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ARCHITECTURAL TECHNOLOGY AT THE INTERFACES

ICAT 2018

TAHAR KOUIDER
GARETH ALEXANDER

CONFERENCE PROCEEDINGS OF THE 7TH INTERNATIONAL CONGRESS OF ARCHITECTURAL TECHNOLOGY ULSTER UNIVERSITY 14-17 JUNE 2018

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We wish to record a further note of appreciation to Dr Niels Barrett, who was instrumental in the formation of the ICAT Board and Congress, and has served as the first chairperson. Having recently retired, Niels is stepping down from the ICAT Board. We hope that his association with ICAT will continue in the future, and we wish him well in the next chapter of his life.

FOREWORD

I am delighted to be able to present the proceedings of the 2018 ICAT conference in Belfast. The conference theme articulates the evolving nature of the issues that face architectural technologists and associated professionals. Change is constant in the modern construction industry. Challenges and opportunities seem to grow at every level from local to global. The roles and responsibilities of individuals and organisations diversify and change even while associated issues are debated. There are dire predictions with regards to skills shortages in the construction sector in many countries. At the same time, the proliferation of new technologies provides a wealth of practical and viable solutions. Innovative methods and practices are emerging that will help to address the challenges and problems with further alternatives to be explored. All the while collaboration and digital processes are fundamentally altering the way the industry operates.

Architectural technology arguably finds its roots in the traditional role of the master builder. A variety of roles have emerged in recent centuries including that of the architectural technologist. Architectural technology is right at the core of the industry, where the interplay of challenges and opportunities provides fertile ground to enhance and influence construction, the economy and society. Varied factors meet at different interfaces and our academics, professionals and students have the opportunity to lead in the enhancement of the built environment. The proceedings of ICAT 2018 highlight some of the excellent and innovative work currently being undertaken in the discipline of architectural technology. In line with the intentions of ICAT, the congress is a vehicle to disseminate research, education and practice related to architectural technology. I trust that each who participates in the congress, or peruses the proceedings, will be caused to engage with further innovations at the frontline, or as it were the interface.

Gareth Alexander, Conference Chair
Belfast School of Architecture and the Built Environment

CIAT VS. ARCHITECTURAL TECHNOLOGISTS IN PRACTICE

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Abstract: Some understand Architectural Technologists to be professionals who make abstract design proposals more practical for use. However, in reality, does this line of thought hold any factual basis? This paper will analyse the opinions of various professors and writers to gain insight into how academics view the Architectural Technology field. This paper will examine the writers' current understanding of Architectural Technology and how they believe the field will develop in the future. Technologists are constantly adapting to new trends and ideas within the construction sector. Therefore, analysis will be provided regarding how the Architectural Technology field is adapting to the requirements of Building Information Modelling (BIM) and the challenges that BIM poses to the profession. The findings of the academic analysis will then be studied against the results of a questionnaire that was completed by Architectural Technologists who are currently in practice. The questionnaire was a necessary inclusion into this study as it is important to also understand the thoughts of those who are actively practicing within the profession. Finally, a conclusion will be provided which summarises the findings of the paper. This will also include a recommendation on how the Chartered Institute of

Architectural Technologists (CIAT) could make the reality of the Architectural Technology field better known to the public.

Keywords: Architectural Technology, generalist, specialist, discussion, architecture.

1. Introduction

The Society of Architectural and Association Technicians was formed in 1965 following the Royal Institute of British Architects' recommendation that a separate institute be formed to oversee Architectural Technicians (CIAT History, 2018). The institute would go on to be rebranded as the British Institute of Architectural Technicians in 1986 before gaining Royal Chartered status in 2005. The institute would subsequently become known as the Chartered Institute of Architectural Technologists and full Members would be given the title of 'Chartered Architectural Technologist' (CIAT History, 2018). Today, the Chartered Institute of Architectural Technologists (CIAT) oversees the development of both Architectural Technologists and Technicians.

In defining Architectural Technology, CIAT (CIAT Homepage, 2017) states that the Architectural Technology profession is:

"the technology of architecture; a creative, innovative design discipline rooted in science and engineering. It forms the link between design and realisation. At its core, is the anatomy and physiology of a building or structure, its relation to context, how it is assembled and how it performs through form, function and fabric."

Architectural Technology achieves efficient and effective construction and robust sustainable design solutions that perform and endure over time."

Whether you need a design or plans for your project, or a qualified professional to guide you, a Chartered Architectural Technologist, MCIAT, can manage all stages from the earliest designs through to final certification, regardless of its size or value" (CIAT Homepage, 2017).

It is clear from CIAT's characterization that the institute views the Architectural Technology profession to be a diverse inclusion of different elements. Features of design such as "science", "engineering", "form", "function" and "fabric" all play a role in defining Architectural Technology (CIAT Homepage, 2017). From the statement above, one could assume that the profession is comprised of different subdivisions in which Technologists may choose to specialise in or forgo in order to become general practitioners. However, are academics and industry professionals also inclined to view the Architectural Technology profession in such a light? Or are they more inclined to believe that Architectural Technologists exist in order to deliver specific tasks within design, such as architectural detailing? This question will be answered in conjunction with further analysis throughout this paper. The analysis provided in this paper will also focus on the extents to which academics view the roles of Architectural Technologists and Architects to be distinct from one another. The comparisons between the two professions will be provided in more detail in the latter stages of the Literature Review once the official definition of an Architectural Technologist has been clarified.

This paper will also attempt to analyse how the skills that Architectural Technologists have developed over time both through practice and academia are being utilized within the field of practice. Through the findings of this paper, questions will be answered as to whether the Architectural Technology profession is seen as a specialism within the Architecture field or if it is a broader inclusion of more diverse ideas. Furthermore, the results of a questionnaire will be used for this study in order to discover any areas of disagreement between the authors and the individuals who are actively involved in the profession.

2. Literature Review

2.1 WHAT IS AN ARCHITECTURAL TECHNOLOGIST AS DEFINED BY THE CIAT?

According to the Chartered Institute of Architectural Technologists, (CIAT Chartered Membership, 2015) one must fulfil certain requirements in order to be able to legally refer to themselves as a Chartered Architectural Technologist. Practitioners must earn the right to be able to legally refer to themselves with the mentioned title once they have fulfilled a number of educational and practical requirements. Only then may they be able to legally use the CIAT's logo on official business documentation and other legal documentation (CIAT Chartered Membership, 2015).

2.2 ACADEMIC ANALYSIS OF THE PROFESSION

In Nuclear Architecture: Perceptions of Architectural Technology, the authors (Robertson & Emmitt, 2016) attempt to explore what they characterise as being the 'pluralist' nature of the Architectural Technology programme. Robertson and Emmitt highlight the importance of the intertwining between initial creative ideas and the construction implementation process (Robertson & Emitt, 2016). Robertson and Emmitt emphasise what they believe to be two distinct forms of engagement within the Architectural Technology field. The first being specific training in a distinct field which will cater to solving particular problems. The second field is to embed the Technologist into a largely creative environment, whereby the Technologist embraces different opinions from professionals of varied backgrounds. This is done with the aim of getting the Technologist to embrace a more general understanding of the architectural field before appropriating the newly gained knowledge into a particular situation. This echoes the rhetoric of that of the CIAT. The broad development system that Technologists may utilize becomes better understood when compared with CIAT's framing of the Architectural Technology profession. CIAT mentions that the field is sympathetic to Technologists who hold "the form, function and the fabric" of the building in high regard. The "form, fabric and function" are three different areas of design that require different sets of skills in order to be executed successfully. The notion that Technologists may develop abilities within different fields is a belief that Robertson and Emmitt appear to agree with. (CIAT Homepage, 2017; Robertson & Emmitt, 2016).

In the paper: The Rise of A Profession within a Profession: The Development of the Architectural Technology Discipline within the Profession of Architecture (Barrett, 2011) author Niels Barrett characterizes Architectural Technology as a 'new specialization' within the Architecture field. Barrett then attempts to analyse the meaning of 'performance' within the context of CIAT's definition as advertised on their website. Barrett comes to the conclusion that 'performance' refers to all of the components within the building, including designing, detailing and the management process of construction projects. However, upon further reading, Barrett refers to a print at a 2008 Copenhagen conference regarding Architectural Technology. Barrett explains that the front page of the program described the Architectural Technology profession as one that provides the techniques on how to assemble the building. This is following the initial creative sketches and models that are produced by the Architect (Barrett, 2011). The definition of Architectural Technology at the Copenhagen conference that Barrett refers to appears to be at odds with Emmitt and Robertson with regard to the primary function of the Technologist. Whilst the Copenhagen Conference, Barrett emphasises the specificity of technical design, while Emmitt and Robertson emphasize the importance of creative environments. Such environments influence the Technologist to embrace a more general understanding of building design (Emmitt and Robertson, 2016).

Yazicioglu and Emmitt (2013) make direct comparisons between the academic requirements that distinguish Architectural Technology from Architecture in the paper: A comparative analysis of Architecture and Architectural Technology Undergraduate degree programmes in The UK (Yazicioglu & Emmitt, 2013). They begin by clarifying that the Architectural Technology courses are provided by newer institutions that cater to more vocational courses. The Architecture programmes, by contrast, are generally offered by older institutions such as The University of Sheffield and The University of Bath. These institutions tend to focus on a more academic syllabus. The authors make a number of conclusions regarding how the Architectural Technology field is developing and where it is headed. Yazicioglu and Emmitt note that there may be a perception amongst prospective students that the Architectural Technology discipline may not be as desirable as that of an Architect. This is due the fact that the status of the Architect may be perceived to be more appealing than that of a Technologist (Yazicioglu & Emmitt, 2013). Upon further reading, one finds evidence that may support their claim. The RIBA salary guide finds that Technologists on average earn less than Architects do (RIBA, 2017). However, Yazicioglu does mention that this perception amongst industry professionals may be due to the fact that the Architectural Technology profession is young when compared to its Architectural counterpart (Yazicioglu & Emmitt, 2013). Should CIAT's name recognition expand over time, the role of an Architectural Technologist will become better known within contemporary culture and the profession may become more desirable to prospective students as time progresses.

2.3 HOW THE ARCHITECTURAL FIELD IS DEVELOPING.

In a 2016 Building Futures study, author Claire Jamieson takes issue with the lack of entrepreneurial tendencies amongst those within the Architectural professions (Jamieson, 2010). She highlights that only half of the Architectural practices in the UK have business models. Moreover, the Building Futures study states that architectural practitioners as a whole need to take greater interest in understanding the "social and commercial environment in which their clients operate." An interesting finding of the study showed that when the study asked Engineers what the future held for building design they felt that the construction industry would become more dominated by Engineers. They believe this to be the case unless Architects became more technical in the future (Jamieson, 2010). Furthermore, the article goes on to explain that multi-disciplinary and commercial based practices are likely to provide the biggest number of opportunities for Architects in the future. It is possible that Technologists will therefore be able to relate better to the technical questioning of the other disciplines such as Civil Engineers. This is due to the fact that Technologists are generally understood to be knowledgeable of the detailing aspects of building design as Niels Barrett alluded to in his study.

2.4 ADAPTATION TO THE REQUIREMENTS OF BIM

Building Information Modelling is a basis on which information can be shared across many different disciplines. It has been brought about in order to improve communication and efficiency within the construction sector. Since 2016, The British Government has been attempting to implement a BIM level 2 programme on buildings that are deemed to be publically procured (Paterson and Kouider, 2013). The importance of BIM is underlined in Armstrong and Allwinkle's 'Architectural Technology: The Technology of Architecture'. They characterize the transition to BIM as being "a major opportunity". They see it as being a necessary move for Architectural Technologists in order for building designs to become more advanced, "efficient" and "effective" (Armstrong and Allwinkle, 2017). Paterson and Kouider go on to raise concerns about the implementation of BIM in their case study of 'Architectural Technology and the BIM Acronym'. They believe that BIM is being introduced to an older generation whose general knowledge of computer technology is not as advanced as that of their younger colleagues. Paterson and Kouider go on to explain that the technical and modern nature of the Architectural Technology course means that younger Technologists are in a good position to adapt to BIM's requirements. Kouider and Paterson go on to state that many Technologists are opting to become BIM Managers in practice, which shows how the profession is adapting to the new BIM requirements (Paterson and Kouider, 2013). However, Paterson and Kouider go on to discuss that the "human and financial resources' needed to create a successful BIM Model within the practices is substantial. Therefore, time will tell before BIM will be embraced on a substantial level across practices of all sizes or if it will become a luxury for larger practices (Paterson and Kouider, 2013).

3. METHODOLOGY

The study consists of a questionnaire that has been formatted on the Survey Monkey website. The purpose of this study is to gain insight into the opinions of Architectural Technologists that are currently working within the construction industry. It was necessary to have such a questionnaire as the format allows for as broad of a response as possible. The research gathered in this questionnaire is qualitative. Only respondents who describe themselves, as Architectural Technologists were offered the opportunity to take part in this questionnaire. This is due to the fact that this study relates in main to the Architectural Technology profession. The Questionnaire had a multiple choice response format. The respondents were asked to respond to basic questions regarding their backgrounds and their personal opinions of the

Architectural Technology field. The favourability scores were ranked on a scale of one to five, with five being the highest and one being the lowest score (Mahdmina, 2017).

4. RESULTS

As of April 2018, a total of thirteen responses were collected for this particular survey. The results of each of the different questions are as follows:

4.1 QUESTION 1: WHAT IS YOUR AGE?

It was important to gain an understanding of the age groups of the participants. The overwhelming number of respondents fell within the eighteen to thirty-four age groups.

4.2 QUESTION 2: DO YOU FEEL THAT ARCHITECTURAL TECHNOLOGISTS SHOULD HAVE MORE, EQUAL OR LESS POWER OVER PROJECTS THAN ARCHITECTS DO?

The Architectural Technology profession is considered by some to be a combination of different components and ideas. However, in the literature review, Niels Barrett generally characterized the profession as being a speciality within the Architecture field (Barrett, 2011). There appears to be a disconnection between the opinions of Barrett and active Technologists with the majority believing that their profession is equal to that of an Architect. Seventy-five percent of respondents believe that Technologists should have equal power to an Architect in addition to twenty-five percent believing that Technologists should have more power.

4.3 QUESTION 3: ON A SCALE OF 1 TO 5 HOW IMPORTANT DO YOU FEEL CONCEPTUAL DESIGN SKILLS ARE IN YOUR JOB?

Conventional wisdom amongst construction industry professionals leads some to believe that conceptual design skills should typically be provided by more creative disciplines. However, the majority of Technologists believe that their profession should also provide this service, albeit to varying extents. Around eight percent of respondents voted two on a scale of one to five. Moreover, around thirty-nine percent of respondents voted three on a scale of one to five. Furthermore, twenty-three percent of respondents voted four on a scale of one to five and thirty percent of respondents voted five on a level of one to five.

4.4 QUESTION 4: ON A SCALE OF 1 TO 5, HOW IMPORTANT DO YOU FEEL ARCHITECTURAL DETAILING IS IN YOUR JOB?

Technologists and academics seem to be in agreement over the role of technical components within the Architectural Technology profession. The overwhelming majority of respondents believe that technical detailing forms an important aspect of their profession. Around eighty-five percent of respondents believe that the importance of detailing is worthy of a five on a scale of one to five. A further eight percent of respondents voted four on a scale of one to five. Surprisingly, around seven percent of respondents felt that Architectural Detailing was worthy of only a two on a scale of one to five.

4.5 QUESTION 5: DO YOU FEEL THAT THERE IS A CLEAR DISTINCTION BETWEEN ARCHITECTURAL TECHNOLOGISTS AND ARCHITECTURAL TECHNICIANS?

Despite the fact that Technologists believe they should have more or equal power over projects than Architects, Technologists do not appear to be cognizant of the difference between the roles of Technologists and Technicians. The majority of the respondents feel there is no distinction between the two fields. However, in reality, Technicians are generally not permitted to run projects from inception to completion whereas Chartered Technologists are recognised as having such a privilege. Technicians are awarded different titles to that of their Technologist colleagues and their progression criteria are different from one another. (CIAT Membership, 2018).

4.6 QUESTION 6: DO YOU FEEL THAT THERE IS A CLEAR DISTINCTION BETWEEN ARCHITECTS AND ARCHITECTURAL TECHNOLOGISTS?

Despite the fact that both professions have the ability to run projects from inception to completion, Technologists believe that the roles of the two do differ. This is most likely rooted in the educational differences between the two disciplines as highlighted in Yazicioglu and Emmitt’s works of 2013.

4.7 QUESTION 7: SOME MAY CHARACTERIZE THE ARCHITECTURAL TECHNOLOGY PROFESSION AS BEING A COMBINATION OF STRUCTURAL ENGINEERING AND ARCHITECTURE. DO YOU AGREE?

There is a belief amongst Technologists that they provide an olive branch between the technical perspectives of the Structural Engineer and the creative minds of the architect. The Architectural Technology community appears to be split on this topic given that forty-six percent agree with this characterization whereas around thirty-eight percent do not and around fifteen percent have given other responses. One of the responses refers to the titles as simply being umbrella terms.

4.8 QUESTION 8: DO YOU BELIEVE THAT CIAT'S EDUCATIONAL PROGRAMMES SHOULD GIVE STUDENTS AN OVERVIEW OF ALL ASPECTS OF BUILDING DESIGN SUCH AS: LEGAL FRAMEWORKS, CONTRACTS, MASTER PLANNING, CONCEPTUAL DESIGNING (TO NAME A FEW) IN ADDITION TO DETAILING?

One-hundred percent of the respondents responded 'Yes' to this question. This underlines the need for CIAT to encourage a diverse approach to its academic syllabus.

4.9 QUESTION 9: THE 2005 ROYAL CHARTER GAVE TECHNOLOGISTS THE ABILITY TO RUN PROJECTS 'FROM INCEPTION TO COMPLETION.' DO YOU BELIEVE IT IS NECESSARY FOR ARCHITECTURAL TECHNOLOGISTS TO HAVE THIS POWER OR NOT**?**

Some believe that Technologists should provide a speciality within the field of Architecture. However, Technologists themselves believe that the power they have to see projects through from inception to completion is an important one. More than ninety percent of respondents believe the power that the Chartered members have is important and around eight percent believe that it was not of great importance.

4.10 QUESTION 10: THE CIAT WEBSITE DEFINES ARCHITECTURAL TECHNOLOGY TO BE: "AT ITS CORE, [IT] IS THE ANATOMY AND PHYSIOLOGY OF A BUILDING OR ITS STRUCTURE, ITS RELATION TO CONTEXT, HOW IT IS ASSEMBLED AND HOW IT PERFORMS THROUGH FORM, FUNCTION AND FABRIC." (CIAT, 2017) TO WHAT EXTENT DO YOU AGREE WITH THIS STATEMENT?

CIAT's definition of the Architectural Technology profession is defined as being a combination of many different aspects of architectural projects. The Architectural Technology community appears to be in agreement on this point with sixty-nine percent agreeing with CIAT's characterisation of the profession. (Mahdmina, 2017)

5. CONCLUSION

After reviewing the literature and results, one can appreciate the writers' much needed analysis with regard to the Architectural Technology field. However, after reviewing the results of the survey monkey quiz, there does indeed appear to be a difference of opinion between the some of the academic writers and active Architectural Technology practitioners.

Author Niels Barrett's belief that the Architectural Technology field is a 'specialisation' within the Architecture field is a common theme amongst writers (Barrett, 2011). Writers such as Robertson and Emmitt express similar beliefs, albeit in different terms. One of the schools of thought which Robertson and Emmitt discuss are Technologists who are used to completing specific tasks within the architectural projects (Robertson and Emmitt, 2016). This school of thought is appreciated to an extent by the results of the questionnaire of Architectural Technology practitioners. The overwhelming majority of respondents deem Architectural Detailing to be an important part of the profession. However, more than half of the respondents believe (albeit to varying degrees) that experience in conceptual design skills are also important principles for Technologists to adhere to. Moreover, Technologists believe that their ability to legally lead projects from inception to completion is an important one. The specific findings of the quiz underlines the fact that Architectural Technologists believe that their profession is not only limited to the detailing aspects of the profession but that their profession includes other aspects of design as well. Therefore, the creative environment that Robertson and Emmitt also discuss in their paper is more in keeping with the results of the survey.

Finally, with the regard to how the Technologist community views the profession as a whole: more than seventy five percent of respondents agree with CIAT's official definition. This demonstrates that the general direction of the institute is in keeping with the thoughts of its members. However, upon analysing the study as a whole, the institute could focus some of its marketing apparatus towards informing members of the public of the broad and vibrant nature of the Architectural Technology profession. This would quash the notion that Technologists are specifically employed only to detail existing designs.

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WAREHOUSE CONCEPT AS A DESIGN STRATEGY

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Abstract. BIM models are often produced and used in the Danish construction industry based on clients' specifications and demands. In Denmark the state has developed rules for government, public, municipal, and regional builders (Transport-, Bygnings- og Boligministeriet, 2013). Publically funded projects with monetary values over a given threshold are required to use Building information modelling (BIM), however many of the industry's clients see the value in adopting the same measures; and it is increasingly common that inexperienced clients request 3D models so that they can see their construction project before the final decision to build. Clients and building designers (AEC) are experiencing benefits by using BIM in areas such as Quality Assurance, in such a way that they can identify and rectify mistakes during the design phases and using appropriate information management reuse the information from the BIM models in other forms, such as simulation etc. and once the project becomes operational. However, there has been lack of focus on value that can be created by using BIM during the design and construction phase. In this paper the following problem will be investigated: How will a design strategy as a concept look like and what benefits, a more structured work method, can complement the use of BIM throughout design and construction processes? Virtual Design and Construction (VDC) is a new way of digitally working with projects, supported by BIM. VDC is a new way of thinking and approaching a project, how to manage information and how to organize people and their working methods so the vision and goal for the project is reached. All projects are different and can be seen as making a prototype that will be the final product. However, no matter how hard you try the projects always have their own distinctive situated character. Everyone who works with projects and participates in the processes needs to have the ability to collect digital construction knowledge and information during the project life cycle and be able to improve the work method constantly. This calls for a more methodical perspective and information structure during the execution of a project, if we make the same mistakes in every project it is therefore important to have some transferable framework that all participants can act and work within. VDC is about how the participants work together across disciplines, how they communicate, plan and make decisions, and it is about creating interdisciplinary insights. One of the biggest questions to be considered when planning and working with the VDC/BIM process should be – "What should we use the DIGITAL objects and information for?" and "What do the different participants need to deliver at certain points to drive the process?" At the University of Applied Science, Lillebaelt (EAL), the education of Architectural technology and construction management works with students in 4th semester (half-year semesters) where they focus on designing and planning a construction project. The BIM process is done continually by focusing on organization and execution of the digital delivery of the construction project starting up the BIM-Model and end the course with optimized planning in location-based scheduling and created budgets for the project using the structured information from the models. EAL uses Autodesk Revit and Vico Office for this type of design work. This type of design method has been applied to a variety of projects, both theoretical/practical study experiments and real-life projects, which both have created valuable insight and knowledge about the complexity in the interdisciplinary and ongoing BIM process as well as knowledge and information delivery between the actors involved in the project.

Keywords: BIM, VDC, Location based scheduling, Digital construction knowledge, BIM process Roadmap.

1. INTRODUCTION

1.1 RESEARCH BACKGROUND

In 2004 the Danish government started to work on the earliest government BIM mandate called "the digital construction" that looked at digitalization of the whole value chain in the Danish construction industry. "The digital construction" intentions were also resulted in the governments early Information and Communication Technology (ICT) regulations aimed at government and public funded projects. The regulations set a number of requirements for the use of ICT on those projects. The ICT-regulations do also require that the clients specify the digital deliverables the AEC's need to deliver throughout the digital design process. This work is complemented by a Danish organization, bips (2016) and their ICT-agreement standards that structure the deliverables according to the ICT regulations paragraphs. This setup does only take care of the overall deliverables and does then need to be broken down into different organised deliverables in the different design phases. This work and standardisation has several Danish and international organizations developed paradigms for, such as Dikon's information levels (2017) and ICT-delivery specifications, BIM-forums (2015) LOD definitions etc. The developments, paradigms and standardisations may be regarded as very confusing and complex ICT-setups, as Hooper (2015) also argues. This confusion and complex setup may be considered as a crossroad or barrier for the implementation of the value-creation that the ICT regulation is supporting. When the setup is becoming too complex, the different participants from the AEC industry, is not able to work within the setup in a structured, open and interdisciplinary way. Treldal, N., Vestergaard, F., & Karlshøj, J. (2016) argues in their paper that there need to be developed a more pragmatic and scalable framework for the digital deliverables and we agree on that. But what's missing in their framework is the interdisciplinary approach that this work needs to underlie. They are complementing that each AEC parties can have their own distinctive view or focus on this framework, but as we will argue against in this paper, there has to be a common interdisciplinary language or work-method all parties can relate to and work within. Another issue with their work is that they don't put much effort to deal with the data and information that needs to be delivered to the operation and maintenance (O&M) phase where they state: "…but we argue that operation, maintenance, renovation, etc. are all use cases which use data from the milestone Handover." (Ibid. sect. 6.2) You can argue that renovation is directly referenced to the milestone handover, but the data and information delivered especially for O&M needs special focus because the information and data that needs to be delivered is gained and stored through the earlier design phases, and this organization and coordination isn't been in focus – the work amount of collecting all this data and information again, is not creating any value for the project. We therefore argue that when developing this framework for a work method there needs to be a "begin with the end in mind" (Anumba C. et al, 2010) mind-set present. Nevertheless, we complement that in their conclusion they state: "…that addressing the completeness and reliability of deliveries along with use-case-specific requirements can provide a pragmatic approach for a LOD framework". We emphasize the general argumentation against the "One size fits all" approach and that every project and ICT organization is different from each other. One thing is the structure of information another is the use of different tools to solve a given problem in the project. As we know there is a large and expanding variety of software's, both design- but also simulation-software such as the Vico Office. The fundamental basis of using ex. Vico office is structure and organization of the building components and their information and the overall structured process.

