Building Information Modelling (BIM) into the Canadian built environment, their main interest is to focus on the primary stakeholders allowing them the right method and pace to understand their roles and responsibilities and to assess their capacity to contribute in this process.

**BIM in the UK**

The UK Government has already shown their awareness of BIM’s benefits in controlling cost, time and quality and the advantages it could offer to everyone involved in the construction industry, including clients, designers, contractors, suppliers and facilities managers. On 31st May 2011 the Government showed its interest in BIM by publishing a construction strategy report that announced that the
Government aims to adopt BIM technologies, process and collaborative behaviors into all stages of the life-cycle of public projects worth more than £5 million by 2016. This is expected to advance the use of BIM as shown in figure 1.

Figure 1: Levels of BIM implementation within Europe

However, to reach these expectations, everyone within the industry will have to step up quickly to reach the required BIM awareness level. Questionnaires were distributed in March/April 2013 to a large number of professionals in the UK alongside interviews with different Academics. 84 participants flagged the concern of misunderstanding BIM and its concept. The response showing in the graphs below expresses the tardiness of many practitioners and organisations towards BIM understanding and adoption.

<table>
<thead>
<tr>
<th>Are you or is your organization aware of the challenges of implementing BIM?</th>
<th>Are you concerned about BIM adoption in your organization?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not sure 15%</td>
<td>No 22%</td>
</tr>
<tr>
<td>Yes 20%</td>
<td>Yes 78%</td>
</tr>
<tr>
<td>No 65%</td>
<td></td>
</tr>
</tbody>
</table>
Those participants who were concerned with BIM adoption were asked an additional question to rate their concerns of BIM adoption challenges. From the results showing below and the comments that were obtained from this research and interviews, an outstanding distress was discovered on the concern of BIM adoption and many professionals seemed to know about BIM but fail to have any knowledge of how and when to adopt it. Also, many realise that adopting BIM is a challenge to many organisations but don’t seem to know what the real challenges are. Therefore, a detailed manuscript is required to outline all the challenges of BIM adoption in the UK.

**Rank the following BIM adoption challenges**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Government help and advice</td>
<td>100</td>
</tr>
<tr>
<td>Lack of educated clients</td>
<td>90</td>
</tr>
<tr>
<td>Lack of BIM education</td>
<td>80</td>
</tr>
<tr>
<td>Legal Issues</td>
<td>70</td>
</tr>
<tr>
<td>More work and fees at risk early in the project</td>
<td>60</td>
</tr>
<tr>
<td>Set up costs and financial support</td>
<td>50</td>
</tr>
</tbody>
</table>

**ISSUES OF BIM**

No doubt, BIM can be of extreme benefit to the industry and potentially improve the industry; however, the use of BIM in the UK could raise a vast number of issues that deserves serious consideration. In essence, it is only as good as the people using it. Many clients are still hesitant toward the implementation of BIM as they are still uncertain and puzzled on what BIM really is. This is due to the nature of all participants within the industry and the high costs of BIM implementation owing to the required extensive training of the different professionals, cost of technical expertise, costs of organising protocols and managing a network server to store and access the model.

Other issues stopping the Implementation of BIM are the Legal barriers surrounding liability, uncertainties to the Intellectual Property Rights, digital information exchange and ownership of the program, which could all be resolved in time.

These issues might appear to be barriers to implementing BIM but many researchers concluded that these issues could be controlled with the support of the government.

**EMERGING PROBLEMS DURING THE IMPLEMENTATION OF BIM**

Most of the above mentioned issues would only arise while using BIM level 3. Implementing BIM level 2 should not create significant additional risks; nevertheless some amendments might be required to smooth the implementation of BIM.
BIM level 1 only contains the use of design software feature within the design stage; this level is currently used and widespread within the UK without any major implementation issues. BIM level 2 is an increased method in using software technologies within separate disciplines. Few matters need to be amended and improved before the implementation of BIM Level 2 could take place within projects:

- The great need of intense awareness campaigns and training courses throughout the industry to clear the doubts and debates surrounding BIM and fully training all the professionals towards their responsibilities and roles throughout the use of BIM.

- Level 2 Implementation will require the removal/major amendments to the intellectual property legislation.

- Contractual amendments and software measures to be arranged to protect from Data corruption and software tool failures especially when different stakeholders use particular tools.

- Organisations operating on level 2 BIM might become limited during tenders when level 3 BIM is fully implemented by others.

- BIM protocol is recommended to be set up during the procurement stage to address risk sharing, detailed responsibilities of all users, technology level of each model, level of definition and an exclusion of liability. All to be clearly outlined within the agreements between the Employer and those responsible for the BIM model (Beale and Company Solicitors LLP, 2013).

Level 3 BIM implementation is not just a step up from level 2 in terms of using software tools; it is also an elevation to a new way of working. BIM level 3 will require using 3D, 4D, 5D and 6D tools within one collaborated platform, this will require many amendments and considerations in order to make the industry ready for this evolution. As detailed below:

1. Barriers to implementing BIM on existing buildings

There have been attempts to use BIM for older/pre-existing facilities. This can only be done if the existing facility was built through BIM or been converted into the form of BIM. However, converting an existing building into a BIM model would require numerous assumptions such as the standards and codes of the existing building design, the used construction methods and the materials used at the time of construction. (Boeykens, S. et al. 2012).
2. Barriers to implementing BIM on New buildings/Projects:

- **Cost** – BIM level 3 will require significant investment from those across the industry. Taking into account the costs of BIM’s software and hardware as well as other costs, such as the extensive training of the different professionals, cost of technical expertise, costs of organising protocols and organising a network server to store and access the model. These costs raise the concerns of many small/medium enterprises within the industry. Failure of these enterprises in fulfilling the cost requirements will generate a large gap between them and other BIM using enterprises in terms of work quality, winning tenders, saving time and money etc.