1.2 RESEARCH GOALS

In this paper we will investigate the mentioned area of focus from above both from a professional view but also from a more academic perspective. The essence of the problem definition will in this paper be: How will a design strategy as a concept look like and what value, a more structured and pragmatic work method, can complement the use of BIM throughout design and construction processes? The outcome of this paper is to develop a pragmatic design strategy that both is as uncomplicated as possible but yet can drive a digital construction process and BIM project through the design phases and into the construction and O&M phases with the use of structured data and information from the models. The paper also discovers and investigate how an academic institution can develop work methods through ongoing development, tests and evaluation in collaboration with practitioners from the AEC industry.

2. METHODOLOGY

2.1 RESEARCH METHOD

The methodology used in this research consists of three different approaches:

- Case study of a real project – Focus on organisation of the ICT process
- Experimental theoretical case study – Focus on organisation of the ICT process and the use of Vico Office
- Mixed case study, both real and experimental theoretical – Focus on the use of Vico Office.

First, it is a case study of a real project, The EAL institutions new campus facility that was executed from 2014 and until 2016 and in the same time an experimental theoretical case study of the same project, done as an interdisciplinary assignment by the students of Architectural Technology and Construction Management programme in 4th Semester. The second case is a completely experimental theoretical case study practical done by students on the programme in 4th semester with the use of a real life project – The PFA dormitory in Odense. The last case is the TBT project. This is a real life project executed by a design-and-build contractor with the help of students and lecturers from the programme.

2.1.2 Campus

EAL bought the old Wittenborg factory on Seebladsgade in Odense, where construction of the 20,000 m2 campus began in autumn 2014. Students and staff moved onto the new campus at the start of the academic year in summer 2016. Centrally located between the railway station and the harbour, in the area known as City Campus, more than 3,600 students are now concentrated in a single, shared campus. The administration building and two halls have been retained from the original factory, but the rest of the buildings on the plot were demolished. The administration building was renovated and turned into teaching rooms. Between the two halls and the administration building a new, four-storey main building has been constructed, with a basement under most of its area. This building forms most of the hub of the new campus. The project was put out to tender as a design and build contract with a given target cost, meaning we had a budget of 300 mill. Danish kroners that had to be kept. The invited contractors had to then come up with proposals for the design and execution of the project. It was also written into the invitation to tender that it should function as a learning arena for the institution’s staff, PhD students and other study-related development projects, and thereby help accumulate the experience that is shared within this paper. The project is conceived as the first in a series of phased expansions with a final layout of 70.000 square meters. Our involvement in the project was as both as an educational representatives but also as the client’s representatives in the following areas:

- Preparation of ICT specifications for service and handover
- Preparations of the strategy and framework for handover and digital operation and maintenance, as well as coordination of the digital handover together with all design disciplines and contractors
- Implemented and launched the Campus in a digital O&M system.
- Worked as the client’s digital “watchdog” throughout the process, as well as assisted the client consultant in the digital field.
- Worked as the client’s representative in the commissioning process for the technical installations.
- Client representative in the project’s environmental plan and DGNB certification.

When we were planning and organizing the ICT and BIM flow on campus, we assumed the statement from a Penn State University report (Anumba C. Et al, 2010) on digital operation with BIM "Begin with the end in mind". The goal of the digital set-up and flow is to be able to operate the building digitally, most efficient from day one, after handover of the physical and digital construction.

2.1.3 PFA – Dormitory

This case, used in 4th semester, is a real project concerning premises for the new PFA Pension dormitory in Odense, which needs to be worked up into a 3D working method and BIM process to be documented within planning and coordination, project proposal and preliminary design, and partly a final design. The plot, which is currently used as a public car park and green area, borders the campus area at the harbour of Odense. The use of the building is both as a dormitory, 98 rooms, with shared kitchens and common areas, but there is also space for externally leased facilities such as a gym and café.

2.1.4 Thomas B. Thrigesgade

The Odeon is Odense's new music, theatre and conference venue. Design-and-build contractor KPC began building the Odeon, Odense's new venue for music, theatre and conferences, in June 2014. The Odeon is built on the land by Odense Concert Hall abutting Thomas B. Thrige Street which will be undergoing a historic urban renewal over the coming years. The Odeon is one of the largest meeting and event venues in Odense. The Odeon is described as the ”Living House”, with stage and conference facilities that have brought together the Music Conservatory of Southern Denmark, Odense Drama School, Odense Theatre, retail outlets and student residences under one roof. The Odeon builds bridges between the worlds of commerce and culture, and creates a modern and innovative setting for both cultural and commercial activities in the heart of the country. With seating for 1,740 or standing room for 3,000 in the Great Hall, the Odeon is one of the largest cultural venues in Denmark. Its location in Odense Town Centre makes the Odeon a unique meeting and conference centre.

2.2 DIGITAL CONSTRUCTION IN DENMARK

The Danish construction industry is required to use BIM models because of the requirements that public and Government clients are required to follow (Transport-, Bygnings- og Boligministeriet, 2013). A construction project carried out under Government auspices is led by a client, who pays for a piece of building work to be carried out. The Danish municipalities are responsible for the construction and operation of their own buildings. Housing associations and self-governing institutions are set up and run by the municipalities, who are also responsible for housing for elderly and disabled people. Where buildings are constructed for public-sector clients, the building process is regulated by law. There are regulations on the call for tender, including EU tendering rules, winter building regulations, regulations on the use of ICT, competition for the client role in non-profit housing projects, and the use of key indicators in the selection of tenderers and evaluation of particular projects; some working environment regulations also apply. Under working environment law, public-sector clients are responsible for allocating sufficient time to individual contractors or phases of the work, which also reduces the risk of a poor planning and/or construction process and the attendant risk of faults, deficiencies, budget overruns etc. Calls may be made for building plans to be brought forward or for the work to be executed quickly, which can affect the client's choice of design or materials and the organization of the building project. With major projects that take years to complete, it may be worth considering dividing the building into stages that can be built and perhaps operated separately as natural units. This is why EAL has chosen to implement and develop the use of together with the Warehouse concept as a strategic management tool for this process. Other major clients, who are not subject to the regulations, have adopted the same requirements because they have seen the value of using a BIM model to manage construction in the future, so that they can work with the phases from 3D to 7D. It has also been gradually shown that many planning errors can be minimized if BIM models are also used in the execution phase.

2.2.1 BIM

The 3D work method (bips, 2017) is a consistent method common to all parties to the project, allowing 3D models to be created, exchanged and reused throughout the project. The Digital Foundation is an initiative of the Danish Business and Construction Authority, aimed at promoting the digitalization of the construction industry, including digital collaboration between AEC parties. The results are intended to point in the direction of object-based design and must be usable and capable of implementation by the EAC parties using currently available software. BIM modelling must support the overall aim for the future digital development of the industry (Bips, 2007):

- Support the products and work processes found in the construction industry today, without at the same time hindering any future reorganization of work processes in the industry;
- Develop a common conceptual foundation for construction products and work processes to facilitate the exchange of digital building models between the different parties;
- Use the power of digital infrastructure with a view to making the information exchanged more structured in terms of data and more targeted at recipients.

The EAC parties are using 3D and collaborating in a common BIM-model. At its core is a common model-based working method which ensures that information is re-used and exchanged between the parties through common rules and standards. The concept assumes that the software is object-based and that design information is linked to objects. 3D models and visualization facilitate communication between all parties, enabling better coordination across all disciplines with the use of discipline models to make design changes less time-consuming and easier to quality-assure in an interdisciplinary way. Drawing production can be reduced as the models take on some of the communication, mainly at the proposal and design stage. 3D makes more complex solutions possible –visually communicated and with on-going optimal use of standard components. Architects are enabled to find more solution options more rapidly, and they can take advantage of others' discipline models, the better to present projects to clients. Engineers get improved coordination of ducting and bushings, including holes in load-bearing structures, while visualization of complex areas can contribute to easer communication among the parties. Discipline models can enable static, dynamic and fire safety simulation and dimensioning of installed systems. Project managers gain a better overview of the relationship between different disciplines, and the ability to detect conflicts when the cost of fixing them is lowest, creating more effective quality assurance at all levels. The client is in a better position to assess whether the proposal meets requirements for function and relative placement of rooms, and to gauge what the finished building will look like, including how it will blend in with its surroundings. Communication between the different actors in the project as a whole is improved, giving better control of rooms, areas and components to the benefit of operation and maintenance. Contractors are able to examine the model, giving tradesmen and managers a better overview of complex assembly details for production planning. By simulating the construction process, the model can aid logistical planning, giving better control of the quantities involved in the project and how they are distributed among contracts throughout the construction period. Manufacturers/suppliers gain the opportunity to bid for configurable subsystems during the early phases and to base their production on discipline models obtained direct from the consultants. This means less risk of faults in the execution phase. Society benefits from 3D modelling as it helps reduce building faults through earlier, more sensitive detection in the design stage. Modelling can also mean cheaper buildings, because tenderer scan work out prices with a high degree of certainty and rationalization in a new division of roles among the various parties in construction.

The goal of using BIM modelling in the project is to specify a consistent, common working method for all parties involved, so that 3D models can be created, quality-assured, exchanged and reused through all phases of the construction project. It does this by showing how the parties involved in the construction should manage and exchange building models so that a building project can run its course on a rational basis.

2.2.2 VDC

VDC gives all parties to the project far better insight into the building project than hitherto. Using this technique provides a significantly improved basis for important decisions on the building's design. The basic idea of VDC is that all project participants have access to the right information at the right time. That means information updated in real time, giving a better understanding of the client's needs and of what it will take to meet their wishes (Lowe, R., D'Onofrio, M., Fisk, D., Seppänen, O., 2012). The four elements of VDC are collaboration, BIM, processes and metrics. Collaboration: How good collaboration is between the various actors involved in a project. This can be improved by means of workshops, during both design and execution, attended by everyone involved in the project. BIM: How information is used from a warehouse concept point of view, and the digital tools to perform quantity take offs for budgeting, scheduling, visualization, hole coordination, conflict control etc. Processes: How processes are used in the design of the project, and the processes for manufacturers and suppliers to draw up call-off plans for production of elements with a long lead-time, such as concrete elements and windows. VDC processes are workflows where the model incorporates information developed during design and construction. VDC processes attempt to apply new technologies to traditional work methods, and to connect the design work built into the information model by the project team with the contractors on site. The information model is the central element in the VDC work process. VDC principles must be used throughout the design and construction process; if these principles run in parallel with traditional workflows, they will not yield maximum benefit for the project. VDC processes must be integrated into the project and day-to-day workflows in order to bear fruit for the whole process. Metrics: how the value of different actors' contribution to the project can be measured. This is also where it is possible to check whether the project-specific idea is reflected in the finished project, and where it is possible to quality-assure that the work done also meets the standard that was promised to the client.

The success of a VDC project depends not only on the talent and keen process-awareness of the team, but also on the organization. In practice, VDC ought to develop with each new project, from the first implementation onwards and taking on board experience from previous projects, as a set of templates, databases and an organized file system. A good VDC specification lays down what the information model is to contain and at what level of detail, and gives important elements of information regarding all phases of a project, from the early design stage to project delivery and operation (Henning Laursen, occupational health chief, NCC Denmark). How VDC should be integrated into a project depends to a great extent on how the project is structured in organizational terms. Every project has different requirements, and the organization of the team varies according to the typology, scale, complexity, client, location and phases of the project. It is vital to provide a detailed description of the implementation of a VDC process, as any omission is likely to affect other aspects of the project. A successful VDC project requires clearly defined standards for the information model, covering file naming conventions and structure, software workflows, component definitions, the level of detail in the model and data transfer. Standardized formats for sharing of 3D data will ensure that sharing, whether internal or external, is done consistently and compatibly. Procedures for implementing new technology, such as choosing software platforms, identifying people in need of software training, and analysing the external technology infrastructure including hardware upgrades, are crucial. A clearly defined implementation plan meeting all the requirements in the specifications is crucial to successful VDC integration. As well as describing in detail how the VDC processes are to be implemented and what software and hardware are to be used, it indicates whether the contractor has VDC capacity. The figure below Inspired by NCC Construction Company, a leading Danish contractor in the sector.

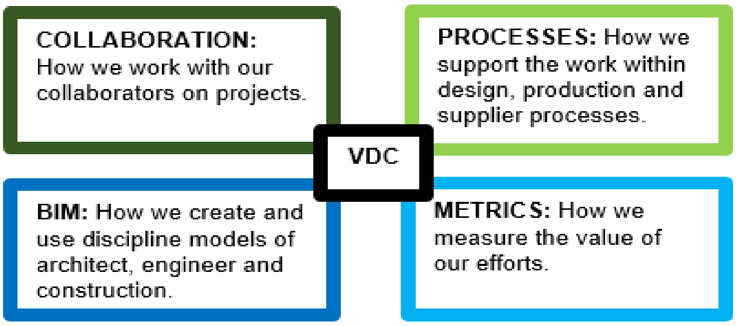

Figure 1: VDC Process

2.2.3 Vico Office

With Vico Office you get the opportunity to do location based scheduling that gives a clear overview over time and activities divided on different locations. By that use, a stable workflow and optimal usage of the whole building site is ensured with ongoing optimization. Many companies that are using Vico Office and location based scheduling is arguing that they are managing 10-20% shorter execution time by implementing the method compared with Gantt chart based methods and tool like Microsoft Project (Vico Software integrating Construction, 2016). By the use of Vico Office it is possible to combine the 2D-drawings with the quantities from the BIM-models and get a combined view over the overall quantities and resources. With automatic issue registration as well as divided locations of quantities it is argued that it is possible to save approx. 80% of the planning time and follow up (Ibid). As it is a BIM tool it is possible to make clash control between different design discipline models and secure that the constructability of the project is put to test before it is carried out in the real world. By this setup it is possible to save 40% of contingency expenses. By connecting the BIM-model with the time plan, you get a 4D simulation with the overview of resources divided on locations, by which you easily can manage the resources and secure even and proper manning (Ibid). This is done with an reasonably manageable interface where it is possible to work flexible and test different issue solving solutions before the project is send out to tender and constructed.

3. Danish Standardization

3.1.BIPS

Bips is a Danish organization that is developing standards for the AEC industry from folder and file structure over work specifications and ICT agreements and BIM-process manuals. Their work have contributed to a framework around the use and agreements of ICT in Denmark. The ICT specifications is divided into several legal and non-legal documents. The A102 – ICT-specifications (bips, 2016) is the legal contract from the client to the participants in form of specifications in the use of ICT on a project. The agreement is divided up into 7 chapters that all in all is fulfilling the requirements from the ICT-regulation. These chapters specify the use Classification of building components, Digital Communication, Establishing communication platform (project web), Digital designing, digital bids and tendering, Tendering with quantities and Digital handover. The A402 – ICT-process manual (bips, 2016) is an non-legal collaboration document between the AE C parties on the project and goes through the same chapters as in A102 but is meant to clarify how the specifications from the client is implemented in the ICT-setup on the project.

3.2. DIKON

Bips is providing a set of paradigms that tie the overall organization of the use of it together on a project but does not complement the dividing of modelling responsibilities and organization of level of information on the different types of building components. DIKon, that is a collaboration between six of the biggest AEC business in Denmark has developed both a paradigm for a delivery specification (DIKon, 2017) that is organizing the modelling responsibilities and level of information of the different types of objects on a project but also a standard for the level of information framework. The standard for level of information or information levels as DIKon is naming them is split up into both graphical and informational specifications.

3.3 BIM7AA

In establishing the Warehouse concept, EAL made use of the template from BIM7AA (2017), a voluntary collaboration among seven Danish architectural practices. BIM7AA aims to develop and continually improve shared BIM tools, methods and processes with an emphasis on interdisciplinary collaboration. BIM7AA's publications are the fruit of the participating firms' considerable ICT and design experience. This method affords students the opportunity to understand the division of responsibilities among the various actors in a given project. The BIM7AA standard is used for type-coding the different types of building components the project consist of and can be seen as the types "barcode" throughout the hole BIM process from start to end (Demolition).

Example: 224019 Stud Wall, Plasterboard, 145, 95L – GG/

The building component code will always be associated with the building object. Other features such as. Description number, classification, entries etc. defined in phase properties under property data or LOD.

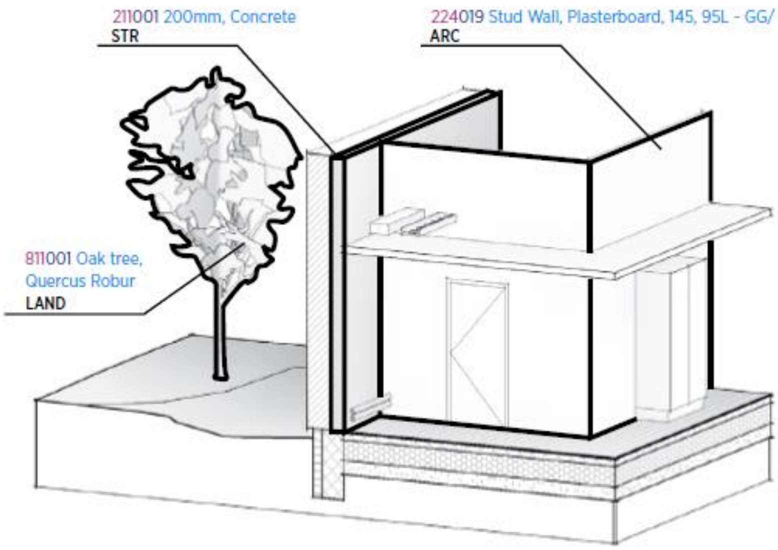

Figure 2: BIM7AA TYPE CODE

4. Findings Literature review

The different parties in the Danish construction industry has done a tremendous job in structuring the digital design process regarding many aspects of the complexity of data and information structure as well as the legal constraints that are to carry out a construction project digitally.

4.1 WAREHOUSE CONCEPT

A project includes hundreds of objects that can only be assigned to the project's areas of responsibility once the initial proposal for the building's geometric layout has been drawn up. This is where the buildings, rooms, building components and floors that the project will consist of are defined, and the proposal then becomes the concrete object of analysis. This analysis may take the form of specific delivery specifications, where each object is specified in terms of what it must deliver at certain points or stages in the process, and where the question of what do WE need to use the digital objects for is central. This initial ICT set-up should not be seen as a completely static document, as it will be revised as the project's stakeholders gain a better understanding of the project, but, equally, this division of responsibilities should also form part of the contractual basis for collaboration among the parties. This division of responsibilities should help define and organize the project-specific objects via the digital process. In addition to responsibility for the individual object, the specification of modelling and information deliverables should also include agreement on the geometric Level of Detail (LOD) each object will have, and its alphanumeric Level of Information (LOI), i.e. all non-geometric information. This sort of overview of the process demands a lot of experience and interdisciplinary collaboration between project actors, requiring the process to be divided into smaller parts. In addition to the detailed organization of the individual object types and their information, a decision must be made as to how this information will be stored and distributed. Will the information live in the building models, or in external databases? The answer depends on what the objects are to be used for, by whom, when, and how. When organizing the objects, it is likewise important to consider which digital processes they will take part in as active elements. This could be anything from price calculations or time estimates to simulation of lighting, energy or internal climate conditions, fire and smoke spread, shading effect on the surrounding environment, the building process, clash control etc.

4.2 BUILDING COMPONENT JOURNAL

The building component Journal (content journal) is the backbone in our warehouse concept where all object information is collected, stored and distributed. When describing the objects in the content journal, it is important that the same structure be followed throughout the BIM model and by all project participants. The diagram above shows how to build up the system with type codes and type numbers; a text description of the relevant component is also used together with this system. Building components must be divided into the various phase-related groups and the respective discipline models. All relevant technical information affecting the workflow is there for collected in one place, which all project participants can access, work in, tribute to and get information from. This information may include:

- Fire safety requirements
- Acoustic requirements
- U values
- Contractor responsibilities
- Modelling responsibilities/information responsibilities
- Classification
- Sustainability information
- Links to work specifications or supplier specifications
- Statistical properties
- IFC categories
- Etc. Etc. Etc. – Whatever adds value to the project.

In order to make this setup more agile and project-specific, we have chosen to split this form of detailing in LOI and LOD so we can organize both the informational but also the geometrical clarification level the individual objects and type should be at throughout the process. As an example, on some projects in Denmark nowadays, there is a one-year delivery time for concrete elements. This of course affects the LOI/LOD for prefabricated concrete structures and related objects or systems, which have to progress more quickly in the project than others. The Content Journal can be thought of as a translation of the construction knowledge into an Excel spreadsheet or database. An overview of the structure of the content journal is seen below. For full size se appendix 2.

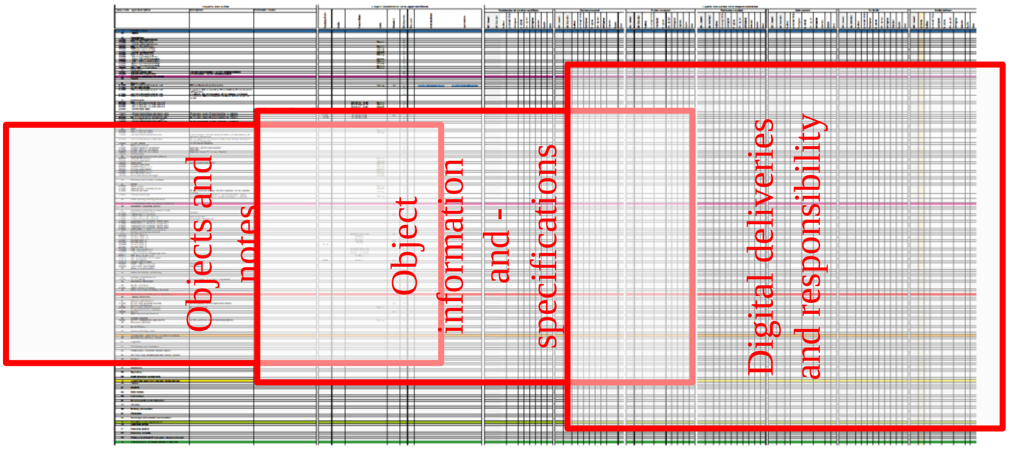

Figure 3: Content Journal

But as we earlier argued, it is very important to look at what information the component journal consist of in a project specific view.

The figure below shows how students set up a building components table and then a Revit file containing the building components they will use in the project. These elements can be transferred to a calculation and planning tool in which quantity take-offs can be performed based on the specific project. In this case, EAL and the students used Revit as the design tool and Vico Office as the calculation and planning tool. These two programs allow the greatest possible quantity of data to be extracted and enable a schedule to be produced showing how the resources are divided amongst locations.

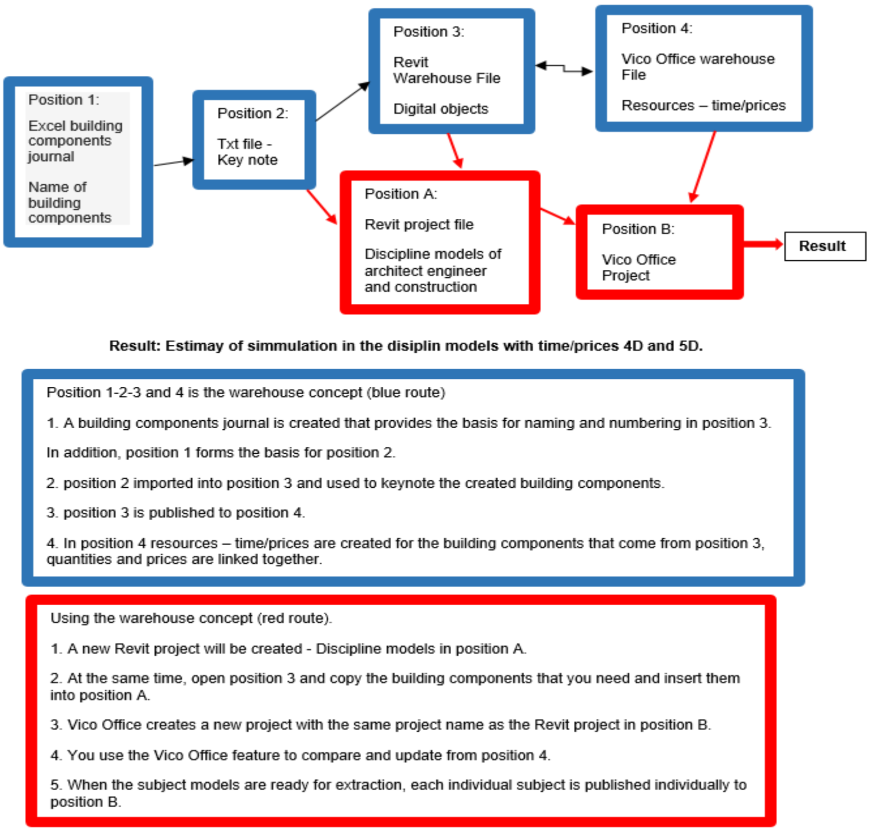

Figure 4: Warehouse Concept

4.3 DIALOGUE WITH INDUSTRY

An exciting way to study EAL's development of the concept underlying the Warehouse approach is to see how it relates to the industry's way of working and whether the concept can add value to a project. To that end, Michael Edwards Pedersen, Head VDC Coordinator and ICT Manager at NCC Danmark A/S, was invited to answer questions about NCC's approach to tackling a VDC process and how it relates to EAL's mind-set. One major, noteworthy comment he made was: "*the tools have to support people's skills, not the other way round*". In this light of this paper's perspective, it may be concluded that the way the Warehouse concept links and stores information can be just such a tool, one that both supports project participants' skills, in that information on the individual building components is stored and linked together in one place, and one that also makes the process more efficient, as time is not wasted gathering information from multiple places, and there is no possibility of information being lost. Another relevant comment was: "*The* *most important thing is the mind-set of the individual project participant; unless they are prepared to change or be changed, using VDC is an uphill task".* This implies that it is important to be open to new initiatives, and a general receptiveness to change is an important skill that must be in place if new digital tools are to be used successfully. Through the Architectural Technology and Construction Management course, students gain experience of a raft of digital tools and gain deep insight into the all-important process underlying it, so that qualified constructing architects are both receptive to change and can be ambassadors for new digital tools and processes.

5 Research: case studies

Case 1 – Campus

At the first hand in from the consultants we received the models and we were somewhat surprised at how the content and the objects had been structured and built. The architect's model alone took up over 700MB. It took a day alone, to update the model from Revit 2016 to the 2017 version. The model, then, was completely overloaded with information, and one wonders whether there had been any attempt to organize the information with regard to the objects that was used. All objects of the model have to be transferred to our management system, of course, but, because the model was so data-heavy, it simply wasn't possible to transfer the data, so we had to go in and manually tidy up the models, deleting all this 2D annotation. Looking more closely at the object and their parameters, the list of parameters and information strings is extremely long and utterly chaotic. In one case, a window object, the amount of different type parameters in the Revit family is in all-in-all about 120. There is potentially information that will never, ever be used in the project, and that therefore has no value for the project. The campus case showcased some issues regarding structure of data in the models. If we look closer at the objects it is clear to see that the consultant has used a company specific window family with, ass mentioned earlier, utterly chaotic amount of data fixed to the object. There is links to YouTube, where you can see how you are using the Revit family and email address to people in the manufacture organization. This information can be divided into two categories: alphanumeric information (such as width, height, description, u-value etc.) and geometric/visual information (such as solid geometry and 2D annotation/section details). There could be many good reasons why the level of detail/information (both alphanumeric and geometric/visual) is so high. It can be very worthwhile for the individual designer, because it is easy, to make detail drawings where part of the detail is applied to the window object. In other words, they have performed a sub-optimization of their own processes. We can ask: does all this information adds any value to the projects overall interdisciplinary process, and are there any good reason at all for its being there if we look at it from a "begin with the end in mind" perspective?

Case 2 – PFA
Students work on the project in teams of three or four. The teachers give them an outline proposal for them to study and develop further. The requirements that are set for the students are described to them as the client's specific requirements for the digital project. The "client" wishes the requirements of the ICT Regulation to be interpreted by the consultants as follows:

- The client leaves it to the consultant to coordinate the overall use of ICT throughout the project and for all those involved, in accordance with the legal basis and applicable guidance.
- All digital building objects are to be structured and classified according to BIM7AA using up to three levels. All rooms are to be provided with information and properties describing: area, volume, and floor, wall and ceiling materials. All building objects are to be provided with information and properties describing: classification, type designations, materials, energy performance and static and fire safety information.
- Project Web is not to be used in this project, but the client will make a file server (drive Q) available for the design work, and this is to be used to document the overall design scope. A project-specific design and project handbook will be set up in Office One Note as a platform for communication between consultants and client. Separate discipline models will be developed in Revit for: the form of the building and its geometry (ARCH), load-bearing and stabilizing objects (CON), ventilation (INST), terrain (LAND), coordinating grid and levels (GRID) and loose interior design. (INV). Modelling is to be carried out at information levels 2, 3 and 4.
- The student are to arrange/plan the project so that quantities and prices of building components can at any time be extracted from, and using, the design project for building and plant cost control, in the first instance to provide an estimate to the client. The client requires quantities and prices etc. to be set in Vico Office so that they can subsequently be used to compile a tender schedule. Prior to tender, the models are to be used as the basis for a detailed tender schedule using Vico Office; object naming must therefore follow the naming convention used in the building component description and subsequently in the tender lists. Type coding must follow the SfB principle for coding of building components, and throughout the project an up-to-date log must be kept of the building components used/agreed and relevant supporting information.

Quantities are not to be indicated in the tender lists, but the models are to be made available to tenderers in IFC format.

The client's specific requirements for the digital project are described as if this were a real project, so as to make it as realistic as possible for the students, with the same outcomes as for a real project team. The teachers play the role of client and coach in respect of the project and of the requirements set to the students regarding output and deadlines.

Case 3 – TBT

The students plan and collaborate according to Lean Construction principles. The goal of using the Last Planner System is to achieve better predictability and reliable schedules that can be adhered to in practice. The way to involve the people who actually carry out the work is, therefore, to arrange on-site workshops. The result is better communication, better overview and better flow, which in turn means better adherence to schedule, cost savings, improved safety and more job satisfaction. The Last Planner System involves breaking down the planning of the construction project into three levels: the master plan, the medium-term plan and the weekly plan. The master plan is the initial planning of the whole project. The medium-term plan is a look-ahead plan that concentrates on removing obstacles to production. The weekly plan is the detailed planning carried out between the crews on the construction site. As well as using the Last Planner System, the students have worked with the calculation and planning principles of Location-Based Planning, using Vico Office software. The stick diagram (Gantt chart) works on the principle of having only one dimension – time – whereas the cyclogram technique indicates both time and a geographical localisation of project activities. This makes it possible to identify where and when the activities are to be carried out, and to record the typical cyclogram 'time/place diagram'. Planning with cyclogram thus makes it possible to establish visually how smoothly and evenly activities will flow when a given resource consumption is applied. In this way, one can proceed from the resources that will carry out the activities and ensure that they have an even workflow and an even workload, while also ensuring that the various resource groups can physically get the job done without getting in each other's way. The cyclogram method belongs to a group of techniques known as linear planning methods, of which Line-of-Balance and Flowline are the best known. Although the basic principles are the same in all linear planning techniques, there are a few significant differences in areas such as the graphical presentation of the schedule. In a Line-of-Balance schedule, the activities are depicted as the extent of time corresponding to the start- and end-points of the activity for the number of finished units that the schedule encompasses. The vertical axis in a Line-of-Balance schedule thus corresponds to the number of finished units. In a Flowline schedule, activities are represented as oblique lines whose angle indicates the work intensity of their execution. The figure illustrates the Flowline version of the Line-of-Balance schedule. Another important difference between Line-of-Balance and Flowline is that the Flowline method divides the vertical axis into physical project locations. The physical locations in a construction project can be divided in a hierarchical structure with, for example, building, floor and apartment levels – see figure below.

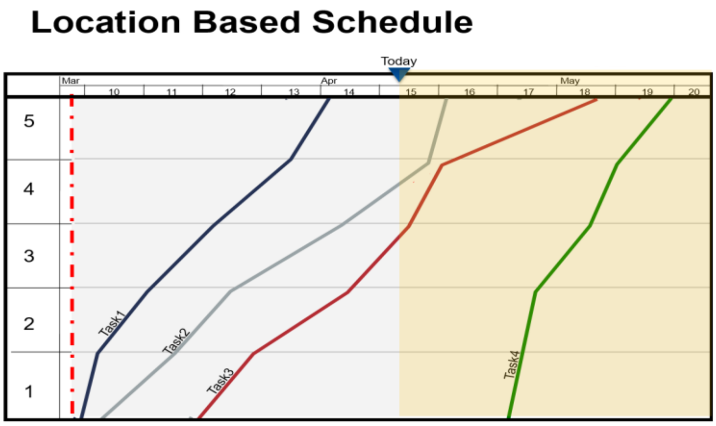

Figure 5: Location Based Schedule

6. Research findings

Perhaps the question that could have been a part of the early organization of the information should be: ‘What are the objects to be used for’ and ’What information needs to be processed and incorporated into the objects so that it adds value to the project?’ The overall idea behind this form of standardisation is actually both rational and quite good. After all, the set-up should ideally be as easy as possible to work with, and at the same time it needs to be simple enough for all project participants to play a part in the set-up. One question that arises for us is this: ’Are the standards driving the project, or is it the project that drives the standards? If the standards are the driving force behind the project, there is a risk of the same mistakes persisting from one project to the next. One argument for working with BIM, as we mentioned earlier, is that BIM helps resolve the paradox that designers EAC parties develops a digital prototype of the final building before it is actual been build. Does this paradox, then, not disqualify the standardization mentality? If we take it that every project executed is a prototype, and that every project has its own characteristics with regards to architecture, construction choices and execution methods, and also the parties to the project, does this not influence how information generation and information streams should be organized in a consistent, project-specific way? Working with students and the industry never gives the same results twice in a row; the outcome is always dynamic. It is always exciting to develop and teach students to work with the traditional method but with a different kind of workflow, applying the Warehouse concept to a traditional building, and see how their traditional project planning develops and how they themselves can get involved in creating coherence in the planning phases and handover to the project contractors. The result of using students as a project partner is a complex factor, as it very much depends on how they deal with the task and whether they get anything out of the learning situation they are helping to create. Students should engage in creating the right learning environment and be able to see the benefit of using the Warehouse concept. The case studies of the third type are also collaborative projects involving students and industry, but here it is more of a parallel activity with students making proposals for possible improvements to the schedule and site preparation, making it easier to introduce students to the principles of the Last Planner System and Location-Based Planning independently of their progress with the building. Naturally, there are also drawbacks to trying out new planning techniques, as the AEC industry is conservative and does not change as quickly as a teaching situation, which needs to be forward-looking and keep up with the changes that are on the way. The greatest challenge in working with cases of this type is that one is starting from scratch, just like the contractors and with the same sort of invitation to tender. The students can see perfectly well that it is old fashioned for the contractors not to be given a BIM model, because they have worked with the Warehouse concept in the previous semester and seen the improvement that the VDC technique can bring to a project.

6.1. BIM PROCESS ROADMAP

One major challenge in the Danish construction industry and especially the Campus case, is a widespread tendency to look at and optimize processes in ’the organizations’ rather than those in ’the projects’ – and understandably so, since all LOD/LOI instructions, such as Dikon (2017) also more or less bear the designation Delivery Specifications – ’Tell me what to deliver, and you will get it’. Experience shows that it is incredibly hard to manage the sender/receiver relationship in these specifications (Treldal, N., Vestergaard, F., & Karlshøj, J. 2016) if we take our eye off the context of the project – once again, it’s the tale of people in a circle whispering the same story in each other’s ears, and when the story has been all the way round, nobody can recognize the original story. After all, agreements and specifications is on a piece of paper and we cannot expect everyone to understand them the same way. We need to have certain concepts and specifications that can act across discipline groups and that it exist in the context and process of the project. In matter of getting a common language and inclusion of our recommendations we have developed a BIM process roadmap to be a “translation” tool so all participants have the same understanding. The roadmap consist of six main areas (See appendix 2 for a larger view).

1. The contractual output and deliverables (Pos. 1)
2. The red arrows represent the digital design process and practice as agreed in the ICT specification and in the ICT process manual; they are also the digital context in which the project will be implemented. (Pos. 2)
3. The digital design process is divided into several BIM design phases representing the processes that we plan into the project. The grey text indicates the BIM phases recommended by Penn State University (2010), while the red text shows the same phases, but in a version adapted for Denmark. (Pos. 3)
4. The information levels indicate the degree of clarification (LOD/LOI) that the project objects or families will have during the individual BIM phases. (Pos. 4)
5. After that, we need to show what construction expertise or knowledge the project needs, where it fits into the process and how it develops in the course of the process – The black text. (Pos. 5)
6. Lastly we also need some digital tools to communicate the construction expertise to the objects and in to the digital context – the coloured text. (Pos. 6)

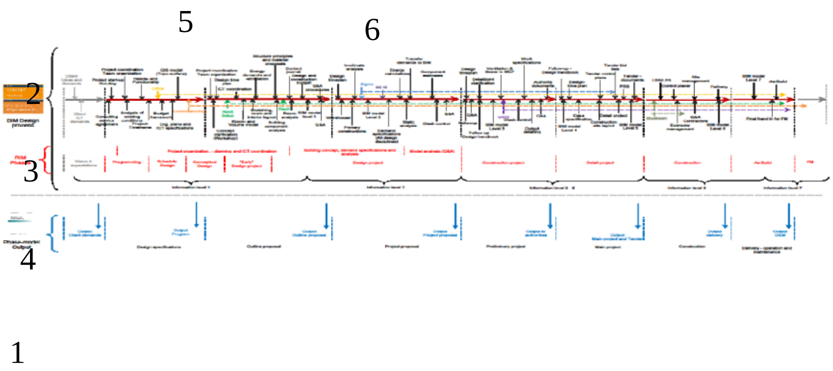

Figure 6: BIM Process roadmap

This is then the project's Roadmap and BIM workflow, and it frames the organization of the project and its interdisciplinary digital framework of understanding.

7. Conclusions

7.1 CHANGE IN THE AEC INDUSTRY

EAL and its students have been using Vico Office since 2012, since when the Warehouse concept has been developed. This has proven to be fertile ground for efficiency improvements in the Danish building industry, because newly qualified constructing architects are ambassadors for the latest knowledge in the field of location-based planning, and thereby for the Warehouse approach, too. However, there is still much to be done in disseminating the principles of VDC, and this undeniably involves the use of BIM models for communicating data and information to the execution phase. Public-sector and Government clients set requirements for the use of BIM models throughout the project lifetime, and the Warehouse concept can be the tool to help reap the benefit of using BIM models. Other major actors in the Danish construction industry have implemented Location-Based Planning in their organizations in order to future-proof productivity factors by ensuring they can deliver the building on time and on budget.

7.2 STRUCTURED INFORMATION

The concept enhances or optimizes the digital process, as disciplinary and organizational information is stored and collected in one place, thereby ensuring that data and information are not lost over the project's lifetime. The concept has other advantages, too, as this form of organization can prevent data redundancy etc. There has for a considerable time been talk of contractors being unable to deal with the data and information incorporated into BIM models by project planners. This is not the case, though, for the largest industry actors. Projects are, however, still being carried out with the participation of smaller contracting firms who still lack the skills/mindset to deal with the technological challenges. This is confirmed by this paper, as it is precisely the mind-set and change-readiness of the actors involved that is emphasized as one of the most important conditions for dissemination of VDC principles.

7.3 FURTHER DEVELOPMENT

A further development of the warehouse approach could be to make it a cloud-based concept, allowing multiple individuals and organizations to access an AEC-common generic requirement database and share their knowledge more efficiently. Further development could also look at more organizational information, such as individual objects' information levels and responsibility distribution, being incorporated into the concept and by last the human interpretation and cognitive processes that needs to be in place to work effectively with the warehouse project. Another aspect of the concept presented in this paper is the actual use and follow-up of the progress of the digital process. This could lead to a new conceptual framework of a 'commissioning'-like work method where the object information is tested and evaluated in the sight of what the information is to be used for in the end of the process.

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EXAMINING QUALITY OF NON-GEOMETRIC DATA VERACITY AT PROJECT HAND-OVER FOR BIM DATA MANAGEMENT

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Abstract. Through the expediential global increase of Building Information Modelling (BIM) adoption across the Construction industry, and the emergence of inter-connected, strategic and data-rich solutions; such as Big Data, the Internet of Things and Smart Cities, the importance associated with activities and decisions reliant on exact data input, transaction, analysis and resulting actions becomes exponentially magnified. The supply of inaccurate BIM data may negatively impact on systems and processes that require fully assured and data of appropriate quality / veracity, to support informed decision making, deliver functionality, facilitate services, or direct actions within the built environment. This preliminary research intends to provide a catalyst for discussion, analysis and information retrieval relating to Building Information Modelling (BIM) processes where non-geometric data errors may; or are predicted to occur within a project environment, resulting in the delivery of data that cannot be described as representing truth or of good quality, and therefore of little value or use to the data user. The wider aspects of this research are investigating specifically non-geometric data veracity & associated dimensions of data quality; in order to discover and explore future solutions to resolve current industry challenges. This paper provides feedback from the research focusing on current state and presents existing industry challenges and proposes further research areas based on initial findings.

1. Background and Research Rationale

Charles Darwin (1903) in 1879 sent a letter to a Stephen Wilson where he communicated “to kill an error is as good a service as, and sometimes even better than, establishing a new truth or fact.” As humankind transitions into an age of increased data utilisation, the importance of eradicating error is as relevant today as it was in Darwin’s time. The emergence of a future state, where seamless interconnectivity through The Internet of Things (IoT) and Smart Cities, is becoming an increasing reality. The construction sector is embarking on a journey of increased digitisation and the importance of providing accurate data and information through BIM associated processes will need to become more robust and go beyond current industry practice, to enable functions to not only evolve but also to play a greater role in the social and environmental impact of a digital age. This research identifies issues and challenges associated with the delivery of non-geometric BIM data at project hand-over as described in the next section.

1.2 PROBLEM STATEMENT

A primary element of Building Information Modelling (BIM) is information and data; this includes the generation, transaction, interpretation, and actions based on supplied data. There are many forms of instruction and legal contract issued by Employers to their supply chain to procure data and information. However, the methods required for a Client or Employer to check that the data is exact or of good quality do not appear to be available at this time. For those suppliers of data who need to meet their contractual requirements, there is little guidance on a robust workflow that will ensure a quality assured approach to the validation and verification of required data intended for use beyond practical completion. This is considered by the researcher as an industry process and workflow gap which requires investigation, and current risks in the process identified.

Inaccurate data can mislead the user, affect decision-making processes and may result in incomplete data sets being disregarded or discredited due to isolated or multiple errors. When we consider the transaction of non-geometric data as part of the hand-over process to an Employer, it is possible that data sets provided are often inaccurate and incomplete which could result in a cultural environment where the recipient may assume the supplied data set cannot be relied upon and trustworthy. Facility management teams are often used to receiving incomplete, inaccurate and late delivery of information from construction teams, which results in the need to survey facilities to gather required information despite the activity incurring additional and potentially avoidable costs for the building asset owner.

At the ICE BIM Conference (ICE, 2015) it was reported that all centrally funded UK Government Departments would need to have “the capability to electronically validate BIM information delivered from the supply chain” and will also need to be “making progressively more use of supply chain data for key business activities.” BIM Task Group chairman Mark Bew stated: “As we move to BIM Level 3, and beyond, the reliability of data is key.” These statements align to this research and confirm that the construction sector requires guidance and clarity on how to practically implement processes such as validation, quality assurance, and achieve reliability of data to advance BIM maturity. Despite the presence of many data schemas, there remains continued ambiguity, and lack of clarity relating to what data is actually required, a standard industry data schema for product manufacture data is just one example (Ravenscroft, 2015).

This preliminary research investigated current state by focusing on data exactness or using the term adopted within the context of this research Veracity meaning trustworthy, veracious, and truthful (Oxford English Dictionary, 2016) and therefore can be considered correct. The decision to adopt the term Veracity was also informed via previous research (Levine, et al., 1999) (Hernon, 1995) and is referenced within BS1192-4:2014 (BSI, 2014), where Veracity is defined as both an instruction and indication of quality 'The information provided should match the intended or actual Facility.' Wang proposed that Data and information are often used synonymously and is commonly differentiated intuitively, and described information as data that has been processed. For consistency, this research has used the term data wherever possible to refer to both data and information to avoid switching between terms (Wang, et al., 2002), since issues and challenges associated with the delivery of both non-geometric BIM data and information at project hand-over are comprehensively and generically considered. This research focuses on non-geometric data only. This is to ensure data, and the interpretation of that data is the focus of this study and not geometric models and model accuracy; which has already been adopted extensively as a research topic.

2. Literature Review

2.1 PHILOSOPHICAL INVESTIGATION

Peter Hernon (1995) states "it is not enough that information is readily available; before relying on any data or information, it may be important to ascertain, for example, the veracity of the content." The Quality of Information (Cooke, 1999) is a term commonly used rather than accuracy by library and information scientists (Alexander & Tate, 1999) although verifying the accuracy of information is commonly used as one of the methods for evaluating the quality of information. Additional methods for assessing quality include accessibility, relevance, comprehensibility, and navigability of information sources. This statement supports the view that accuracy of information within a BIM workflow should be a consideration and part of the process, but additionally, other dimensions may need to be considered; this also poses the question whether there is a logical sequence of steps or linear process to achieve a validated set of quality information.

It could be argued that inaccurate information may not be an issue as long as the user can identify the information that is inaccurate (Wachbroit, 2000) or as Vinton Cerf implied has the ability to apply critical thinking (2015). Barbules (2001) questioned how much evidence is required, and theorised that it might be dependent on how sure we need to be of the accuracy of the information. Which leads to the issue of ownership and responsibility of delivering required evidence, it could be proposed this can only be provided by those who acquire and distribute true beliefs (Smith, 2002) and not by those who utilise it. It should be noted that a user may be misled by incomplete information as well as by inaccurate information; therefore, we may need to consider the completeness of the information (Frické, 1997). Not all information is verifiable. Baird observed that "some information is verifiable" and can be readily checked once it is revealed (Baird, et al., 1998). Within the context of this research data & information could potentially be classified as being verifiable or non-verifiable data. Within COBie time focused activities such as cleaning regimes may be based on approximations, median data outputs or assumptions and therefore non-verifiable in terms of veracity. Don Fallis (2003) hypothesises that increasing the verifiability of information may actually be more cost-effective than teaching people how to evaluate information. Each person who needs to verify the accuracy of a piece of information has to expend energy to acquire and to apply these new skills. However, only one person (e.g., the author) has to expend energy to make the information more verifiable. This observation with regards current industry practice does lead to question who should be rewarded or compensated for ensuring information is verifiable. Kristo Ivanov (1972) concluded that Accuracy might be impacted by Motivation, Variability, and Frequency (familiarity), the concept of motivation and therefore a vested interest in information veracity on the part of the data provider may apply to future research.

2.2 DIMENSIONS OF INFORMATION QUALITY

A polygen model was developed in 1990 (Madnick & Wang, 2009) to answer data quality questions such as "Where was the data sourced from?" which in turn led to the development of a Quality Entity-Relationship model (Wang, et al., 1993) to enable the processing of hierarchical data quality metadata (Wang, et al., 1995). In the latter of these papers it was stated that it is not always necessary to obtain zero defect data, as an example, postal services can make deliveries using a zip or post code even if the city name is incorrectly spelled. This statement is important with regards BIM, and structured data at hand-over as this asks the question "Are we collecting too much or irrelevant data?" The question of the actual cost to achieve zero defect data; if at all possible; was also highlighted within the research, indicating that cost to deliver may be a contributing factor to poor data quality. Relating this to the construction industry; which is cost driven and adversarial in nature; this incurred cost may also result in non-delivery. There may also be a correlation with Philosophical thinking (Ivanov, 1972) that energy required or motivation is a contributing factor to poor data quality.

Madnick & Wang (2009) identified that organisations who collect, store and process data are faced with a number of challenges. This includes the integration of data from disparate sources, and a lack of cohesive strategy to ensure appropriate stakeholders have the required information in a useable format, and at the right place and time. Deming (2000) proposed a Total Quality Management (TQM) framework, extended by Juran and Godfrey (1999) and developed further by Madnick and Wang through the MIT Total Data Quality Management (TDQM) program (MIT, 2002) which includes continuous data quality improvement by following the cycles of Define, Measure, Analyse and Improve (Madnick & Wang, 2009). During the TDQM program, data quality was defined from the consumer's point of view in terms of fitness for use.

Further research developed an information quality assessment instrument (Lee, et al., 2002) for use in research as well in practice to measure data quality in organisations. The instrument in operation separates each dimension, such as Accessibility, Timeliness, Completeness, Security as examples, into four to five measurable categories supported by functional forms to enable a method of scoring to be applied. Pipino's research also focused on assessment (Pipino, et al., 2002), of note to this research specifically is that Pipino, like Lee did not adopt the dimension accuracy as used by Strong (Strong, et al., 1997) but has replaced this with a term Free-of-Error further supporting a view that a consistent term for data considered as exact and truthful is required. Lee (Lee, et al., 2002) conducted a gap analysis and identified differences between data dimensions and roles associated with data quality. In later research three major roles defined were data collectors, data custodians, and data consumers (Lee & Strong, 2004) this is relevant to this and future research as it provides roles that may be incorporated within a proposed framework. Within the Improvement stage it was hypothesised that it was more effective to change processes than actual data when quality issues were evident (Ballou, et al., 1998) (Wang, et al., 1998). In this regard, this leads this research towards new processes to avoid data change through increases transparency and ownership.

3. Research Rationale and Description

The objective of the research areas presented in this paper was to explore the following:

- What is the current state and potential quality of non-geometric data provided to Clients / Employers at the end of a construction project?

- What gaps may exist in current processes relating to veracity?
- What are the key issues that may need to be considered when developing a solution to the problem?