- **Industry mind-set** - The current traditional way of working will not easily adjust to the high-tech collaborative way of working that BIM offers to the industry. BIM level 3 will completely change the way that professionals approach their day-to-day duties, from the fragmented paper method to having to work within an informational collaborated model that requires regular communication between different participants from early stages. Therefore, all project team members that have responsibilities; duties should be considered and drafted within the contractual documents to ensure services are carried out according to the collaborative nature of BIM.

- **Information control** - BIM level 3 considerably relies on information technology and software systems. This reliance raises many concerns as to the need of various control procedures in order to limit and control access and inputs, data protect with firewall systems, data backup features in case a corruption of data appears, provide technical support facilities and professionals etc. The BIM model is the core data platform of the project; one error within the model can be very costly and time wasting.

- **Ownership** - so many debates currently surround this topic; all the stakeholders within the industry are concerned with who should obtain the final version on the model and surrounding data. These debates are mostly due to the misunderstanding of the concept of BIM; if they correctly categorise the model generated by BIM as a product then legally it should only be retained by the buyer i.e. client. However, the data contained within the BIM model is a separate issue. This data is generated from contributions of various team members; they should be authorized to obtain a copy of their contribution for future records. These issues should be considered and discussed by the government to outline and verify the legal regulations towards ownership of the BIM model and surrounding data during and after construction.

- **Liability exposure** - different professionals from various enterprises contribute toward the BIM model throughout different stages of the product’s life cycle
through a collaborative software system, this new way of working may create irregular liability issues. BIM’s software system is protected by “blanket limitation of liability” clauses that generate the question of who is liable for any software errors caused by the software. Another concern is who is reliable if works were carried out incorrectly due to inaccurate information given by a different professional in the early stages? This risk should be dealt within contractual protocols and carried out accordingly to distribute risk and liability evenly.

- Insurance - few insurance companies currently offer to insure BIM. But due to the limited use of BIM and doubtful impressions surrounding BIM’s benefits and risks, it seems to be incredibly expensive to insure but it is expected to reduce once BIM is successfully implemented within projects. For the time being, it is important for parties to consider taking out the appropriate insurance to cover their engagement in the BIM process to obtain their usual coverage and protect themselves against liabilities and risks.

- BIM within contractual documents – BIM level 3 offers new roles and responsibilities for existing and new professions such as BIM managers and Architects and Draftsman etc. Therefore, all projects should include a detailed brief of these roles and outline the duties of each profession role to suit the use of BIM within projects. Making sure the same set of BIM privileges and requirements are flowing through the different contracts to avoid clashes between the clauses of the principal contract and the legal terms of the BIM protocol.

CONCLUSIONS

It is arguable that the future of the construction industry can benefit from the integration of BIM in order to improve the current fragmented way of working, overtake the overpowering issues and possibly provide potential solutions and advantages to the industry. As of the undertaken literature review and case studies, BIM implementation can possibly provide enhanced products throughout the industry by:

- Reducing errors and omissions, this will make works smoother, reduce RFIs, reduce professional liabilities and insurance costs.
- Provide opportunities to discover errors in early stages, earlier error discovery reduces repair costs in comparison to discovering them once project design progresses.
- Reduce time. Where involved managers, designers and drafters can spend less time developing designs and more time providing creative solutions for clients.
• Have a positive impact on firm’s reputations with an increased number, scale and variety of opportunities
• Enhance the reputation of the industry towards sustainability and efficiency
• Increased client satisfaction through visual verification of design intent
• Enhanced way of working with knowledge sharing and virtual Design before construction.

Although these benefits might appear astonishing, they are currently only presented on paper because in reality BIM could just be another idea that could not proceed due to the lack of valuation and misunderstanding. Therefore, detailed implementation plans and arrangements are required to assist with the government’s strategy of working with BIM by 2016, which is currently realistically impossible due to the many unclear points surrounding BIM and the obstructions of BIM Implementations. The query of a well-built implementation plan was raised from the research due to finding the necessity of outlining and applying the required procedures throughout all participants within the industry, such as:

• Communicate and enhance the understanding of BIM, this could be done by providing a wide range of seminars, conferences, workshops and training courses to existing professionals in all sectors. As well as promoting the publication of articles and carrying researches on BIM.

• Organise and provide many educational and training sessions to allow the new professionals to have the correct knowledge and skills to blend with BIM applications to ensure the new and old professionals within the industry are ready for the 2016 digital BIM switchover.

• Set up clear definitions of roles and responsibilities of each different participant within the new way of working.

• Locate who is responsible for setting up the level of BIM and model standards applied within a project, and when.

• Outline the required outcomes from the use of BIM within projects.

• Examine the contractual and legal issues to find solutions to ownership, sharing, copyright, IP allocation and Insurance and issue a framework to outline the legal process and procedures of BIM.

• Establish BIM guidelines for the UK that can also be integrated with international BIM guidelines.
These brief bullet points need to be broken down and investigated to outline a proposal plan to make the implementation process of BIM clearer and closer to reality in the eyes of all involved parties within the industry.

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