This research focused on non-geometric data veracity only, to ensure data, and the interpretation of that data is the focus of this study and not geometric models and model accuracy; which has been adopted extensively as a research topic.

During the literary investigation, the term accuracy / accurate appeared to be defined and adopted but without consistency. The US Institute of Building Documentation (USIBD) provides guidance on Level of Accuracy (LOA) (US Institute of Building Documentation, 2014), the framework adopted defines different levels of accuracy in terms of standard deviation, focused exclusively on line-work or geometric model documentation, expanding on the existing European DIN 18710 standard (DIN, 2012), but does not consider non-geometric data. However, the USIBD does state that level of accuracy specifications is something that industry has long struggled with, and if left undefined this can create problems in as-built deliverables. ISO 8000 (The International Organization for Standardization, 2009) defines data accuracy as the closeness of agreement between property value and the true value and therefore is adopting a measurement approach but provides no detail how this should be achieved. This research also needed a term that divorced itself from the word accuracy due to its common association within the construction sector as a measured tolerance, and not necessarily an undisputable truth, such as digitally scanned data being described as having an accuracy of 2mm. The term Veracity has been adopted for this research, and resulting research introduces the concept of Level of Veracity (LoV).

4. Methods

In order to investigate current perceptions, understanding, working practices and challenges that may, or may not exist across the construction industry relating to data and information veracity, the following data collection tools (TABLE 1) were employed to collect required data.

TABLE 1: Data Collection Tools

Data Collection Tool	Participants	Total Number
Survey	Industry Population - To provide an industry-wide perspective.	111
Interview	BIM Experts / Practitioners - To provide expert opinion from extensive industry experience.	14
Interview	**Software Developers - To provide an opinion from a technology and data management perspective**	**7**

The BIM Expert / Practitioner and Software Developer interviews applied a Qualitative data collection process to provide the greatest opportunity for interviewee's to provide feedback and where applicable additional insight. Quantitative data collection is often used to expose new knowledge associated with an under-researched area of study. Qualitative research is generally inductive and allows the opportunity to create a theory or new hypotheses (Jensen & Laurie, 2016). Both of the above methods have been applied to this research, and combined have increased the richness and value of the data collected. The overarching hypothesis that encompasses this research is that the AEC industry has serious challenges in delivering quality non-geometric BIM data and information; using a Mixed Methods approach within this study allows the greatest opportunity to establish current state and begin to develop new theories for further research by using both Quantitative and Qualitative methods (Johnson & Onwuegbuzie, 2004).

5. Analysis and Discussion of Results

From survey data, 74% of respondents confirmed the view that non-geometric information should be 100% correct at project hand-over. Additional feedback via survey comments implied a common opinion that 100% correct was not a realistic possibility and that Clients needed to state their requirements clearly within contracts and EIR's to support delivery. During the interview, BIM Experts / Practitioners agreed that the information should be correct if requested by the Client or Employer and indicated that a contractual requirement might be needed to better ensure delivery of requested data at the agreed quality or veracity.

During interviews, there was a common consensus that data associated with real-world physical components should reflect reality. However, the realities of this being achieved currently across the industry were considered unlikely due to complexities such as:

- Process gaps through lack of checking, verification, and validation
- Technology limitations

- The ability of those actually reviewing the correctness of the information not having the required knowledge or experience

The survey indicated that 72% do not believe that Employers know how to check non-geometric information for correctness and that 64% do not believe the Employer will check the data provided. This feedback does not indicate whether an Employer should actually be responsible for the task of checking, but it does indicate a perceived lack of process, supporting tools or knowledge on the part of an Employer to undertake this task.

Interviews with Software Developers indicated that there was a consensus that Employers would find the checking of non-geometric information challenging when compared to their supply-chain, the reasons stated included:

- The Employer was the most remote from the information process
- The Employer does not have the skills or tools required
- There was currently little interest to review received data or information
- Responsibility lies with the supplier of that information; therefore, there is an element of faith.

Interviews with BIM Experts /Practitioners provided a number of additional insights which included common opinion that:

- There was an element of apathy within Employer organisations to check received information
- It is not the Employers role to check contractual deliverables
- Required skill sets to check would not typically exist within Employer organisations.

The opinion that a specialist team is required to check received data was a popular response and should be employed by the Employer directly or via the project management team. This role could in the future be undertaken by an Employer-side Information Manager.

Of those surveyed 92% did not believe traditional hand-over documentation such as Operation & Maintenance manuals and drawings were 100% accurate when supplied to the Client. This data highlights the need for this research by exposing a significant quality issue and waste of resource due to poor outcomes. BIM Experts / Practitioners further supported this hypothesis and agreed without exception that information received by Clients / Employers was never 100% accurate, and many reflected on personal experiences and observations which included comments such as; "I have never seen a project release an accurate as-built drawing", "O&M's are never complete", "Nothing close to accurate just full of generic information".

During interviews, there were evidently conflicting views that industry either needs to employ new roles such as "data wranglers" or that industry needs solutions that are "under the hood," i.e., Simplify data collection to such an extent that individuals do not need to understand data structures such as COBie. The issue of who actually inputs the data and how many times it is transacted before final input was highlighted.

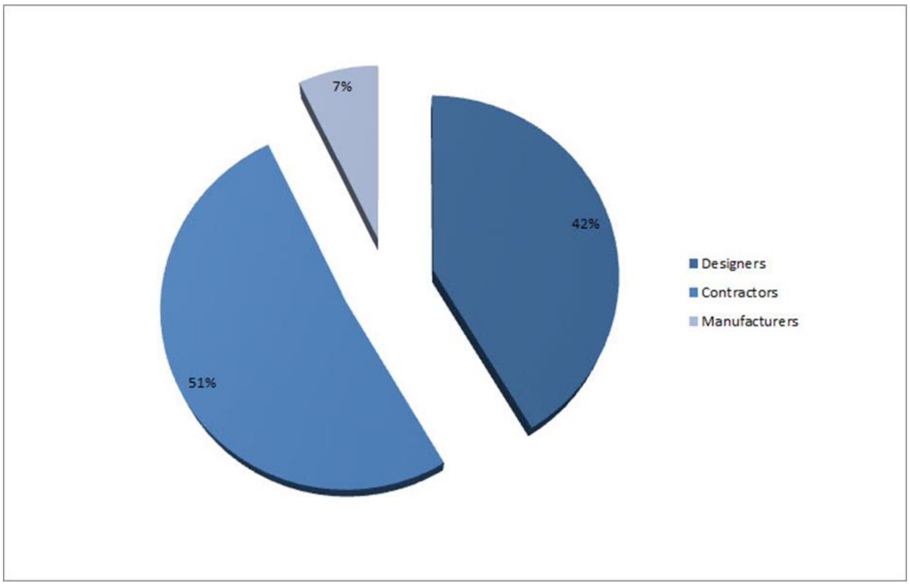

Figure 1. Questionnaire - View on who has the greatest challenge producing non-geometric BIM information

The survey (Figure 1.) indicated that respondents' consider Manufacturers' having the least challenges (7%) when producing non-geometric BIM information. There was no clear consensus whether it is more challenging for a Contractor (51%) or a Designer (42%). Interview responses from interviews supported the hypothesis that it is less challenging for Manufacturers to produce exact non-geometric BIM information when compared with Designers and Contractors.

Interviews produced the following findings (TABLE 2) when comparing Designer and Contractor challenges in delivering non-geometric data & information.

TABLE 2: Designers / Contractors challenges in delivering non-geometric data & information

Designers	**Contractors**
Do not work with exact information	Are contracted to deliver
Are now being asked for new and different information via BIM processes (unique ID's and classification of spaces as examples)	Have supply chain challenges, and need to collate data and information from many third parties
The design is always changing and fluid in nature	Have to model a final product
Designers do not know what is going to be procured.	Need to adapt to site conditions and change
	Skill gaps exist on-site recording site data
	The contractor is not the original author
	Contractor mistakes or omissions due to a lack of design or product understanding
	May select wrong manufacturers specification information
	Contractors have to do a lot of fact-finding
IFC is not delivering what was intended	
There is little industry agreement whether data should be in a model, database or spreadsheet	
Industry requires a seamless data transfer solution	

The comments received indicated that a method to confirm and report to the Employer that the hand-over of data is of the required quality / veracity and complete may be required, without the need for direct intervention by the Employer. This supported a related common view that the Employer should not need to directly check the data.

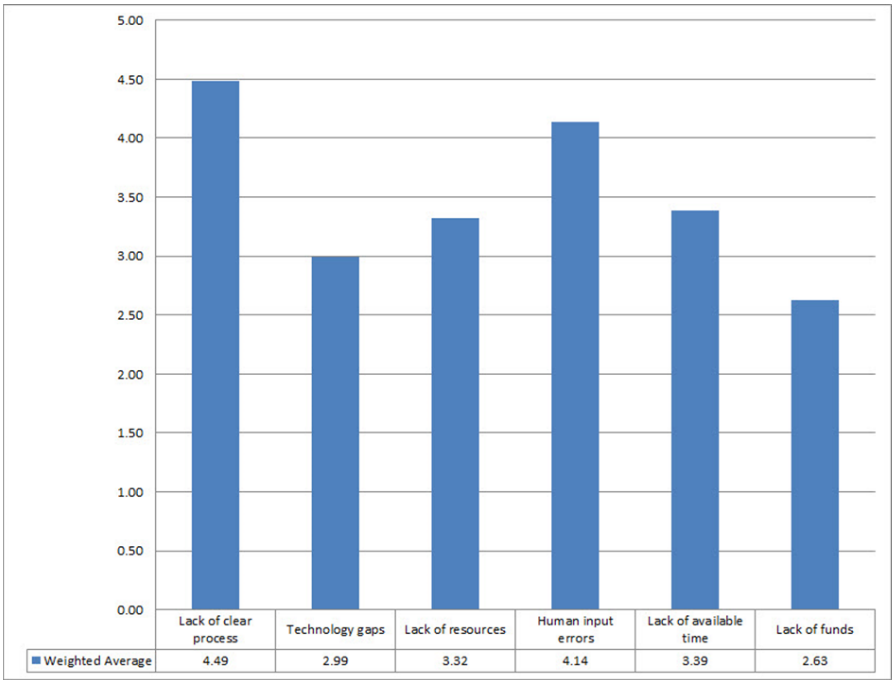

Figure 2. Questionnaire - Identification of risk to non-geometric information veracity

Survey data (Figure 2) ranked lack of clear process as the major contributor to risk of non-geometric information veracity, followed by human input error, technology gaps ranked only 5th, which may infer that risk to information veracity may be best mitigated through the process rather than enhancing current technologies initially. When asked what would help to deliver exact non-geometric information, survey respondents replied 23% Industry standards, 23% Technology to assist, 21% Company workflows, 18% Time for the task, 15% Specific training. Once again there was no indication that technology advancement alone would provide a viable solution and two Software Developers during interviews stated that workflows were a prerequisite for the development of the technology. BIM Experts / Practitioners when interviewed typically stated appropriate standards would be the most helpful.

During interview Software Developers responded that their individual systems did consider non-geometric data exactness, but the veracity of that information could not be guaranteed using the technology, because the technical content and therefore confirmation of the veracity of that data must be provided by the author.

Technology processes for checking data were identified and included:

- Checking the presence of data against employer's requirements.

- Checking data is in the expected format such as Omniclass, date or currency
- Checking specified data against manufacturers data via comparison rules
- Checking and interrogating data using algorithms and rule sets.
- Identification of expected parameters associated with elements, such as a fire door object requiring a fire rating parameter.

When asked what has been the greatest challenge conceptually or during software development with regards data veracity; the responses received from all interviewed were very similar; the challenges identified included.

- Not receiving data in the first place
- Not being able to trust the data
- Not receiving data that was structured
- Project teams are not specifying requirements
- Lack of understanding within design teams and a need to change working practices
- Classification systems are required and need to be issued to software developers
- Misalignment between construction specialists and a data management specialists (individual knowledge and experience need to be aligned)

From the above feedback, it indicates a difference of opinion regarding a single uniform approach to the data structure for the AEC industry or a mapping approach between classifications, although classifications were regularly referred to.

6. Discussion

This research presented evidence that multiple challenges currently exist in the procurement and delivery of non-geometric data in both quality and veracity. This has been achieved by collecting and analysing industry BIM experts, practitioners and software developers point of views and identifying consensus of opinion and experiences. This research has identified a number of key findings as listed below:

6.1 CONTRACTS AND STANDARDS

Current contractual requirements and legal frameworks may need to be amended to include clauses relating to the Data Quality or Veracity required by the Employer and clearly state method of measurement(s) for compliance. In addition current UK BIM standards and specifications do not include specific guidance relating to data veracity or level of accuracy and only make reference to approval validation and verification processes, where validation is a process to check if data is sensible and reasonable, but it does not check the accuracy of that data, and where verification is often a manual process to check data entered matches the original source but is totally reliant on the competencies of the person undertaking the task.

There is an opportunity to expand and build upon existing BIM standards by developing supporting guidance in areas such as validation & verification and as suggested by this research towards a state of veracity.

6.2 COMPETENCY AND PROCESS GAPS

There is consensus that data associated with a real-world physical component should reflect reality, however, the realities of this being achieved currently across industry were considered unlikely due to multiple complexities which included; process gaps through lack of checking, verification and validation, current technology limitations and those individuals who are tasked to review non-geometric data not currently having the required competencies.

There are strong indications to suggest that suppliers do not believe the Employer will, or has the capability to check supplied data and that there is an element of apathy within Employer organisations to check received information.

This may be due to the following reasons:

- The Employer was the most remote from the process, therefore, the information
- They do not have the skills or tools required
- There was currently little interest to review received data.
- Responsibility lies with the supplier of that information; therefore, there is an element of faith pertaining to a guaranteed of veracity.

A specialist resource representing the Employers interests may be required to resolve this issue and could be incorporated into a revised Employers Information Management role. Industry perception is that hand-over data & information has always been poor in quality, incomplete and rarely reflected as-constructed. This indicates a long-standing culture on the part of the Employer and its supply-chain that this situation is inevitable and has to be accepted. Via BIM and industry digitisation this view and cultural acceptance are being challenged, and this research may further support industry improvement and change.

6.3 TECHNOLOGY AND SYSTEM CHALLENGES

For technology providers, the changing industry standards relating to BIM adds extra complexity in developing future toolsets, and there is also a lack of clarity on how dispersed or centralised construction related data sets and repositories will be in the future to suit project data and information requirements. Existing tools are limited in their ability to confirm veracity and instead the only person who can confirm the veracity of data is the original author. This is of importance as all processes relating to data delivery that is 100% truthful and therefore, reaches a state of veracity must ensure the original author provides the required provenance, knowledge and confirmation because technology cannot measure or confirm data veracity as human interpretation is required to put context to data and data-sets.

It is unlikely that all data can reach a state that can be termed as exact; as an example data associated with radiator wattages will not always reflect the physical installation as that will be dependent on factors such as heat source and settings on items such as thermostatic radiator valves. When considering the use of terms accuracy and veracity associated with BIM, veracity could be utilised to describe a target to reach 100% truth, where accuracy has already been adopted to define different amounts of deviation from the truth and the actual physical world.

The Employer is not in a position to approve or confirm the veracity of data received, but can accept other dimensions of data quality such as completeness, and determine if all data requested has been received. During interviews with software developers, a number are incorporating this type of functionality within their applications. This will assist the project management and efficiency of the data checking process, but it will not confirm that the data supplied is appropriate for use or exact.

7. Conclusion

During data collection, it was evident that there needs to be extensive education across the industry to explain what quality dimensions and criteria are required to deliver exact data that is beyond dispute and reflects the physical built environment. The research from data collected indicates that secondary data entry by third parties, presence checking via visual inspection or scripts, and checking processes to confirm that BIM data requested by the Employer has been provided appears to reflect best current working practice at this time. All indications from the data collected suggest that all three of these processes have scope to become more efficient and improvement can be made.

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APPLIED VISUAL INTERACTIVE RESOURCES FOR BUILDING REGULATION SUBJECTS

An Evaluation of the Design and Use of Applied Visual Interactive Resources for Building Regulation Subjects in Higher Education Built Environment Programmes

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Abstract. This research is situated in the field of Higher Education teaching and learning and specifically relates to Building Regulation (BR) pedagogy. A research gap has been identified with scope to develop online Visual BRs for use in Higher Education Built Environment programmes, and in parallel, contribute to the research fields of Higher Education online learning and visual literacy. The aim of this research was to evaluate the design and use of applied visual interactive resources suitable for use in BR subjects in Higher Education Built Environment programmes. One research question was investigated, namely, whether three examples demonstrating Applied Visual Interactive Building Regulations (AviBRs) were effective and useful in their design. Informed by constructivist theory, an animated video, an interactive learning object and a gamified learning object were profiled as examples of AviBRs within a dedicated research website. Four anonymous survey forms were included on the website to capture feedback. Data received was then evaluated using a single-loop developmental evaluation methodology which informed their systematic redesign during the survey. Survey participants unanimously agreed that AviBRs were effective for online learning. The three examples profiled were acceptable to the majority of survey participants. The research findings conclude that there is significant scope for further research and development in online Visual BRs for Higher Education.

Keywords: Applied Visual Interactive Building Regulations, Visual Literacy, Applied Learning, Online Learning, Visual Building Regulations

1. Introduction

This study has been situated in the field of Higher Education teaching and learning and is relevant to any subject which incorporates BRs in its educational remit, such as within the disciplines of Architecture, Architectural Technology, Engineering and Building Surveying and so on. BR compliance for design and construction should be an essential training component for any Built Environment profession.

Acts and BRs have been written and legislated for by Governments throughout the developed world as a direct response to societal requirements for consistency, safety and best practice in the Built Environment. Governments have also published Technical Guidance Documents (TGDs) in Ireland or Approved Documents (ADs) in the UK to demonstrate how BR compliance can be achieved.

Having lectured BR compliance for twelve years on an Architectural Technology undergraduate degree programme in Ireland, the authors' opinion as an educator has been 'constructed based on personal experiences and hypothesis of the environment' (J.L. 2015). Frequent discussions have been had with Architectural Technology students in relation to learning, teaching and applying BRs.

International students have indicated that they have time-consuming difficulty translating the TGDs into their native language, after which they are left with little time remaining to apply their findings to project work. A similar sentiment has been noted by the Higher Education Academy, where 'non-English speaking background students are likely to struggle at first with language in lectures and tutorials, complex reading and writing tasks, and new academic and disciplinary concepts' (2014, p1).

Dyslexic candidates have found the diagrams in the TGDs useful but have struggled with the extensive written elements. They have voiced their preference for visual learning using pictures, which is reinforced in the literature relating to reading disorders such as that written by Heelan (2015, p2).

This research has been designed within a constructivist theory to explore an additional, rather than exclusive or substitute approach to current BR pedagogy, namely an AviBR approach. To explain further, one could liken the concept of AviBRs to a series of steps or scaffolds which could be used in a staged progression to learn new competencies, transitioning from a place of none or little knowledge of BRs to one where building compliance requirements for design, contract drawings and building site certification and sign-off are clearly understood and assessed as such, within the confines and safety of an educational setting.

Using applied visual interactions, AviBRs could be used as a visual, teaching version of the BRs in an early-stage educational setting alongside current educational practices or as Continuing Professional Development (CPD) for those upskilling or refreshing their knowledge while working in practice.

2. Literature Analysis

The following section covers a brief overview of literature relating to current BR educational practice and Higher Education applied visual interactive learning.

2.1. TGDS/ADS, BR LITERATURE & PEDAGOGY IN THE BUILT ENVIRONMENT IN IRELAND

The depth of knowledge of BR requirements varies depending on the discipline. While a Construction Industry Federation training programme had claimed to be ‘the only accredited building regulations course offered in Ireland’ (CIF 2017), in reality BRs have always been embedded in Built Environment programmes, and more extensively so in the field of Architectural Technology (QQI 2016) and Building Surveying (SCSI 2017).

The BRs can be taught in lectures or applied to project work within Built Environment Higher Education programmes using detail design pedagogy in studio (Robertson & Emmitt 2016, p16) or in a Computer Aided Design or BIM (Building Information Modelling) laboratory. This process epitomises a ‘hands-on, inquiry-driven, project-based learning’ pedagogy (Chance et al. 2013, p131).

There are great strides linking pedagogy to practice using BIM from authors like Mathews (2013) and Kouider et al. (2016). Industry collaboration injected straight into the classroom as documented by Comiskey et al. (2016) and the use of live projects by Harriss (2014) are examples which epitomise the ongoing exemplary practices in Higher Education Built Environment programmes.

More traditional overarching Architectural Technology pedagogical papers have been written by Crean & Prunty (2010; 2011), Prunty (2011), Comiskey, Alexander, et al. (2016), and Harty (2016). The author has noted that these have not been specifically written about teaching BRs. The search for literature outlining BR pedagogical practice linked directly to BR compliance requirements from a design and construction perspective has been less successful.

Pacheco et al. (2014) outlined an exercise in Legal Architecture in Spain, which consisted of lectures, workshops, seminars, group work and a written test combined with a final evaluation, which is commendable research, but may be more traditional in its approach to learning-teaching, while exemplifying yet another regulation-pedagogy out of the many already outlined.

No defining papers or guidance documents were found specifically on BR pedagogy. The hope was to find case studies or publications which capture how BRs can be taught and assessed in Higher Education Built Environment programmes. One book was published in 1944 (Neufert), but as it predates current BRs, it would not necessarily be relevant. Therefore, one can conclude that there is a wide scope to research and catalogue current BR teaching practice across all Higher Education Built Environment programmes, and a new area of research not currently published in educational research being the specialist area the author has termed 'Visual BRs'.

How effective are programmes when it comes to educating students on BR requirements? A recent forum post online stated: 'I am a BA Architecture graduate and throughout our course didn't really get educated on building regs. I want to take a course or qualification to develop this knowledge… (looking for) the best (online) route to gaining a good knowledge of Building Regulations and the laws' (Nickwm 2016). This is not surprising, given that BRs are not expressly stated in the Quality and Qualifications Ireland document defining the Architectural educational award standards, as an example (QQI 2014a).

One can conclude that it is not only what is taught and assessed within the Built Environment Higher Education programmes but also the transition from graduation to the workplace and professional development up to a competent level which needs to be addressed when adjudicating BR pedagogical and competency practices in Built Environment disciplines.

Similar to Architecture, BRs are not expressly stated in the 'Engineering - Award Standards' document published by the QQI (2014b). At present, the profession of Building Surveying has no award standards currently defined by the QQI.

It is interesting to note, then, that all three professions are expressly stated as 'Assigned Certifiers' under the 'Building Control (Amendment) Regulations 2015' in Ireland (Irish Government 2015), whereas Architectural Technology currently is not. There does not appear to be a clear correlation between BR training, updates in practice and what happens within an undergraduate programme, nor has account been made of the time from graduation up to a professionally competent level in the workplace, if viewed through the lens of a BR educator. And another question remains unanswered: are BR competencies for design and construction assessed consistently between disciplines?

Generally, after graduation this standard is set, controlled and monitored by professional bodies, such as Engineers Ireland (EI), the Royal Institute of

Architects of Ireland, the Society of Chartered Surveyors Ireland and the Chartered Institute of Architectural Technologists, to name a few.

One can conclude from this that BR educators in the Built Environment should foment CPD practices from graduation on, in consultation with professional bodies and key stakeholders, to inform educational upskilling requirements stemming from regulation updates or changes, while addressing BR requirements in educational standards at a national level in these specific disciplines in Ireland.

A commendable example of how post-graduate training has been realised is the nZEB (Near Zero Energy Building) training programme which was pioneered by DIT (Dublin Institute of Technology) (Mcguinness 2017). Its remit was to upskill professionals ahead of the publication of a new version of TGD L 'Conservation of Energy' (DoHPCLG 2017d), which had gone through a public consultation phase in Ireland by May 2017.

A national framework of initiatives such as this should be further investigated by Higher Education BR educators to address shortfalls in BR education, upskilling in new BRs, and adjudicate unquestionable transparency and rigour in all processes relating to proving an unequivocal BR compliance base from design to construction, in consultation with professionals and key stakeholders in these fields.

TGDs in the Republic of Ireland are freely available to the public as downloadable PDF files from the Irish governments' website. Students are in a difficult position, particularly the first time they are introduced to TGDs. They need to familiarise themselves with these documents, which is a daunting task of 1,010 pages for Part A to M inclusively (DoHPCLG 2012; DoHPCLG 2006; DoHPCLG 2017b; DoHPCLG 2004; DoHPCLG 2013; DoHPCLG 2014a; DoHPCLG 2009; DoHPCLG 2011; DoHPCLG 2016a; DoHPCLG 2014b; DoHPCLG 2014c; DoHPCLG 2017d; DoHPCLG 2008; DoHPCLG 2010b).

For example, to complete a Fire Safety Certificate application, depending on the purpose group of the building, it may require a student to refer to additional documents, such as British Standards (British Standards 2017), Building Bulletins (Bissell et al. 2007) or Building Research Establishment publications (Chitty 2014). These documents are referred to within the TGDs and can therefore be interpreted as being bound by the same compliance rigour.

To prove compliance with TGD L or Part L, 'Conservation of Energy', for example, Part F, J, L and the supplementary documents need to be familiar to design a dwelling, amounting to 462 pages (DoHPCLG 2009; DoHPCLG 2014a; DoHPCLG 2017d; DoHPCLG 2008; DoHPCLG 2016b). These need to be read in conjunction with a Dwelling Energy Assessment Procedure assessment to calculate a Building Energy Rating. Incidentally, the documents required to be accessed for this assessment amount to an additional 1,000 pages approximately and require the use of a software package and an excel spreadsheet, both of which are freely downloadable from the Sustainable Energy Authority of Irelands' website.

Having to refer to overlapping TGDs when designing a building for the first time can be challenging. An example of this would be the design and specification of glazing. This would require a student in Ireland to refer to Part B (DoHPCLG 2017b; DoHPCLG 2006), Part K (DoHPCLG 2014c), Part D (DoHPCLG 2013), Part M (DoHPCLG 2010c), Part F (DoHPCLG 2009) and Part L (DoHPCLG 2017c; DoHPCLG 2017a). This compares to the UK BRs, which include an additional Part N, 'Approved Document N – Glazing – Safety in relation to impact, opening and cleaning' (HM Government 2013), which somewhat reduces the number of documents which need to be referred to.

A search for dedicated web-based teaching resources for BRs identified that no open-access resources exist. A few useful websites exist, however, they appear to be blogs for professionals (Murray et al. 2017) or else wiki sites (Designing Buildings Ltd. n.d.). No dedicated BR teaching resource was found in searches, although the Chartered Association of Building Engineers have useful 'You Tube' videos online relevant in the UK (CABE 2016) and EI have an extensive webcast archive available online.

A search was conducted on iOS and android platforms for apps containing information relating to BRs or appropriate teaching resources. Two apps were available which contain information relating to Irish BRs, namely 'The Building Regulations IE' (QQI 2016) and 'BuildRegsIreland' (Designdirekt Ltd 2015). However, on inspection, they were simply repositories which regurgitate the TGDs while not offering engaging learning in their design. The second app, which was subscription-only, did illustrate TGD clauses hyperlinked to visual representations of buildings, but as such was not a teaching resource, and quoted regulations line-by-line, rather than implementing visual teaching techniques to aid understanding.

Gaming techniques have been used for Health and Safety Construction Site Training for a few years, pioneered by Teesside University (Dawood et al. 2013). This software makes learning site safety believable, with various scenarios of what could go wrong on a building site played, learning how to avoid them without putting oneself in danger on a real building site. This technique would be useful alongside other techniques to teach BRs.

Game Based Learning 'offers a potential way to stimulate… creative, independent learning' (Ryan 2014, p4), where knowing can be demonstrated 'inseparable from action and environment, and… inseparable from issues of access and empowerment', thus leading to 'the empowerment of learners'

(Foucault 1975; cited by Carlile & Jordan 2005, p23). This has informed the design of example 3, outlined in primary research.

The Irish Health and Safety Authority's Safe System of Work Plan communicates visually used pictograms (HSA 2014). It has been successfully implemented for site safety. The precedent is there to follow suit with a visual application of BRs for educational purposes, taking the lead from initiatives such as this.

When searching for Technology Enhanced Learning examples in order to teach BRs, Comiskey et al.'s (2013) paper describing the use of an Apple iBook in Architectural Technology classes is to be commended. Without having seen it, a suggestion could be to develop it further with interactive and gamified elements to greatly enhance the usefulness of the reusable learning object. If it were designed to meet the remit of an AviBR, for example, it would need to be written with learning, teaching, assessment and evaluation pedagogy embedded into the BRs elements, in an applied, interactive, visual manner.

One could argue that there is a distinct gap between educational practices and industry in this regard. One instrument which can bridge this gap is BIM. BIM cab be used to lend rigour, transparency and validity to BR checks, compliance requirements and sign-off. Can this be extended to education? With the Construction Industry in the UK at BIM Level 2 (Mellon & Kouider 2016), it is early in its process evolution. It is still to be adopted in some countries, including Ireland with the exception of new Government Contracts (McAuley et al. 2017, p6). When routines and scheduling are applied wholesale in one dedicated level 3 BIM model, universal BR compliance checks will be fully realised and a dynamic shift of power to practitioners performing this functionality will become even more evident.

A fourth year Architectural Technology student from DIT has completed a dissertation last year entitled 'Could Revit be Automated for Code Compliance Checking and Demonstration' (Garvin 2017), which shows great promise in the area of BR compliance from an Architectural Technology research perspective. Changes to BR compliance practices will need to be fed in tandem into academia. This will be extremely useful in the context of teaching and learning BRs.

2.2. VISUAL APPLIED INTERACTIVE LEARNING

Visual learning is a learning preference many students in Built Environment programmes have, as Mange et al. alluded to in reference to Architectural students (2015). However, it is not an exclusive learning preference.

'Architects are visual learners… Show me how to do something and I have got it. Tell me how and I am shaky on it. Make me read a manual and I will fall asleep before I finish', although 'nothing replaces being taught directly from a human being standing in your presence' (Calisti 2011).

What this Architect is describing is experiential learning or applied learning. It is a multi-sensory approach to learning, using the visuals in drawings to the touch of paper, cardboard models, colouring pens as tactile learning to the sound of a persons' voice as aural learning to the social interactions in the studio setting, learning with peers or learning by demonstration. One can copy-by-doing in an experiential model using multi-sensory approaches to learning. The author would suggest that they are a kinaesthetic learner, preferring 'learn(ing) by doing and solving real-life problems… (with) hands-on approaches to things and learn(ing) through trial and error' (Friedman, 2013, p12), which incidentally epitomises studio-based practice.

The fact that a visual learning style cannot be used in isolation also rings true from the findings of Mange, Adane and Nafde, where they mention 'visual + other sound/teachers voice' as a way to keep Architectural students concentrating for longer rather than simply visuals alone (2015, p210).

Kolb's experiential learning cycle demonstrates a simple experiential learning model (Kolb 1984; Kolb & Fry 1975). This has been overlaid with learning styles by Chance et al., concluding that even Kolb found that students from 'engineering, architecture, art, and sciences learn' and make decisions differently (Chance et al. 2013, p135; Sheehan & Kearns 1995). In other words, their tendencies towards applied or experiential learning is heightened with project-based learning.

The use of 'multimodal immersive learning experiences' including 'animation, audio and video' among others, can be used to meet visual learners needs when designing AviBRs (Articulate 2015). The mode, medium and form of AviBRs will need to be examined closely as part of their design, as mentioned by Bezemer (2012), encompassing 'multimodal literacy' defined by Lim (2011). Would a passive video be a suitable technological tool appropriate for use as an AviBR? This has informed the design of primary research example 1.

Semiotics specifically for the Built Environment is standard practice, so AviBR design would need to embed 'semiotic resources' for such 'discourses' (Heimans, 2011, p385). This can aid 'meaning making… sign-processing and meaningful communication' (Wikipedia 2017) applied in the context of BR compliance drawings and site take-offs, for example. This could call for the standardisation of a visual-compliance-etiquette, for TGD K/M/B compliance requirements when designing a stair, for example. There is scope for further definition of semiotics within BRs. If AviBR design is approached with a semiotic lens it could, in theory, somewhat standardise and unify compliance requirements across disciplines.

Just as an educator needs 'positive interactions and relationships' with peers and learners, so too does a learner with the material they are being taught (Hagenauer & Volet 2014, p371). A student with dyslexia 'can learn better by doing experiments, viewing You Tube clips or using technology to listen to audio books rather than having to depend solely on reading in order to learn' (Heelan 2015, p2). In other words, a visual, reduced-language, applied, multi-sensory learning approach. This has also informed the design of primary research example 1.

The integration of Universal Design for Learning techniques can further enhance and inform AviBR design, 'addressing the different learning needs of students … and reducing barriers to learning', using a scaffolding approach (Alberta Education 2015). The 'simplicity' and clarity of formulating a concrete beginning, middle and end to a BR lesson plan using Universal Design for Learning principles 'precedes the complexity' of opening and making reference to multiple TGDs for design purposes which might typically be required in studio practice (Cabaj 2009; cited by Patton 2011, p9).

The visuals proposed for AviBR design would be specific scaffolds used either in the classroom or as blended learning (Donnelly 2016) between classes made available online, for example, taught in the spirit of constructivist learning, where students could engage in the AviBR material for a short time and the lecturer could intervene if required. However, the author still holds firm that this must be delivered in the context of project-based learning and be directly relevant to the project for this process to be successful.

As an educator in Higher Education, Race argued that it was 'our responsibility to cause learning to happen, because it doesn't always happen just by itself' (2011). This has informed the design of primary research example 2 and 3. Can an interactive image aid BR learning and understanding when integrated into a bespoke learning object design?

To summarise, this study identifies that there is a gap in resources freely available, particularly online resources and applied visual interactive resources for teaching BRs. The fact that BRs are best learned in an applied, contextualised manner, stemming from knowledge gained from studio practice, where this 'knowledge is constructed based on personal experiences and hypotheses of the environment' (J.L. 2015), this should inform the design of AviBRs and has influenced the design of all three primary research examples 1, 2 and 3.

When researching visual learning, the literature available was found to be diverse and plentiful, and included multimedia learning, multiple representations learning and multi-modality. Concept mapping (Magna Publications 2011) and a knowledge of the 'spectrum of visual learning' would be useful when designing AviBRs (Moore & Dwyer 1994). Hill outlined ‘activities based around the idea of using pictures to stimulate language learning’ (1990). A similar publication of activities would be useful to stimulate BR learning.

And while searches for applied learning and interactive learning yielded results from Kolb, constructivist theories, and student centred learning (Lea et al. 2003), strategies for social interactive learning conducted in the classroom could only be sourced from videos created by the University of Texas in Austin (2017). These resources were reported to be easy to follow and suggest good examples of how to get students to engage in teaching material and interact with each other in their learning environment.

Gilly Salmons’ five-stage model of e-learning is one such model which could be followed for online learning (Salmon 2013). This, however, falls outside of the scope of this study.

If one were to use an interactive learning object, the cause-and-affect nature of the design completed using visuals with touch-screen animation, or touch-screen photo-realistic images, for example, the author would suspect that this may make learning even more effective. Similarly, three dimensional environments using BIM 360 or fully-immersive environments using gaming software such as Unity could equally be explored in the context of visual BRs. Literature searches for this type of approach yielded limited results and fell outside of the scope of this pilot study.

Similarly, applied visual learning and applied visual interactive learning did not yield conclusive results, both in general and in the context of BRs. While Wolfe outlines teaching practices to customise the curriculum including some of these techniques (2005), what he was actually describing was a Universal Design for Learning Process.

To conclude, this paper has thus identified a research gap in Visual BRs and online teaching tools suitable for use in Built Environment Higher Education programmes, while in parallel, in the context of Higher Education learning and teaching, findings may contribute new knowledge to the fields of online learning and visual literacy.

3. Aim and Research Question

The aim of this research was to evaluate the design and use of applied visual interactive resources suitable for use in BR subjects in Higher Education Built Environment programmes.

One research question was investigated, namely, to ascertain if three examples of applied visual interactive BRs were effective and useful in their design? How did relevant stakeholders evaluate these examples in relation to the choice of learning medium (e.g. video) and form (e.g. animation)?

4. Methodology

The methodology has been conducted as a developmental evaluation from a utilization-focused perspective, which allowed the author to 'test … how to foment change in the face of uncertainty in situations characterised by complexity' (Michael Quinn Patton, 2011, p14). Developmental evaluation sits within the overarching 'utilisation-focused evaluation', which 'is evaluation done for and with specific primary intended users for specific, intended uses' (Patton 2011, p7, 13).

The author aligned the research approach with a constructivist ontological lens, recognising that 'social phenomena and categories… are in a constant state of revision' (Bryman, 2012, p33). It was also in keeping with an epistemological basis of interpretivism, 'where knowledge is believed to be acquired through involvement with content instead of imitation or repetition' (Kroll & LaBosky, 1996; cited in UCD, n.d.). Developmental evaluation 'has the purpose of helping develop an innovation, intervention or programme' (Mathison 2005, p115; cited in Patton 2011, p20). 'Outcomes will emerge as we engage' with the three primary research examples (Patton 2011, p5), within a constructionist paradigm of learning-by-doing.

To generalise findings from this research, the first three survey questions for each example were quantitative in nature, using a Likert-scale-type approach for the third question. The fourth question was qualitative, seeking findings from 'multiple-validities' in the data-capture (Onwuegbuzie & Johnson 2006 p57; Cohen et al. 2011 p198).

The 'two different lenses' of positivism and interpretive paradigms resulting from mixed-mode findings (Cohen et al. 2011, p31) was resolved by adopting a pragmatism paradigm, 'to address research problems' (Creswell 2007, pp10, 14-15) but also 'honour each and be explicit about when each is used' (Greene et al. 1989; Creswell 2007, p15).

The survey questions were designed to collect 'data from multiple sources (triangulation)', namely from a variety of key stakeholders, to validate research findings as part of an effective evaluation for knowledge (Felder & Brent 1994, pG-2).

The developmental evaluation was conducted using a single loop developmental evaluation process (Bornstein, 2007; Michael Quinn Patton, 2011, p11) with feedback from survey questions reviewed on an on-going basis, thus 'obtaining a deeper understanding in some specific area', (Chelimskey, 1997; cited by Saunders, 2006, p205). This approach was in keeping with a constructivist theory of learning, where 'learning is perceived as an active, not a passive, process, where knowledge is constructed, not acquired' (UCD n.d.).

4.1. METHODOLOGICAL TOOLS AND SURVEY DESIGN

Three examples of AviBRs were delivered asynchronously within a dedicated research website created using 'Weebly': http://avibr.weebly.com/. The website was not searchable online. The freeware functionality within 'Weebly' allowed only four questions per questionnaire. As a result, the author did not ask age, sex, ethnicity, discipline or disability but instead focussed the structured questions on the examples themselves. Such information could have been perceived as discriminatory if the research were subsequently seen to give greater validity to one groups' opinion in comparison to another. It was felt that it would be unethical to do so.

The survey questions related back to the research question and overall aim of the research. Four survey questions were included in each of the four pages on the research website. Participants were requested to provide feedback on the three examples before providing feedback on the first webpage, which sought further information in relation to the use of AviBRs in education.

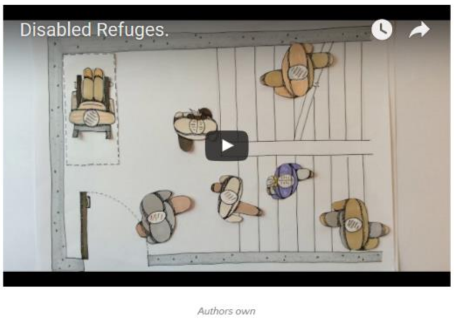

Figure 1. Example 1 – Animated Video

Example 1 was an animated video. It was posted on 'You Tube' and created using a 'Stop Motion' app on an i-pad mini. All illustrations were drawn using 'pro-markers' and 'tech-liners'. A screenshot of the page can be seen in Figure 1.

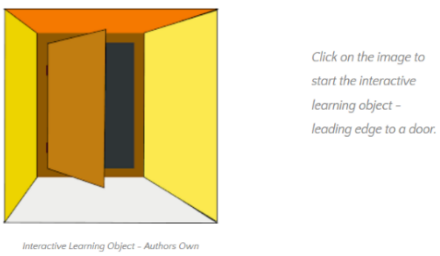

Figure 2. Example 2

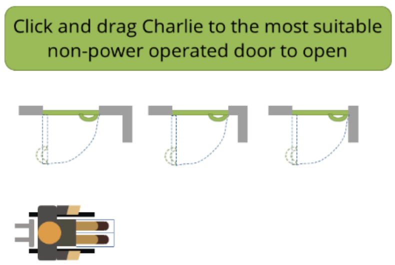

Figure 3. Example 2 – Leading Edge

All apps and web applications used for the purposes of this research were freely available. Example 2 and 3 were created using a thirty-day free trial of 'Articulate Storyline 2'. This software was chosen as it allowed the author to create interactive visual images relatively easily. Figure 2 and 3 illustrate screenshots from example 2 which was intended to demonstrate an interactive learning object representing TGD M 'Access and Use' leading edge requirements of a door (DoHPCLG 2010a).

Figure 4. Example 3

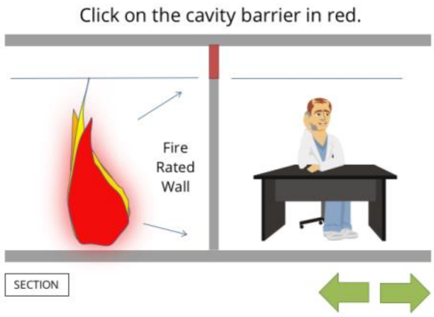

Figure 5. Example 3 – Cavity Barriers

Figure 6. Example 3 – See how you score

Example 3 involved the demonstration of cavity barriers for TGD B 'Fire Safety' (DoHPCLG 2006) within a gamified learning object. Screenshots from this web page can be seen in Figure 4, 5 and 6.

4.2. PARTICIPANTS

The survey was sent by email on 10th of April 2017 to staff and students in the Department of Building and Civil Engineering at Galway-Mayo Institute of Technology, where the disciplines of Civil Engineering, Architectural Technology, Quantity Surveying and Construction Management are taught.

It was then circulated on 'LinkedIn' and 'Twitter' and emailed to industry and educational contacts. The survey was circulated by the CIAT to all members internationally via an electronic newsletter on 27th of April (CIAT 2017).

Feedback was requested from any country and from practitioners, educators, lecturers, tutors, researchers and students alike. Space triangulation was considered in an attempt 'to overcome the limitations of studies conducted within one culture or sub-culture' (Cohen et al. 2011, p196), in other words, to gain feedback from individuals from more than one country.

4.3. METHODS USED FOR DATA ANALYSIS

The responses received from four survey questionnaires were downloaded into an 'excel' spreadsheet directly from the 'Weebly' website on the 10th of May 2017. One spam entry was omitted along with two duplicate entries. All remaining entries were considered genuine with unique, verifiable IP addresses.

The data was colour-coded into three classifications: positive feedback, suggestions for improvement and negative feedback. Answers were coded line by line until all four spreadsheets were coloured in, thus facilitating easier understanding and extrapolation of themes and findings.

4.4. ETHICS

Permission to refer to the Irish BRs was received from the Irish Government by e-mail. A disclaimer was added to the research website to explain that the three examples were not a substitute for the legally binding BRs and that they were based on the Irish BRs alone.

Ethical clearance was obtained for this research and findings were kept anonymous with informed consent. A 'Consent Form' and a 'Participant Information Sheet' were directly downloadable from the research websites' first page (Bryman 2012, p142).

4.5. SCOPE AND LIMITATIONS

This research has excluded other types of Technology Enhanced Learning and Web 2.0 tools, quizzes, document uploads, screen-recordings, 3D prints, 3D visualisations, augmented reality, virtual reality, any assessment or evaluation practices, as well as laboratory, physical or electronic experiential learning options for AviBRs, to name a few.

One limitation of this research is that only Irish BRs and legislation is referred to. A further limitation is that a broader scaffolded curriculum design and online pedagogical approach has not been considered in this pilot study.

5. Research Analysis

The survey was responded to by study participants (S) from England, Wales, Northern Ireland and the Republic of Ireland.

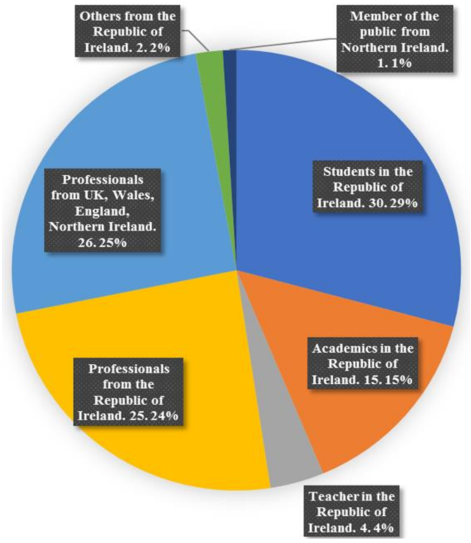

Figure 7. Spread of survey participants

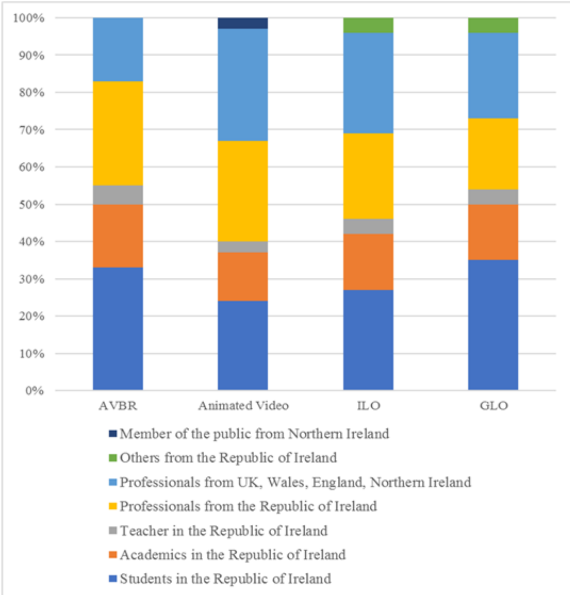

Figure 8. Range of survey participants per questionnaire

103 valid entries were received and represented approximately 50% professional and 50% academic, teacher or student, as illustrated in Figure 7 and 8. This presented findings from a balanced range of key stakeholders and included a variety of countries.

Single-loop design changes which were completed during the developmental evaluation process have not been published in this study but have been retained by the author. The technique of single-loop learning embedded 'a problem-detection-and-correction process' to fine-tune the design of the three examples. It facilitated a process of 'getting beyond surface learnings to deeper understandings of what's happening in a system' (Patton 2011, p11).

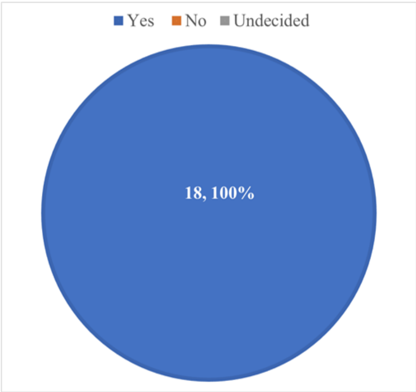

Figure 9. Survey responses: Do you think AviBRs can be effective as e-learning tools in education?

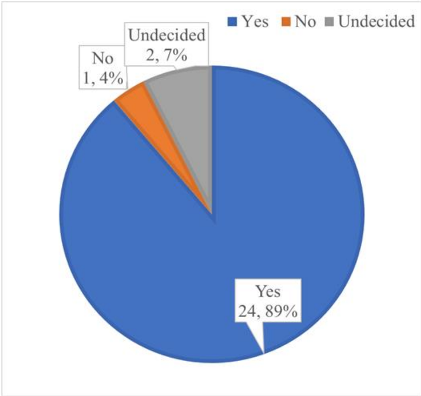

Figure 10. Survey responses: This is an example of an animated video. Do you think it can be effective as an e-learning tool?

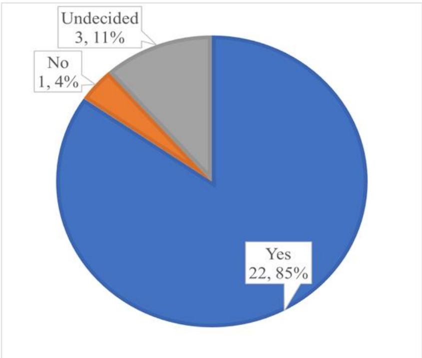

Figure 11. Survey responses: This is an example of an interactive learning object. Do you think it can be effective as an e-learning tool?

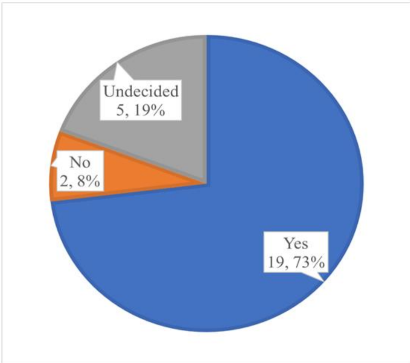

Figure 12. Survey responses: This is an example of a gamified learning object. Do you think it can be effective as an e-learning tool?

Illustrated in Figures 9, 10, 11 and 12, feedback was generally positive in relation to the design and use of AviBRs as an e-learning tool in education. 100% were in favour of AviBRs as effective e-learning tools in education with 89% in favour of the animated video example, 85% in favour of the interactive learning example and 73% in favour of the gamified learning example.

The animated video received the largest number of comments. It could be presumed that this was because it was the first example on the research website. Also, it contained a large amount of technical content, it was the least likely to have a technical glitch, it was an example which could be viewed by simply pressing play and it was viewed via ‘You Tube’ which is a familiar platform to many.

Nearly all study participants commented favourably, except one who commented that ‘the approved documents are so clear that this exercise is irrelevant (S42)’. In terms of facilitating easier learning practices for learners, S48 commented that ‘as a person with dyslexia, I find this video would have great benefits for someone with reading difficulties, in helping them understand the TGD's’. S36 agreed, noting that ‘yes, it is effective as visualisation can help to explain especially for people with varying abilities’.

S6 reported that ‘regulations aren’t necessarily suited to everyone, they are suitable for those who can take in lots of information reading tedious amount of text. For people who get lost in text like myself, visual, interactive aids help’. S38 agreed, commenting that ‘for people with different learning preferences I feel it’s important to deliver the information in a variety of ways. This is my preferred way of learning and if the same information had been presented in a separate way e.g. all written down, I would probably not have understood it at all clearly’. S102 noted that ‘sometimes a visual representation of the regulation is easier to understand than reading the regulations’. S49 commented that ‘it would be very beneficial to foreigners working in Ireland who have poor English’. S69 noted that the BRs were ‘very easy to understand with images’, while S21 reflected that ‘it’s easier to watch something than to read!’. These findings mirror the authors’ own observations, in that a visual, reduced-language form of BRs can be useful for many in an educational context, for a variety of reasons.

In terms of visual learning, S10 stated that AviBRs ‘will benefit people with a visual learning style’ as did S27, reporting that they were ‘effective for a visual learner which I consider myself to be’ and S28, stated that ‘they are great especially for visual learners’. S52 reported that AviBRs were ‘easy to visualise’, S58 reported that ‘visual aids always help in digesting the information’ and S60 commented that the AviBRs were ‘great, easy to remember, visual’. S70 concluded that ‘visual aids always give a clearer insight to understanding concepts behind subject learning’. S86 reported that ‘for me, the best way to learn is to create an image in my mind, so this is useful’. Agreeing with the general consensus, S45 reported that the AviBRs were ‘excellent visual material that effectively communicate the required information and core concepts’. So, the author can conclude that the visual media used in the three examples were suitable when applied to visual BRs. There is scope to explore in-depth visual literacy within learning objects, the mode and medium choices and to consider multi-modality and semiotics in further research.

However, the author did not consider a visual approach in isolation to be enough. All three examples were directly relevant to the BRs, in other words they were active or applied learning examples (Kolb, 1984). S96 alluded to this by stating that the AviBRs were 'very effective at bringing theory into practice', agreeing with S91, where 'interaction as a mode of learning requires the participant to engage in active learning and draw on existing knowledge or recently learned'. The last two examples demonstrated interactive learning objects. Feedback included S5 stating that 'personally I found examples two and three better than example one. This is down to the interactive elements which I believe will hold peoples' attention better than a video' while S13 reported that 'it involves the learner in a more dynamic way'.

Other comments comparing video to interactive examples included S53 stating that 'having to engage physically to manipulate the images to get the correct answer is more gratifying than just watching a video showing the same thing'. S80 considered that 'it is definitely more engaging than watching a video'. S61 reported that the interaction 'engages the student, requires them to think rather than just try to absorb information'. To conclude, there is an argument to further explore the interrelationship between video and interactive learning objects and their most appropriate application, to try to understand this issue in further research.

Many favourable comments on the design of the interactive BR examples were received. S81 stated that 'I think this is an effective e-learning tool as it helps students to greatly understand the key aspects of the Irish Building Regulations'. S27 commented that 'the speed of the interactions keeps the content engaging allowing associations to be made and making the learning experience fun'. S59 reported that 'it is satisfying when your interaction asks and gives the immediate feedback of the answer to the learner, this is very effective. Very good interaction overall'. S63 noted that the AviBR was 'interactive and "forces" the participant to engage and think about the learning presented previously. Provides a clear question and clear answers - no ambiguity. Reinforces and ensures understanding of the objective before concluding'. The author can conclude from this that the order and sequence of information within the AviBR is as important as the interactive elements themselves. The beginning, middle and end of the design of AviBRs will need to be considered in further research.

The gamified and interactive elements within some of the AviBRs was considered noteworthy by some participants. S6 commented that 'interactive learning is fun, engaging and there is a trial by error aspect to example three which also aids memory in recall'. S64 noted that 'it's interactive which adds to and aids learning. You have to put some thought into your selected solution, but if you choose incorrectly you will eventually figure out the right answer which you are more likely to retain in your memory'. S71 reported that 'this is effective in communicating the core concepts of the specific issue. It is also interesting as it allows the user to test the spatial constraints themselves via a scaled representation. Very interesting and informative'. S1 considered that 'the game-based mechanic might be motivational, especially if linked to a scoring system. That might drive competition within a class group and motivate some students to try harder'. S12 noted that 'the quiz will ensure the participants are paying attention as they have to pass to proceed'. Gamified resources are intuitively interactive, so to conclude, gamified or motivational learning resources would be suitable for consideration in further research when designing and developing AviBRs.

In comparison to current educational practices, S9 noted that 'interactive learning engages the brain and requires the student to apply knowledge on an ongoing basis - large chunks of written or spoken material delivered over a two, three or four-hour period is not an effective learning tool as the brain is not capable of engaging and focus for extended periods lest retain the information'. S12 stated that 'they proved a different perspective from reading books and journals'. In other words, the concept of AviBRs may be more suitable than some current pedagogical practices or offer an alternative or be used in tandem with current practices. This warrants further research.

The design of the three examples still requires further redesign, consideration and evaluation. Caution and varied opinions were found in participant feedback. S17 stated that AviBRs 'can generally convey the concept of the subject learning quickly and effectively, provided that the visuals and right/wrong methods are shown to enable comparison'. Similarly, S95 reported that it 'could be effective but needs more explanation of the correct answers and why this is correct or incorrect!' Again, relating to the design of the examples, S33 stated that 'I think the way the information is presented is critical and there's a fine balance between the visual images, text and voice over commentary'.

The mode (e.g. video) and medium (e.g. animation) choices in example 1 had opinion divided, with S50 reporting that 'it was a very informative presentation and the simplicity of the hand-drawn/hand-written notes added to the direct yet simple way of delivering the information. The animation was fun to watch, and made a refreshing change to computer generated animations', whereas S24 stated that 'they are a bit unprofessional by comparison to some of the videos that are available online. However, they do convey the information effectively' and S26 stated 'I think something edgier and snappier may be required to get through the extent of the building regulations'. S4 reported 'I would suggest a voice recording to ask the questions and to give feedback. It would make it feel more interactive. Maybe adding sound effects would also help. Typing the text would look better than handwriting in the first example' whereas S43 suggested to 'keep writing to a minimum' altogether. S30 and S41 reported that the video was fast, whereas S34 and S46 considered it too slow. S94 reported that they would like to see more content added, reporting the gamified example ‘would be more effective with some video demonstrations of how fire will travel within a building’. To conclude, there is more in-depth analysis on the design-choices for the AviBRs yet to be conducted.

From the perspective of survey participants, there was varied opinion as to the application or use of AviBRs. For example, S29 considered the approach would be ‘beneficial for students, year one or two undergrad, as it is easy for the student to understand the information, and it explains the reason for the specific regulation’. Similarly, S48 reported that ‘these visuals would be perfect in a classroom environment while the teacher or lecturer are explaining the regulations’ and S85 commented that the pilot was a ‘perfect example of how the regulations can be taught to accompany large text documents’. In other words, the concept of AviBRs would be very suited within an educational setting alongside current pedagogical practices.

However, participant S45 considered AviBRs to be suitable for use in a different context, reporting that ‘this could also be used in the professional environment, perhaps for CPD’. In a similar suggestion, S58 considered the pilot ‘a nice test. Like the NCT theory test for building regulations. A full program like that can be clicked as this example. This will be retained in memory’. S15 suggested that the ‘tool could be used to convey reasons to clients as well through screenshots etc’. S6 commented that ‘you could design it as interactive aids to accompany the regulations, be it an app that highlights the 'new' Codes and Regulations. This is the future.’ S27 reported that ‘the tool can be controlled and managed by me from a stop, start, and replay point of view. Accessibility of e-learning tools by their nature allow anytime anywhere learning’. S11 commented that ‘in a world where people are using phones, tablets, etc. to find information’, that AviBRs would make a positive contribution in educational fields. S57 commented that ‘it allows you to try and think back on stuff you have done before to see if you still remember them’ while S84 stated that it ‘gives great information … and lets you interact allowing you to see how much you know’, both comments appearing to allude to prior knowledge and the possibility of revision CPD training. This warrants further research.

The conclusion from this overall is that AviBRs, in an educational context, could be useful, both in the classroom alongside current BR pedagogical practices as well as within professional upskilling courses and CPDs. The fact that the original pilot study was conducted online directs continuing research exclusively online.

One unexpected outcome from the survey findings was that the reasoning behind some BRs may not be fully understood. The author would be of the opinion as an educator that an intuitive understanding of why a BR dimension is required is essential to remember in ones’ design work. S68 commented that 'now I understand why a leading edge is needed whereas with the current way the information is delivered – as with other section of the ADs the reasons aren't obvious or set out meaning you don't understand the whys of the requirements'. S75 also commented that 'I think this video will help students understand why it's necessary to have these regulations in place'. This should be used to inform AviBR design choices wherever possible.

6. Conclusions and Recommendations

By exploring the aim and research question forensically in this paper, one can conclude that there is significant scope for a new visual applied interactive approach to BRs or to abbreviate, online Visual BRs, in Built Environment Higher Education. AviBRs can substitute the technical language in some TGDs with project-rich, visual case studies and interactive, applied, visual examples. This can be designed within an online, scaffolded approach based on Universal Design for Learning principles.

The design of AviBR teaching tools will require significant emphasis on medium and form, acknowledging multimodal literacy and appropriate BR semiotic techniques and make consideration for further pedagogical and supportive educational theory choices, software and hardware options, mode of delivery and scaffolded discipline-specific curriculum design. If they are activities which can be completed online, it would be advantageous to embed learning, teaching, assessing and evaluating into the design of the AviBRs to facilitate instantaneous data capture and fast turn-over in a multiple-loop utilization focused evaluation process.

Further and ongoing research in AviBRs beyond this study is hoped will continue to contribute new knowledge to the field of Visual BR pedagogy for Built Environment Higher Education programmes, while developing relevant educational literature and teaching tools and in parallel, contributing knowledge to the field of Higher Education online learning and visual literacy.

The extremely challenging requirements of BR compliance is reflective of the responsibility of Built Environment professionals to ensure that peoples' safety is paramount. One could argue that through this lens, the link between education and practice is neither direct enough nor clear enough. Explicit traceability and accountability for BR compliance in and between the three progressive areas of undergraduate education, transitioning to work and professional working life is going to be an ongoing challenge, from a design and construction viewpoint. This, no doubt, will eventually be achieved within a BIM environment. If AviBRs are used in education as either teaching tools or as overarching online pedagogy, it will inform best practice if all three steps towards professional progression are designed holistically with this intention at the outset and run in tandem with advances in BIM.

The rigour of scaffolded explicit transparency in BR compliant educational practices should be taught exactly as it would be required in practice once basic regulation concepts and construction sequences and details are understood. It is pertinent as educators in the Built Environment that we verbalise, acknowledge and act on our duty of care to our learners to ensure that this is done in a direct, considered and consistent way across all Built Environment disciplines.

ACKNOWLEDGEMENTS

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A QUEST NEEDS FOR BUILDING INFORMATION MODELLING TOOLS TRAINING IN A DEVELOPING NATION

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Abstract. Computer Aided Design software and their kind are generally considered as Building Information Modelling (BIM) tools; moreover, the sophistication level of one in use may determine the BIM maturity level. Education and research are the backgrounds to innovation while training is a window to continuity in skills transfer. The experts are evolving from the industry professionals who are first trained in the Universities. This study determined how ready Nigerian Universities are to providing trained (on BIM tools) graduates for BIM adoption. A questionnaire survey was used; 59 structured questionnaires were distributed out of which 39 were successfully retrieved and analysed by descriptive statistics. The study revealed a significant correlation between the output (BIM skilled graduates) and the required software as well as trained tutors. The institutions are found to be physically ready with relatively sufficient hardware, however technically not ready! Due to lack of training software and skilled BIM tutors. More than three-quarter of the students are graduating on 'file-based collaboration' – 2D and 3D CAD knowledge with proficiency level between limited and practical application. However, the collaborative software training received proficiency level from basic to practical application with just 13% receiving training on the collaboration software, therefore contributing very little to the industry. Thus, this reveals a setback in the BIM tools training to carter for BIM uptake.

Keywords: BIM adoption, BIM tools, CAD training, Nigerian universities, proficiency level.

1. Background

Since the beginning of Computer Aided Design (CAD) in the 1960s, technologies continued to evolve, changing from Computer Assisted Drawing to Computer Aided Design. CAD technologies development is driven by the industries' applications (particularly, manufacturing) but research still remains the basis. Major manufacturing companies solemnly backed the development of CAD systems at its early stage (Ye et al. 2004). Regardless of how the CAD technology and the industry evolve, students in universities want to acquire technologies that can best aid their career; also improve their employability (Eadie et al 2014).

Its apparently difficult to providing necessary needs to include Building Information Modelling (BIM) training in university education, at the same time it is the right step to preparing the future employees (built professionals) for the industry (Construction, 2008). Educational institutions – their training, played a key role in BIM transition (Javaja and Salin, 2014). This may be seen as one of the reasons for US's high rate of BIM adoption; they are ahead of every order country (Construction 2014).

The 2007 BIMForum survey of eight US academic institutions on their level of BIM training reveals that more than 80% of them teaches BIM in their courses, and even the minority (<20%) had introduced BIM in their teaching curricula since 2002 (Barison and Santos, 2010). This may have helped the US Architecture Engineering and Construction (AEC) industry to be at the forefront of BIM adoption and also the widespread of BIM concept even before the government legislated on it (Construction, 2014).

However, developing nations are lagging behind in BIM awareness, adoption and BIM experts (Eadie et al., 2013; Froise and Shakantu, 2014); could that be due to a shortage of knowledge? Thus, lack of BIM tools training poses a great challenge to adopting BIM in developing countries. It is generally accepted that institutions offered a wide range of professional knowledge, while students are expected to enhance their knowledge in some or specific areas (Dankwort et al, 2004).

Universities in Nigeria are regulated by an agency "National University Commission (NUC)" under a body of Federal Ministry of Education (FME). The NUC was established in 1962 as an advisory agency in the Cabinet Office. However, in 1974, it became a statutory body under the FME. The commission has four main functions as follows:

- Granting approval for all academic programmes run in Nigerian universities;
- Granting approval for the establishment of all higher educational institutions offering degree programmes in Nigerian universities;
- Ensure quality assurance of all academic programmes offered in Nigerian universities; and

- Channel for all external support to the Nigerian universities

In 2017, there were no more than forty-one approved (accredited) engineering schools in the country where civil, electrical and mechanical engineering courses are taught, and not more than twenty-nine accredited architectural schools out of which only six of the universities do not offer the above engineering courses (NUC, 2017). NUC also benchmarked the student capacity for every course based on the accreditation result (based on manpower and infrastructural capacity).

Although NUC accredits universities and the respective courses; but courses curricula modifications generally come or initiated by departments/institutions. Curricula in Nigerian universities are generally dated, many of which were since the development of the courses, Architecture is one of those that follow this trend "…teaching of architecture as a course of study in a Nigerian university dates back to the 1960s'. Although slight changes were being effected in the ensuing years, the curriculum on architectural education has largely remained the same" (Ogunrayewa 2013, pp.8).

BIM is the latest development in the AEC industry, a paradigm that is changing the industry very fast. This concept would be fully understood and realised while integrated into the AEC courses in preparing the future employees of the industry.

This study aims to investigate the ability of Nigerian universities in providing BIM tools training against BIM adoption in the AEC industry through an assessment of institutions infrastructure (hardware and software); skilled/manpower capacity; as well as level and proficiency of CAD(s) training offer to graduates of the built environment and engineering schools.

2. Literature Review

2.1. GENERAL CAD KNOWLEDGE AND IMPACT

The survey carried out by Ye et al. (2004) shows that all CAD users have some knowledge of computer hardware; however it is necessary for them to be hardware experts, therefore it could be helpful to acquire the fundamentals. Moreover, CAD users do not need to have any programming skill and knowledge. CAD knowledge is more of practical and application altogether, but many times taught in a conventional way of teaching computer science. A survey carried out by Ye et al (2004) reveals that over 70% of the participants think that CAD should have been taught more especially in terms of physical training and application development.

In the US, the population of their practising engineers was more than one million thirteen years ago; over the years, computers have played a significant role in their day to day jobs, their CAD usage varies from lowest of “not at all” to being “highly dependent” (Field 2004). Moreover, CAD innovation found its way not only into industries but also into higher institutions in different ways and taught in different disciplines for different applicability and focus (Ye et al. 2004). CAD technologies may be taught explicitly as a tool for design, drawing and drafting in architecture and engineering disciplines; and this is now becoming very obvious in the US (Abbas et al, 2016).

It was revealed that the BIM training or modules offered to undergraduate students in Nigerian universities generally rotates within the introduction to computer science I and II, computer programming I and II, introduction to CAD, computer in architecture and AutoCAD (Ogunsote et al 2007). Hence, the study proposes additional modules (see Table 1) across the years of studies for architectural schools. However, Oladele (2009) recommends curriculum review but focusing on preservation of socio-cultural backgrounds, to respond to societal needs while adopting the global principles (i.e. innovations) where necessary. This recommendation is very near to Wu and Issa (2014) study where integrating BIM into the conventional modules is recommended.

TABLE 1. The proposed curriculum for Nigerian Schools of Architecture (Ogunsote et al 2007).

Level	1st Semester	2nd Semester
100	Introduction to Basic Computing	Computer Graphics in Architecture
200	Introduction to CAD	Integration into 200L Studio Project Elective
300	Introduction to 2D CAD for Architecture	Integration into 300L Studio Project Elective
400	Introduction to 3D CAD for Architecture	Integration into 400L Studio Project/ITF Elective
500	Visualisation and Animation in Architecture	Integration into final year project

Moreover, electives modules were also recommended to enhance proficiency in specific software, these include:

• Mastering CorelDraw
• Mastering Microsoft Publisher
• Introduction to AutoCAD
• Advanced AutoCAD
• Introduction to ArchiCAD
• Advanced ArchiCAD
• Mastering 3D Studio Max

On the other hand, engineering students suffered the most. The curricular of engineering programmes in Nigerian universities consist mainly of the fundamental knowledge of mathematics, natural sciences and technology. This fundamental knowledge is good and very necessary to acquire the basics for understanding engineering problem, but it does not end at the fundamentals (Onwuka 2009). The signals/feedbacks (i.e. not fit and confident to work in the industry) received from employers of engineering graduates is an evidence of lack or inadequate engineering applications in their educational curriculum. Very little trace of that can be noticed in the engineering courses curriculum; such as structured programming, elements of architecture as well as computer methods in civil engineering (computer application in the design of structures) for the civil engineering discipline.

There is very limited literature to establish a BIM training in the engineering schools of Nigerian universities, "Accreditation of Engineering and Architectural Education in Nigeria: the way forward" by Agboola and Elinwa (2013) is a clear evidence. Moreover, Onungwa and Uduma-Olugu (2017) study reveal lack of incorporating BIM education in Nigerian universities amongst major barriers to adopting BIM in the country.

2.2. BIM TOOLS TRAINING AND WHY

A better but expensive way of CAD training is a practical course (face-to-face) with guidance by an instructor (Dankwort et al. 2004). Subsequently, several advantages can be deriving from a practical course, such as direct feedback, direct interaction and curiosity by students to learn more. However, graduates with little knowledge of application packages are typically facing challenges in trying to get absorbed into the industry. Although, the challenges are determined by the size of a company: generally it can be said that the bigger or the more specialised a company is, the more tailored CAD training is.

Design methods and procedures are generally taught in universities, and the fundamentals are also included; however, the CAD technological aspect is missing and needs to be included (Dankwort et al. 2004). Moreover, "design knowledge" is generally taught completely in universities and because in the future practice companies' special necessities are diverse.

The procedure and methods used for design in the industry are never adopted as a formal method as being taught in universities. Companies consider it highly beneficial if students were taught possibly in more than one of the standard systems; it is also important that students would have worked with sequences of a CAD systems (for modelling, designing and data exchange) from university (Dankwort et al. 2004).

From the inception of CAD, manufacturing industries have been the heavy users of the CAD; it was initially known as "Design Augmented by Computers" at General Motors to stress the design being done by human and computation by computers (Field 2004). Construction (2008) associated slow adoption of BIM in the industry with lack of proper training. However, there is significant progress by architectural technology schools who are leading the inclusion of BIM to their educational curriculum. Although, the engineering and construction schools are now following the suit considering the number of universities (especially in the US) integrating BIM into construction management courses.

The United States (US) and Europe are actively implementing BIM education (Tang et al, 2015). In 2006, the US mandated BIM in public building service at design stage (Zeiss G., 2013); UK mandated level 2 BIM by 2016 in the year 2011; Norway 2007-2010; Finland 2007; Hong Kong 2014; South Korea 2016 and Netherlands 2012. Therefore, the AEC industry has huge market demand for a trained graduate in BIM. Two years after the UK's BIM level 2 mandate was released, Eadie et al (2013) reported that lack of BIM experts ranked as the top reason for slow adoption of BIM in the UK. Tang et al (2015) equally reported an insufficiently trained staff on BIM with a growing demand of the BIM experts in the Chinese AEC industry.

The 2015 survey on Beijing and London MEP international firms reveal very low training from institutions (with only 19% learned BIM from college) while those that were not trained from institutions find it difficult and very difficult to acquire the BIM tools skills.

It can be realised that amongst those that played a key role in BIM transition is the educational institutions (Javaja and Salin, 2014) - training. This may be seen as one of the reasons for the US's high rate of BIM adoption; they are ahead of every order country (Construction 2014). There is a good start of BIM education implementation across institution around the world and this can be noticed mostly from the US. To mention but a few with: Penn State University (PSU), Montana State University (MSU), Kent State University (KSU), California State University, University of Florida, Metropolia University of Applied Sciences Finland, Dublin School of Architecture Ireland and University of Nottingham Ningbo China (Tang et al 2015). And here are some few case study universities: Auburn University, the University of Arkansas at Little, Philadelphia University, University of Washington, University of Southern California and Purdue University (Abbas et al, 2016). Abdirad and Dossick (2016) review on integrating BIM education in higher institutions established that most investigations in this area comes from the US and typically as conference papers; forty-four out of fifty-nine reviewed papers published between 2007 and 2014 happened to be from the US and mostly case study bases. This indicated a significant commitment to integrating BIM education in the country's higher institutions and also vindicates the country of having the highest BIM adopters in the industry.

Considering investment cost associated with adopting BIM in AEC industry (Migilinska et al, 2013), educational institutions may also find it costly to integrate BIM training in the AEC courses. Developing training on BIM stage 1 and stage 2 could be a bit easier and cheaper compared to the stage 3 (integration); as the stage 1 and 2 are achievable using the basic BIM tools whose "educational versions" are within reach and are capable of modelling and collaborating (Autodesk, 2018). But inadequate awareness and lack of experienced BIM educators remained critical challenges (Hon et al 2015).

On a bit of leap, the developing nations are lagging behind in BIM awareness, adoption, and also lacking BIM experts (Froise and Shakantu 2014; Onungwa and Uduma-Olugu 2017); could that be knowledge shortfall? Lack of BIM software skills posed a great challenge to students that are graduating for over a decade. Several survey findings demonstrated discontent with curriculum development regarding BIM (in relation to technical advancement) by students and educators (Sabongi and Arch 2009; Sylvester and Dietrich 2010).

Introducing BIM module is also inspiring students regarding their career in the AEC industry, especially those interested in the industry practice (Tang et al 2015). Moreover, the BIM module should be taught more with encouragement to collaborate with other team members than the emphasis on the software skill (as it is in 2D CAD training).

There are two popular approaches to integrating BIM education in the higher institutions' curricula these are: introducing standalone courses/modules and integrating the BIM into the conventional study courses/modules (Wu and Issa 2014). But one of the essentials of adopting the BIM is "the collaborative working" therefore Pikas et al (2013) suggest the implementation of BIM education to be at programme level rather than isolated module or training. On the other hand, Eadie et al (2014) preferred "standalone module (combining theory and software) taught in multidisciplinary class" as the most appropriate delivery method. Although lecturers response reveal that BIM component in each course/module is an important opportunity to meeting the industry's needs.

Most of the findings regarding non-inclusion of BIM into the universities' curriculum (Sabongi and Arch 2009) are related to the following:

- No room in the current curriculum for additional classes
- Lack of time or resources for the faculty to develop a new curriculum
- Constraint to additional required or elective module and still graduate in eight semesters
- Unavailability of resources specifically on BIM for students' use.

The curriculum of architectural schools need to be reviewed to produce CAD proficient graduates; while lack of facilities and their maintenance for CAD training as well as funding were considered a major setback to CAD training in Nigerian universities (Ogunsote et al 2007; Ogunrayewa 2013). National Universities Commission (NUC) and the Architects Registration Council of Nigeria (ARCON) have guidelines for accreditation of architectural programmes, the prerequisites include having adequate physical infrastructure such as laboratory and studio, equipment of the laboratories and studios, classrooms and lecture theatres, equipment of the classrooms and lecture theatres, office accommodation as well as manpower of different qualifications and experiences (Ogunrayewa 2013). However, attention has not focused on the availability of software/CAD training connecting that to the industry's emerging or current challenges.

The students' inputs to the best way of incorporating BIM into their courses suggest the combination of both creations of standalone BIM that discusses varieties of BIM uses with emphases on the use of software; and additional modules to the existing ones to deliberate how the BIM is relevant to the subject/area of study (Clevenger et al 2010).

Rezgui et al (2010) concluded that the perspective of knowledge management adoption in AEC sector is creating adding value which is done through knowledge sharing. On the other hand, training and educational systems must also evolve in parallel with CAD development (Field 2004).

SUMMARY

To promote BIM-enable learning and to balance the student and the industry desires, integrating approaches could be the most effective way of delivering BIM education. Few disadvantages can be foreseen with any of the two popular approaches alone. The standalone BIM courses is a good idea to integrate the other disciplines (as team members), however creating a slot for additional courses might prove difficult as the curricula are filled up to accommodate additional courses (Sabongi and Arch, 2009). On the other hand, the BIM-embedded into the conventional courses may be considered easier; but may not necessarily achieve the intended collaboration and perhaps integration because multi-disciplinary training (with other departments as team members) may not be possible. Moreover, not all schools offer all the courses in context (i.e. Architecture and the Engineering courses).

3. Research Methodology

The purpose of the survey was to determine the level of BIM software/tools training received by students (from engineering and built environment schools) in Nigerian higher institutions of learning for BIM adoption in the Nigerian construction industry. The research is quantitative in nature and its approach is interpretative. The primary data for the investigation were obtained from tutors/lecturers in the Nigerian universities through a questionnaire survey. To avoid been bias, the respondents were chosen randomly from amongst higher institutions of learning in the country where civil, mechanical and electrical engineering as well as environmental courses are taught. A structured questionnaire was used to extract information based on the research question.

The multiple choice, close-ended questions were drafted and sent directly to individual's (lecturers) emails. The respondents were mainly from the following zones of the country: North-west, North-central and South-west in sliding order of quantity than with very few from North-east and South-east; therefore the result may not reflect the true picture of the entire country but most of its parts.

The surveys were prepared and sent electronically. A total of 54 emails were sent, out of which a total of 39 responses were collated which represents 72.2% response rate; very adequate for this study according to Ballantyne (2003). The responses were distributed based on professions considered in the industry; the responses received from building departments were 2 which represents 5.1%, architectural departments returned 10 (25.7%), land/quantity surveying departments returned 2 (5.1%) and engineering departments returned 25 (64.1%).

The questionnaires were randomly distributed across forty-one (41) universities where engineering courses (civil, electrical and mechanical) are taught inclusive of thirty-three (23) where architectural technology plus additional six (6) universities where only Architectural technology is taught. The questionnaire targeting tutors in those departments was prepared in 'google docs' where the link is distributed via emails obtained from various universities' websites.

The number of the targeted audience (considering at least a representative from each department) can be deduced as:

There are 41 no. of institutions accredited for the engineering courses (in context);

3 no. of engineering departments were considered (civil, electrical and mechanical);

29 no. school of Architectural technology

- (41x3) + 29 = 152 (departments) as an estimated sample size.

- 39/152 = 25.6% response, beyond 12% (liberal condition) according to Nulty (2008).

Out of the fifty-four (54) distributed questionnaires, thirty-nine (39) responses were received; this represents 72.2% response rate, hence considered adequate for validity and reliability (Rubin and Babbie, 2009, p117). And, satisfied both the 55% and 47% paper-based and online-based response rates respectively (Ballantyne, 2003).

The respondents were engaged to assess the institutions' hardware and software capacities; after which a proficiency level of training received by undergraduate students was also assessed. Basic and simple questions were asked considering the very low level of BIM awareness and knowledge within the institutions (Onungwa and Uduma-Olugu 2017) and the industry (Hamma-adama et al 2017) in general. The limited literature in this context can be noticed from the only citation (Agboola, and Elinwa 2013) reported in "a review of tertiary BIM education for advanced engineering communication with visualization" by Badrinath et al (2016).

4. ANALYSIS AND DISCUSSION

The analysis and findings from the generated data (via questionnaire) of this study are presented in this section.

The survey outcome reveals that 82.1% of the respondents are lecturers; while 17.9% are technicians and technologist (see Table 2). Over 70% of the lecturers are having qualifications ranging from M.Sc. to Ph.D., and fewer than 30% are first degree holders. More than 50% of the respondents are experienced tutors ranging from 5years to over 15years in the academia. The below chart (Figure 1) is representing respondents' academic qualifications.

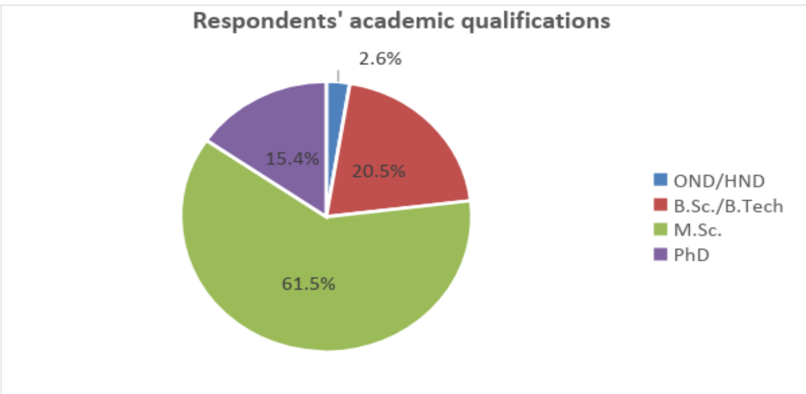

Figure 1. The respondents' academic qualifications

The below Table 3 illustrates the rates and the distribution of respondents: Architectural technology has recorded higher response rate at individual career level; this can be seen to be associated with a keen interest on the subject matter. Engineering departments constitute over 60% of the responses, perhaps because of the number of disciplines involved in the engineering profession (civil, electrical and mechanical), followed by architectural technology (25.7%) and the remaining contributed 10.2%. However, when individual courses (splitting engineering to the three branches) are considered, architectural technology can be measured as first in the succession.

TABLE 2. Demographic Profile of Respondents (N=39)

		n	***%***
Respondent affiliation	Architecture	10	25.60
	Building	2	5.10
	Engineering	25	64.10
	Land Surveying	1	2.60
	Quantity Surveyor	1	2.60
Cadre	Lecturer	32	82.10
	Technologist	7	17.90

4.1 SURVEY FINDINGS

A reliability analysis was carried on the data with the aid of SPSS V21. This is done to determine whether the instrument do measure the same construct. The Table 3 below presents the reliability analysis of the hardware and software capabilities as well as the level training offered with the available resources.

TABLE 3. Instrument Reliability Test

Instrument	**Scale Statistics**					**Reliability Statistics**	**Validity Statistics**	
Source	No. of Items	No. of Samples	Mean	SD	CV	Cronbach's Alpha	F-value	P-value
Impact of Hardware and Software on BIM Tools Training	3	39	10.5	4.74	0.156	.910	20.453	0.000
Input-Output Training on BIM Tools	2	39	5.150	2.581	0.012	.949	41.632	0.000

The response reliability test was carried out by means of a standardised Cronbach's Alpha which .910 and .949 were obtained regarding hardware and software impact, and input-output on BIM tools training respectively. These suggest that the evaluating instrument is very reliable as they (.910 and .949) are more than the threshold value (.500 for items <10 or .700 for items >9). Moreover, the 0.156 and 0.012 coefficient of variation (CV) justified the homogeneity in the response rating by the respondents.

It is also revealed that the test is significant at F-values equal to 20.453 and 41.632, and P-values <0.05. Therefore, the instrument is adequate since there no significant variation on the items' rating.

TABLE 4. Correlations

		Proficiency at graduation	Number of computers	Highest software for training	Training proficiency
Pearson Correlation	Proficiency at graduation	1.000	.556	.649	.903
	Number of computers	.556	1.000	.742	.659
	Highest software for training	.649	.742	1.000	.804
	Training proficiency	.903	.659	.804	1.000
Sig. (1-tailed)	Proficiency at graduation	.	.000	.000	.000
	Number of computers	.000	.	.000	.000
	Highest software for training	.000	.000	.	.000
	Training proficiency	.000	.000	.000	.
N	Proficiency at graduation	39	39	39	39
	Number of computers	39	39	39	39
	Highest software for training	39	39	39	39
	Training proficiency	39	39	39	39

Table 4 above presents the correlations between the final outcome as a dependent variable (proficiency of training at graduation) and three independent variables (no. of computers, training software and training proficiency – input). The result indicated a significant correction between each independent variable with the dependent variable. The significance appeared in ascending order; no. of computers, available software for training and training proficiency with corresponding values of .556, .649 and .903 respectively. The significance level of each indicates its level of influence to achieving higher level of proficiency. To quantify the level of influence by these independent variables, a regression analysis is then carried out.

Table 5 below presents the model summary of the analysis. The regression is <0.001 which is very significance; and the R Square is 0.833 which is greater the lower limit of 0.300. This indicated that there is 83.3% variance in the dependent variable with respect to independent variable.

TABLE 5. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.913[a]	.833	.818	.576	.833	58.082	3	35	.000

a. Predictors: (Constant), Training proficiency, Number of computers, Highest software for training
b. Dependent Variable: Proficiency at graduation

Subsequently Analysis of Variance was carried out; the result summary is also presented in Table 6 below. With Sig.<0.05, null hypothesis is rejected and this confirmed that it's statistically significance that the independent variables influenced the dependent variable. Therefore, the regression expression comes to F (3, 35) = 58.082.

TABLE 6. Analysis of Variance (ANOVA)

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	57.822	3	19.274	58.082	.000[b]
	Residual	11.614	35	.332		
	Total	69.436	38			

a. Dependent Variable: Proficiency at graduation
b. Predictors: (Constant), Training proficiency, Number of computers, Highest software for training

To establish the training capacity, it was discovered that 76.9% of the institutions are having relatively adequate computer laboratories as represented in the pie chart (Figure 2) below. And 56.7% of the schools have more than thirty (30) PCs in their respective laboratories (Figure 3) but only 20% happened to have collaboration software in their PCs (Figure 5); while only 13.3% of the students are enrolled for such software training.

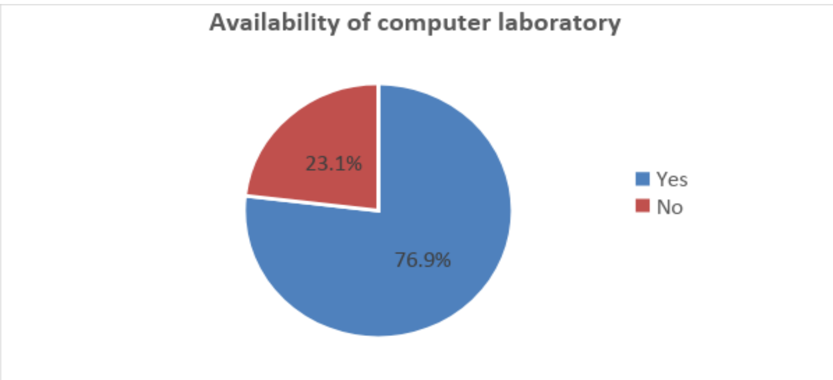

Figure 2. Availability of computer laboratory in the subject department

With over 50% of departments of architectures/ surveying and engineering having more than 30 computers for students training, a considerable number of schools can be considered to have relatively enough computers for the training as indicated in the bar chart (figure 3) below.

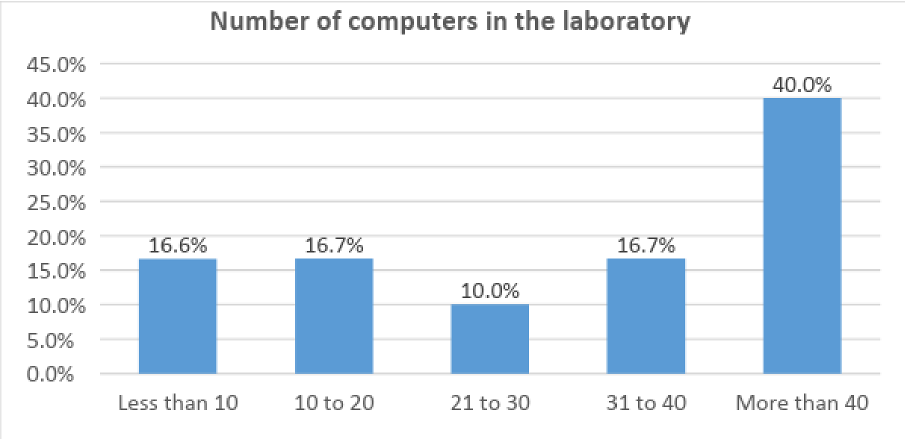

Figure 3. The quantitative capacity of the computer laboratories

4.2 PROFICIENCY OF APPLICATION SOFTWARE TRAINING

From Figure 4 below, it can be observed that the intermediate, fundamental awareness, as well as the novice are toping the proficiency level of training offered to students; however, higher percentages of a deficit can be noticed at fundamental and intermediate levels (the yield is lower than the efforts). Hence students receiving intermediate and fundamental awareness level of training are having output challenge where the outputs are less than the inputs (43.3% to 33.3% and 36.7% to 30% consecutively). However, the novice, advanced and expert got outputs greater than inputs (16.7% to 23.3%, 3.3% to 6.7% and 0% to 3.3%); hence these indicated the possibility of some trained students advancing their proficiency level; these positivity has been noticed to be associated with the type of software available (advanced software) and the student computer ratio.

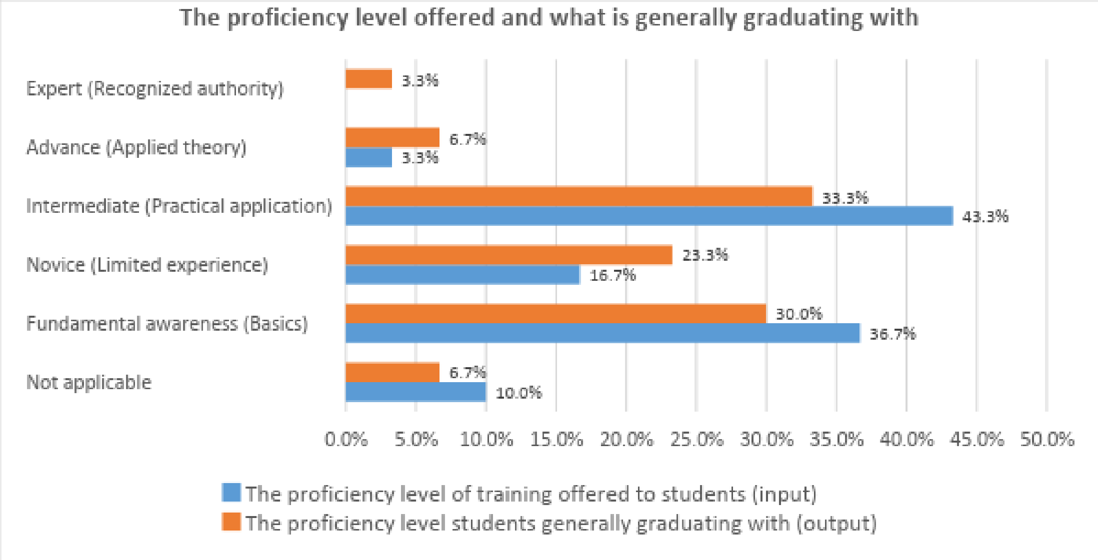

Figure 4. Proficiency level offered and what is generally graduating with

The 2D CAD can be seen to be a basic tool to all the institutions offering application software packages training to students. Not more than 73.3% are receiving training on 2D CAD basics up to the application level. For the 3D CAD training, everyone trained on 3D CAD is equally trained on 2D CAD as well; means those trained on 3D CAD are a subset of those trained on 2D CAD.

Succinctly, most students are graduating on 2D CAD knowledge acquiring limited and basic knowledge. Although, over half of the schools (53.3%) have 3D CAD software which is normally incorporated with the 2D CAD, but only 36.7% uses the 3D CAD – quite below average compared to the 2D CAD. On the other hand, 20% of the institutions were observed to having the collaboration software (Revit Arch, Struct, MEP) however, only 13.3% enrol students for the software training; perhaps due to skill shortage. Find below a chart (Figure 5) presenting variations in the software availability and usage.

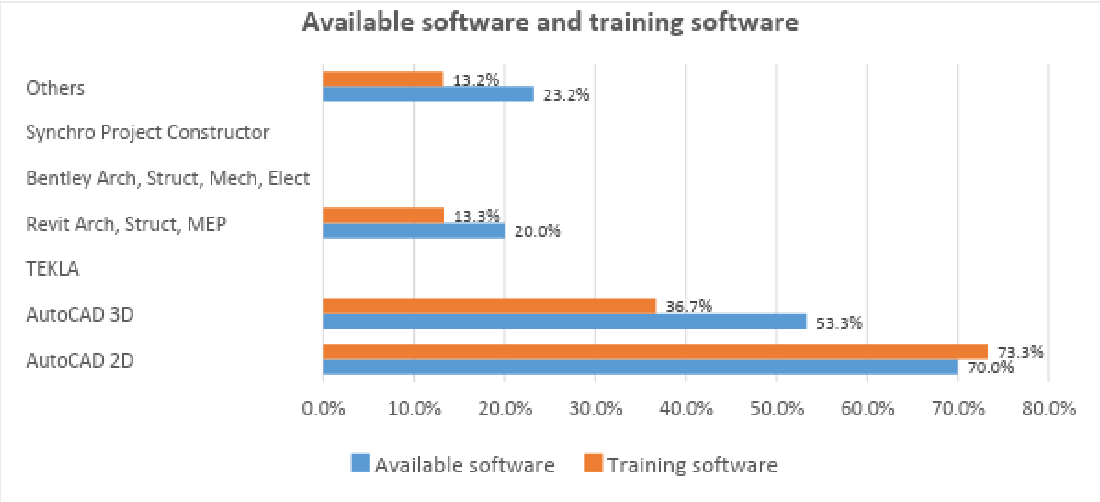

Figure 5. The available software packages and the training software

5. Conclusion

This piece of work aimed to: investigate the ability of Nigerian universities in providing BIM tools training against BIM adoption in the AEC industry through an assessment of institutions infrastructure (hardware and software); skilled/manpower capacity; as well as level and proficiency of CAD(s) training offer to graduates of the built environment and engineering schools. Architectural technology has a keen interest in the subject matter. In the same vein, more than 50% of the collaboration software is acquired by architectural technology schools. Hence, architectural technology schools are at the forefront of CAD training. Considering most institutions having relatively sufficient hardware (personal computers), the institutions can be considered physically ready to offer BIM tools training, however technically not ready, because collaboration software are virtually unavailable as well as intensive training in that regard. Moreover, there is an indication of a serious shortage of skilled tutors in BIM, because those having the collaboration software are not effectively utilising them. And this vindicated the literature (Onungwa and Uduma-Olugu 2017). There is significant connection between the availability of hardware and software, level of training provided and the skills acquired at graduation in BIM tools. The more hardware and software are supplied, provided that there are trained tutors, the more and higher skilled graduates are produced.

Most of the graduates are generally trained on ‘file-based collaboration’ – 2D and 3D CAD. A clear setback can be noticed at institutional level regarding training on collaborative working because there is no indication of collaborative design (with some of the team members). Although the proficiency level received at graduation mainly ranges from basic to practical application. On the other hand, the higher the software sophistication, the higher the proficiency level of training received and acquired by students. With 13.3% collaboration software training across the institutions mostly architectural schools, then the institution has very little to contribute to the industry. Succinctly, the level and type of training received by the students in the subject have indicated a high possibility of a shortage in BIM skilled graduate ahead of BIM adoption or collaborative working in the Nigerian construction industry. Therefore, the adoption rate is likely to be low due to a continuous shortage of trained graduates on BIM tools.

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"AN ANALYSIS OF THE IMPROVEMENT IN BSC (HONS) DEGREE MARKS OF STUDENTS ATTENDING THE UNIVERSITY OF MALAYA EXCHANGE PROGRAMME."

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Abstract. Self Determination Theory (SDT) is a body of theoretical thought that was established by Deci & Ryan, (2000) and Sheldon, Ryan, Deci, & Kasser, (2004) in determining an understanding of individual's behaviour in sectors such as education (see Deci, Vallerand, Pelletier, & Ryan, 1991. Reeve, 2002; Reeve et al., 2004 and Ryan & Deci, 2000, for reviews) and sports (Sweet S.N. and Fortier M.S, Strachan S.M. Blanchard C.M.). The theoretical study involves the notion that intrinsic rather than external motivation is better in establishing a self-will to develop and succeed. External motivation and introjected or identified regulation is less likely to produce a will in the individual to learn (Downing. K, Fraide A. Ganotice, Jr., Barbara Chan, Lee Wai Yip). It is with this in mind that this Pedagogical Research will look at how students' decision to carry out half a module over one month at University of Malaya, not only improves their marks but improves their willingness to learn and develop. Students on the BSc (Hons) Architectural Technology and Building Surveying courses are given the opportunity between Level 5 and 6 to study for one month at the University of Malaya. This gives them the opportunity of completing half (50%) of the Level 6 module entitled "BUILDING APPRAISAL, APPRECIATION AND CONSERVATION". This has obvious benefits such as reducing the workload in Level 6 for students so that they can concentrate on other work but also has a further reaching effect on student's attitude toward their studies. Students on this programme study two urban centres in Malaysia, designated with UNESCO World Heritage Site status: namely Malacca and Georgetown in Penang. This study looks at how being exposed to a different cultural heritage can inspire students who initially may be achieving less on the BSc (Hons) course at Level 5 to go on to clearly improve marks at Level 6. This cultural heritage is that of the Chinese Shophouse building typology, which is a built form that is rich in historical overtones. Students are also encouraged to meet and discuss these buildings with the current Chinese owners who are often related to the original descendants who were responsible for their construction.

This gives the students a link to conservation that is alive, which would not necessarily be the case in the United Kingdom.

This Research Project is intended to promote the five Staff and Educational Development Association (SEDA) core values.
•Developing understanding of how people learn
•Practicing in ways that are scholarly, professional and ethical
•Working with and developing learning communities
•Valuing diversity and promoting inclusivity
•Continually reflecting on practice to develop ourselves, others and processes

Keywords: Self Determination, Motivation, Third Cultural Space, Pedagogical Research, Introjection

1. Physical Background.

Figure 1. Typical Chinese Shophouse - Author

1.1 THE UNESCO

World Heritage status of Penang and Malacca is a critical aspect of this study although the paper intends to look intrinsically at the data improvements of students' marks. Penang and Malacca have some similarities to Liverpool in that the building typologies in the World Heritage Sites are of a maritime and commercial warehouse nature. The students immediately understood this link and found an affiliation between 'home' and the tropical region of study. The quality of work produced both individually and in groups was exemplary. Looking at the work on face value it is vibrant, interesting and carried out with eagerness to learn and that is without looking at the data to indicate this improvement. Despite the sites being in Asia; an area of the world to where most of the students previously had not been: their maritime link to Liverpool opened up new possibilities to the cohort, which is discussed in the next section. These new possibilities could be described as a type of Damsacene awareness that global working was possible and that the programme that they had enrolled on was truly dynamic and international. This provides credence into the self-determination theory in that the students finds their own creative and inspirational space to learn.

Figure 2. Students at the Abu Samad building, Kuala Lumpur designed by A.B.Hubback; a Liverpool-born architect. Author

2. Theoretical Background

As well as the Self Determination Theory where students become empowered by their choice to study in a different way, such as learning overseas, G. Gutiérrez Almarza, R. Durán Martínez & F. Beltrán Llavador (2015) discuss another pedagogical concept of Intercultural Communicative Competence (ICC). The basis of this is a study of language students overseas but this could be applied to all disciplines in that students become aware of a 'third cultural space' that empowers them. We have our own culture and other cultures but when we are exposed to another culture Gutierrez Almarza aligns this to finding a kind of third space where students develop an understanding different to both their home culture and host culture. Guttierez Almarza cites that this offers students an opportunity to expand their thoughts and develop a learning identity that they would not necessarily find in their home culture.

"Within the above framework, we understand that ICC is achieved through a relational process, where the mobile learner places the host culture in relation to their own, engaging in a many-sided communication system where neither cultural patterns of behaviour nor the people who embody them will remain unaffected. This demands a readiness to confront self and other perceptions, and to change. After all, the history of culture is embedded within the stories of personal communicative encounters and the dialogue with people with similar experiences, as it is the case of students participating in mobility programmes: 'In and through these dialogues, they may find for themselves this third place that they can name their own' (Kramsch 1993, 257)." (G. Gutiérrez Almarza, R. Durán Martínez & F. Beltrán Llavador 2015).

Traditional methods of Teaching and Learning in Building Conservation have been concerned with formal lectures and the study of historic monuments in the student's home surroundings. At most, students of Architecture are exposed to a one-week study trip in the undergraduate programmes to study conservation abroad. Studying in a student's home habitat can be nullifying and can have a tendency to expose an individual to introspective study that focuses their locality. This can also give the student the overriding impression that they are being 'taught at' rather than given the opportunity to learn and develop academically. Although there has been a long history of Architecture students studying abroad, in the new millennium the subject has taken a more pertinent role in that problems with Climate and local economies have opened up opportunities for individual development and progression overseas. David N. Myers, Margarita Hill, and Stacy Anne Harwood (2005) argue that; "Cross-cultural learning has emerged as a critical pedagogical objective in design education in the new millennium. Globalization and urbanization, the dominant forces defining the movement of people and power on our planet today, require of teachers and students a greater understanding of cultures, peoples, and places.

As is true in other design disciplines, landscape architecture educators are engaged in ongoing conversations on how to construct opportunities for meeting both the local and the global challenges facing students today (Robinson 2003)."

There is also evidence to suggest that the student's ability to study internationally gives them a new insight into the World of Work in that they can relinquish some of the financial pressures, which are a result of the University fee structure in the UK. Opportunities that they see whilst receiving a taste of working internationally instils confidence and a longing to try other cultures and economies after completion of their undergraduate courses. (Hopkirk, E. 2011). Whereas at home they may view Conservation study as usual to their surroundings, studying Conservation abroad gives them a new cultural building typology that reignites the senses and enhances self-learning within.

This paper describes and analyses the pedagogical theory behind both learning exchange programmes overseas and specifically learning Architectural Conservation overseas and produces quantitative data evidence to suggest that students who take up such study have improved marks between Level 5 and the final year of their degree programmes.

3. The Language of International Architectural Conservation

According to Rokeach (as cited in Hicks & Holden, 2007), the "essential task [of the education system] …is to develop 'open' views of the world, as distinct from 'closed'". In fact, Nussbaum (cited in Hicks & Holden, 2007) identifies this process as being integral to the "three overarching aims of education". An "open" student will "develop the capacity to examine [himself] and one's traditions critically", as well as will "see [himself] as part not only of one's neighbourhood and nation but also of world society" and will "cultivate a 'narrative imagination'- the ability to read intelligently the stories of people in locations different from [his] own".

"In essence, the "open" child is one who is culturally self-aware and who uses that context of self to carefully and sensitively decode the experiences of "others", then interpreting these experiences (or "stories") as having greater relevance to his own narrative. The "open" child will be, and will see himself as, a citizen of the world." Thorley, J.C. Dr Davies, T. St Martin's Academy (2015).

This view at Secondary School level is reflected in the work of Ihsan Unlu (2015) in her article "Teacher Candidates' Opinions on Erasmus Student Exchange Program".

TABLE 1. Data on the Students Studying Abroad as Part of the Erasmus Program (National Agency (Ulusal Ajans), 2014)

Period	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13
Number of the Students going Abroad	1,142	2,852	4,438	7,119	7,794	8,758	10,065	10,263	12,358

Ulusal points out that there is a low number of the scientific publications on this issue (Eurydice 2009), but discusses all the previous elements of pedagogical literature that has been written on Erasmus.

"In fact, current studies are focused mainly on participants' expectations and levels of satisfaction from the program "(Özdem, 2011). These are such as the effects of the programs on academic life, the success of the program in terms of strategical cooperation, the intercultural interaction dimension, cultural adaptation, evaluating the program in terms of joining the EU, academic challenges experienced in the academic process, lecturers' opinions on the program (Kış & Konan, 2010), the reflections of the program on foreign language learning.

In the above-mentioned paper, eight students were interviewed concerning the importance of the Erasmus Exchange programme to academic learning. Table 1 clearly shows that the number of students drawn to Erasmus study has constantly grown from 2004 to 2011. This emphasises the importance that students put on learning overseas for their development. The spread of reasons for joining Erasmus are given in Table 2, inferring that the highest proportion believe that meeting new cultures is the most important vehicle for studying abroad.

TABLE 2. Teacher Candidates' Reasons for Joining the Erasmus Program (National Agency (Ulusal Ajans), 2014)

	Teacher Candidates' Reasons for Joining the Erasmus Program
	Themes
Reasons for Joining The Erasmus Program	Meeting new cultures (7) Improving foreign language (5) Academic development (4) Developing self-confidence (1)

Table 3. Teacher candidates' resulting comments about the Erasmus Program (National Agency (Ulusal Ajans), 2014)

GAINS MADE AS A RESULT OF PARTICIPATION IN THE ERASMUS STUDENT EXCHANGE PROGRAM

Academic gains	cultural gains	personal gains
interactive learning	life without prejudices	learning a foreign language
professionalism	the idea of living together	being open to innovations and differences
different teaching strategies		self-confidence
using time efficiently		openness to different job opportunities
Research examination		sense of being able to succeed
Self-expression skills		changes in future plans
Being able to think in a multi-dimension manner		
Producing projects		

However, in compiling the results of the questionnaire in this research paper, Ishan Unlu shows in Table 3 that the most important gains from the Erasmus programme are concerned with academic development, which shows a shift between student's pre-programme expectations and post-programme attitudes. Part of this study aims at showing that students attitude to learning overseas overrides their intrinsic academic capabilities. Hence the student's willingness to choose the overseas exchange programme at the University of Malaya is a key factor in the success of their studies there and is not reliant upon their original academic capabilities.

Downing. K, Fraide A. Ganotice, Jr., Barbara Chan, Lee Wai Yip (2013) studied the reasons for Mainland Chinese students travelling to Hong Kong to as part of their academic degrees. They proved that through a Self Determination scale of regulations the students' responses coincided with the previous work of Chirkov et al., (2008); Guns, Richardson, & Watt, (2012); Pan et al., (2007). In an increasing degree of self-determination, these regulations are:

- *external regulation* (students are motivated to study abroad through external pressures from parents' demands),

- *introspective regulation* (students were motivated by internal pressures such as obligation to meet the expectations of people),
- *Identified regulation* (students'' motivation based on personal commitment to study abroad) and intrinsic motivation (motivation based on students' conviction that studying abroad is interesting, exciting, and inherently satisfying).

The questionnaire was adapted from the Sociocultural Adaptation Scale (SCAS) (Searle & Ward, 1990; Ward & Kennedy, 1999). The researchers demonstrated that introspective regulation had an important part to play in the sojourns' adaptation to Hong Kong. They found that introspective regulation, a kind of behavioural regulation construed to be resorted to by students primarily to gain social approval and avoidance of guilt, negatively predicted socio-cultural adaptation but positively predicted negative psychological adaptation. These results show that motivation by internal pressures such as wanting to meet parents or social expectations does not consistently result in good achievement. This is aligning to the central argument of SDT. The study goes on to state that the importance of social adaptation in the host country is paramount to or consistent with good academic achievement. This evidence closely relates to the work of Byram and Zarate (1997) and G. Gutiérrez Almarzaa, R. Durán Martínez and F. Beltrán Llavador (2015) which gives evidence that ICC, Intercultural Communicative Competence provides a 'third space' for study which is in between the host country and the home country and improves students' chances of achieving good grades.

This is a kind of social adaptability theory appropriated to the University of Malaya exchange students adapting to a new culture with positive results. The 'third space' achieves an autonomy or aligns to a self-determination and self-efficacy theory expressed in the poster presentation within this module. (Biggs et Al.(2007), Bandura (1986)). Bandura cites that in an environmental of self – powering i.e. groups, students "self-perceptions of capability" are increased. With an increase in self-efficacy come "critical determinants of how well knowledge and skill are acquired in the first place" Bandura (1986).
Moreover, this study aims at analysing whether group study abroad has its own intrinsic benefits in that students adapt more quickly to the host culture by the fact that they also have some cohort identity which is a special kind of 'third space'. A 'third space' in which they feel self-autonomous in their learning and even released from the current financial pressures of learning in their home country. A new outlook manifests itself upon the world of work to the learner with new possibilities and outcomes in economies that are thriving. (Hopkirk, E. 2011).

Myers,D.N, Hill,M., and Harwood,S.T. (2005) produced evidence concerning a ten-week overseas programme in Costa Rica to study sustainable and social projects. It is interesting at this stage to mention the format in which the course is delivered. The ten-week study-abroad program consists of two four-week sessions, with a weeklong orientation preceding the first session and amid-session break. Faculty members from the United States participate in residence for one of the two sessions, while MVI staff provide logistical and academic support. During the four-week sessions, the major program components include homestay with local families, Spanish language classes, intensive service-based studio work, and a series of seminars and lectures on sustainable development, intervention theory, GIS, and similar subjects. This follows the University of Malaya exchange programme in that there were lectures given by UM staff and then supported trips to two centres of historic interest, Penang and Melaka, which both had UNESCO World Heritage Status. In a similar way during these trips, students had to interact with members of the community to find evidence of the historical importance of the Chinese shop houses in these conservation areas.

The overarching aims of the above-mentioned paper were threefold, underpinning:

- the situation of each student's self and the cultural horizons in which he or she experiences the world,
- the affirmation of each student's particular cultural position, and
- The promotion of the understanding of differences as a way to cultivate students' ability to work with other cultures.

Within this paper, Forsyth et al. provide a summary of literature outlining the differences between the learning models that characterize traditional studio instruction and the types of learning that occur in service learning studios. Service learning depends on interweaving community participation methods into a curriculum, reflecting John Dewey's belief that "the transfer of knowledge between two people is self-corrective, allowing them to gain valid knowledge through experience" (Sanoff 2000, 14). In this programme a similar cultural adaptation philosophy to the work of G. Gutiérrez Almarzaa, R. Durán Martínez and F. Beltrán Llavador (2015) and (Ulusal Ajans), 2014 with two other added outcomes. One is a connection with the service users in a sustainable way, i.e. learning sustainability through doing and direct contact and the other is a sharing of the climatic and social conditions of the service users. This results in a special bond with the service user or 'client' in a similar way as the University of Malaya students bond with the owners of the Chinese shop houses in Penang and Melaka.

Internationalism is a core principle of both the QAA Benchmark Statement for Architectural Technology and Building Surveying and the LJMU Strategy Map. The very existence of the University of Malaya programme allows a vein of Internationalism to run throughout all years in both courses. The Level 4 and 5 students are constantly reminded that they will be offered the opportunity to join the exchange programme and then post-Malaysia the results of the study tour are disseminated throughout the Level 6 even to those students who have not attended the trip. (QAA Benchmark Statement Construction, property and surveying 2008, Section 2.3; Subject Benchmark Statement Architectural Technology October 2014.; Section 2.2). Dr. David W. Brasfield, Dr. James P. McCoy, Mary Tripp Reed, (2011) in their paper entitled;" Effect of Global Business Curriculum on Student Attitudes", offer insight into data concerning the types of global input into curricula in Universities. They conclude that although internationalism in formal teaching is important for understanding global economic trends and cultural issues, there is evidence to suggest that experiential understanding actually aids the post-graduate's willingness to put their global knowledge into practice by working and carrying out business abroad. There is also more likely the chance that experiential knowledge gained in international exchange or study trips increases students understanding of culture; more so than by purely teaching internationalism. This also improves global citizenship, in that students who have a better understanding of cultures and global experiences are more likely to accept and understand international business people working or visiting the UK. This is under-pinned by the policies of LJMU in the Foundation for Citizenship, which are manifest by the Roscoe Lecture Series. These policies aim at the Common Good in a multicultural society.

4. Aims and Objectives

Aims:

- To determine if there is an improvement of grades brought about by the University of Malaya Exchange Outbound Programme.
- To analyse and correlate the marks of two student cohorts over a three-year period.
- To determine recommendations for future research in this subject with a view to improving student exchange programmes and Level 6 marks for all students.

Objectives:

- Use the conclusions of the study to inform future International Exchange Programmes.
- Produce a research evidence to improve the curriculum within future International Exchange Programmes
- Evidence how students learn in the international setting and how they use their knowledge in the World of Work.

5. Methodology

5.1 INTRODUCTION

The paper will use quantitative data methods in the discussion of the research topic. There will be three forms of data to analyse; the first will be directly obtained from the resulting marks from the module that is being discussed, 6104BEUG BUILDING APPRAISAL, APPRECIATION AND CONSERVATION and secondly two previous modules from the Level 5 Architectural Technology and Building Surveying BSc (Hons) courses respectively. These modules are 5113BEUG DESIGN TECHNOLOGY and 5122 REFURBISHMENT PROJECT respectively. This data analyses two student sets. The first who began Level 5 in the academic year 2013/2014 and the second set who began Level 5 in 2014/15. Each cohort progressed into Level 6 in 2014/15 and 2015/16 respectively. The fact that two cohort year samples are used gives a more varied view of marks of the two periods. Data graphs present final marks for each module and are separated into logarithmic mean values for Malaysian Exchange Students (MES) and Standard Students (SS). Students, who did not carry on to Level 6 through failure or taking a year out, were removed from this sample; as they showed no continuity. Also a more accurate sampling is achieved by separating the BSc (Hons) Architectural Technology from the B.Sc. (Hons) Building Surveying courses as there are fewer AT students who took the University of Malaya Exchange option.

The final year module sampled 6104BEUG is split into two assessments of 50% although all marks have been shown with one final 100% mark. The distinction between the two modules is not important for the analysis of marks as the comparison of MES students and SS students will be sufficient to analyse whether there is an improvement in marks for the outbound University of Malaya cohort. The main difference between the 6104BEUG assessments, which are taken by both AT and BS cohorts, is that within the University of Malaya assessment students are asked to complete a journal and test about their cultural observances. This takes the place of a 50% assessment that students complete in the UK in the first semester of Level 6 in this module. Other than this, the study requirements of the buildings in Malaysia and in Liverpool are similar.

The third form of data is quantitative and exhibits the results that were achieved by BSc (Hons) Building Surveying sandwich year students who took a year in placement after the study exchange at the University of Malaya. The aim of this is to determine whether further improvements in marks were made with the sandwich year option. No BSc (Hons) Architectural Technologies took sandwich year placements so no marks for these cohorts were available.

5.2 DATA ANALYSIS.

5.2.1 Marks Analysis- BSc(Hons) Full Time

Four scatter dot graphs show sequestrated data on four student cohorts:

- 2013-15 Level 5 and Level 6 modules on the BSc (Hons) Building Surveying and the BSc (Hons) Architectural Technology courses respectively.
- 2014-16 Level 5 and Level 6 modules on the BSc (Hons) Building Surveying and the BSc (Hons) Architectural Technology courses respectively.
- All four graphs show a similar trend in presentation of the marks. The scatter dot approach shows clearly each individual final mark and then a logarithmic mean line indicates the overall trends. Four colours have been used; Blue, Orange, Grey and Yellow. The logarithmic lines show the following results:
- Blue – marks from the University of Malaya Exchange student option (MES) Level 5 Module
- Orange – marks for the Standard Student option (SS) corresponding Level 5 Module
- Grey - marks from the University of Malaya Exchange student option (MES) Level 6 Module
- Yellow – marks for the Standard Student option (SS) corresponding Level 6 Module.

The aim is to determine whether there is a difference in marks between the two groups (MES and SS) at Level 5 and if there is an increase in the unit marks at Level 6. The two cohorts were split into two groups as it was deemed important that a separate comparison is made as there were considerably more BSc (Hons) Building Surveying Students on the programme than BSc (Hons) Architectural Technology students in both sequestrated intakes.

Table 4. shows that there was a slight difference at Level 5 between the two groups (blue and orange) with the MES students' results being higher. This could be detriment to the study if the MES students initially prove to be better students before they attended the University of Malaya Exchange programme. However, the resulting gaps between the Level 5 and Level 6 logarithmic trend-lines differ. The blue and orange trend-line at the greatest logarithmic mean point is about 9% increase from SS to MES students. With reference to the Level 6 results, the greatest increase from SS to MES students is 15%. This shows clearly that there is an improvement in marks within the MES student cohort between Level 5 and Level 6. Despite the Level 6 SS Level being lower than the Level 5 SS marks, this pertains to the fact that there was a greater degree of difficulty in the Level 6 module exponentially. Moreover, the MES logarithmic mean between Level 5 and Level 6 increases. The SS logarithmic mean between Level 5 and Level 6 increases in part but there is a section where Level 6 dips below the Level 5 marks, indicating that the SS marks actually got worse in part at a time when students are usually trying harder (final year).

TABLE 4. Graph showing the 2012-15 Level 5 and Level 6 sequestrated marks in Building Surveying – Full Time. LJMU

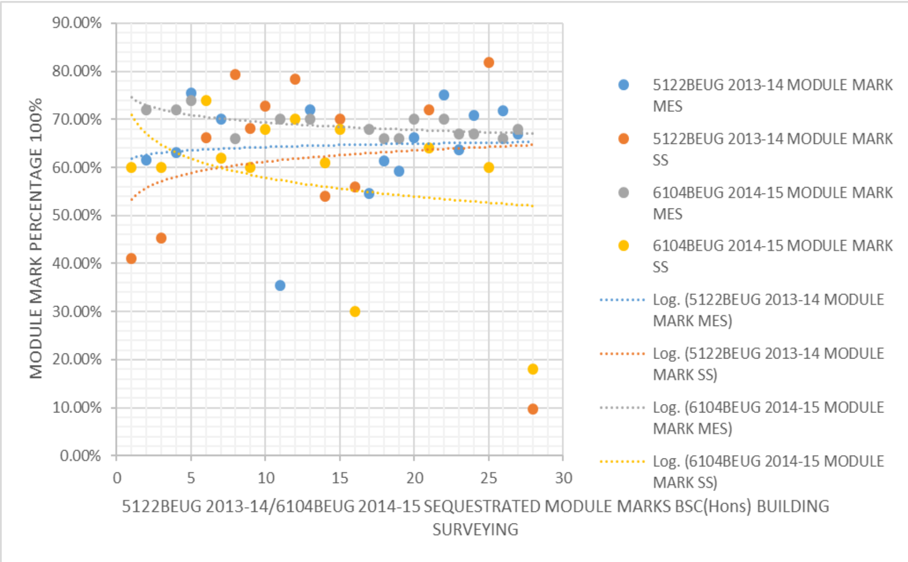


Table 5 aligns to this theory also, although there are some differences. Generally, Level 5 MES marks were better than Level 5 SS marks. Indeed, Level 6 MES marks were worse that Level 6 MES marks on the whole but the evidence shows that the percentage step decrease between MES Level 5 and 6 marks and SS Level 5 and 6 marks differs by 7% and 14% respectively. This decrease contributes to the fact that the measure of difficulty was greater in the Level 6 module resulting in the fact that MES students work actually improved in Level 6.

Table 6 indicates to a similar result in Building Surveying although the differences between the decreases in 2015 graduate years' cohorts are narrower. The blue and the orange logarithmic mean trend-lines (Level 5 MES and SS respectively) are closer with blue being 6% lower at its worst case although there is large area that is 4% higher. The decrease of MES marks to SS marks goes to 9% in Level 6 that follows the trend that MES marks are better generally after they have studied on the University of Malaya programme.

TABLE 5. Graph showing the 2012-15 Level 5 and Level 6 sequestrated marks in Architectural Technology – Full Time. LJMU

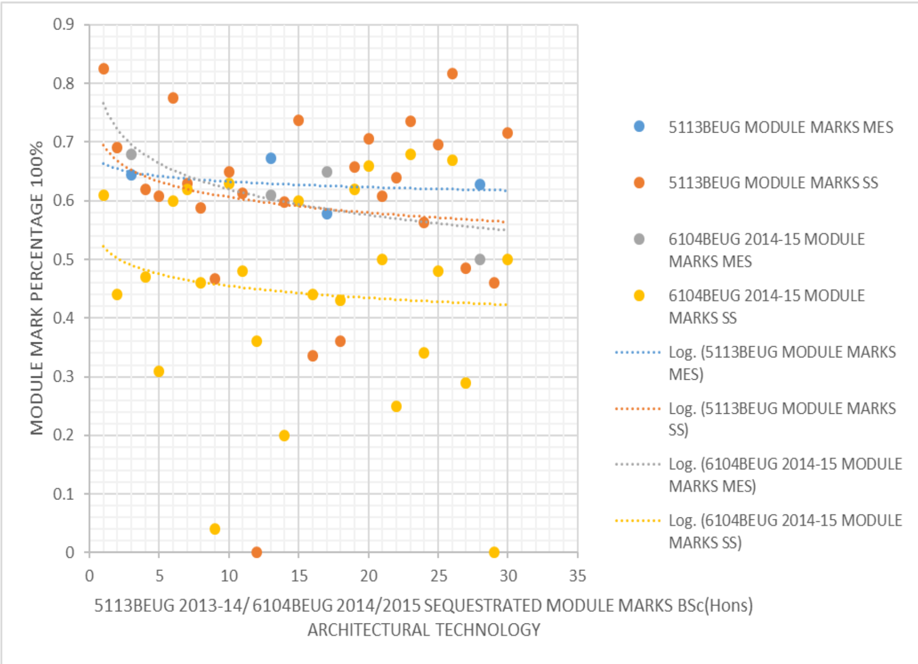


TABLE 6. Graph showing the 2013-16 Level 5 and Level 6 sequestrated marks in Building Surveying.- Full Time. LJMU

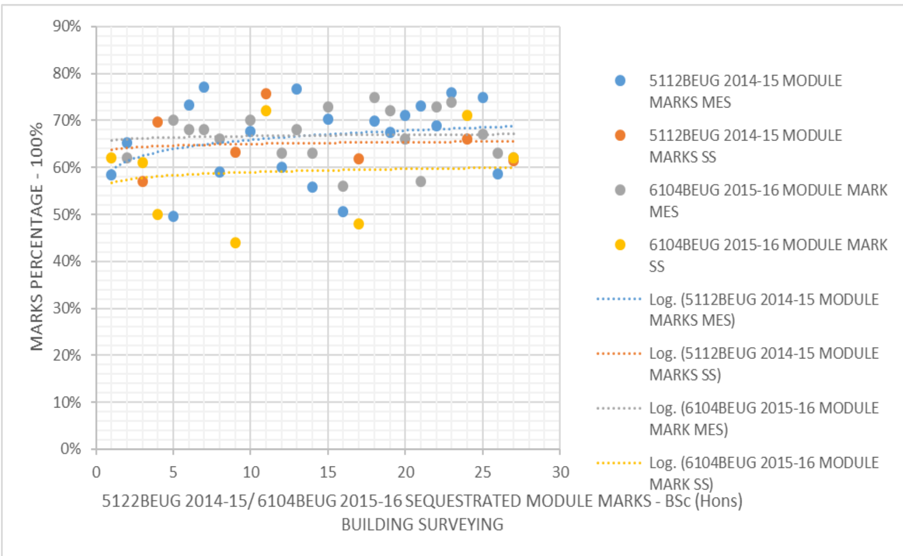
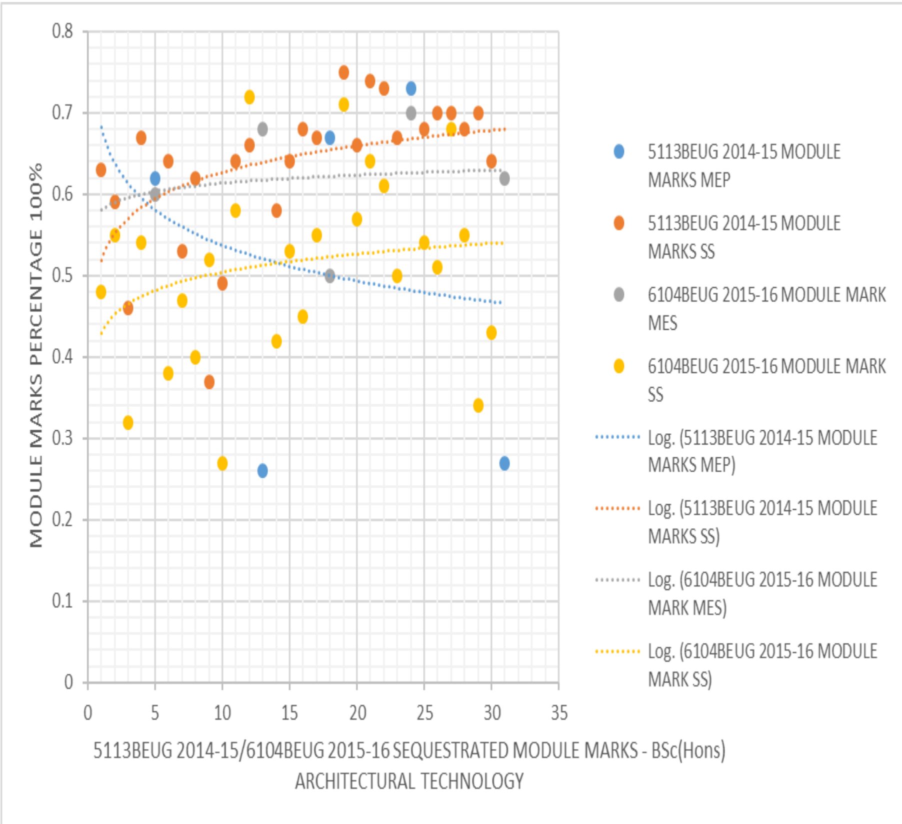


Table 7. Shows a greater step-decrease in results between the MES and SS students. The level 5 work is especially interesting in that the SS students for

the first time in Architectural Technology in this year show greater results by an increase of 21% at the highest differential. When we look at the Level 6 marks, however, the trend-line follows on from the previous graphs in that MES students' marks are 15% better at the greatest differential. Table 7. Shows the clearest indication that attendance on the University of Malaya programme actually improved students chances of getting better marks at Level 6, the year immediately after the study trip which occurred in June previous to the Level 6 new semester in September 2015.

TABLE 7. Graph showing the 2013-16 Level 5 and Level 6 sequestrated marks in Architectural Technology – Full Time. LJMU



5.2.2 Marks Analysis- BSc (Hons) Building Surveying Sandwich Year

Two scatter dot graphs show sequestrated data on two student cohorts:

- 2013-16 Level 5 and Level 6 modules on the BSc (Hons) Building Surveying with Sandwich placement in the 2014-15 academic year.
- 2014-17 Level 5 and Level 6 modules on the BSc (Hons) Building Surveying with Sandwich placement in the 2015-16 academic year.
- Both graphs show a similar and enhanced trend within the sandwich year placement. In both graphs the sandwich year students who also went on the Malaysian Exchange had better marks on average than both those who were on the full time course and went on the University of Malaya exchange. This is true for the 6104Beug Module.

Table 8. Graph showing the 2012-16 Level 5 and Level 6 sequestrated marks in BSc (Hons) Building Surveying – Sandwich Year. LJMU

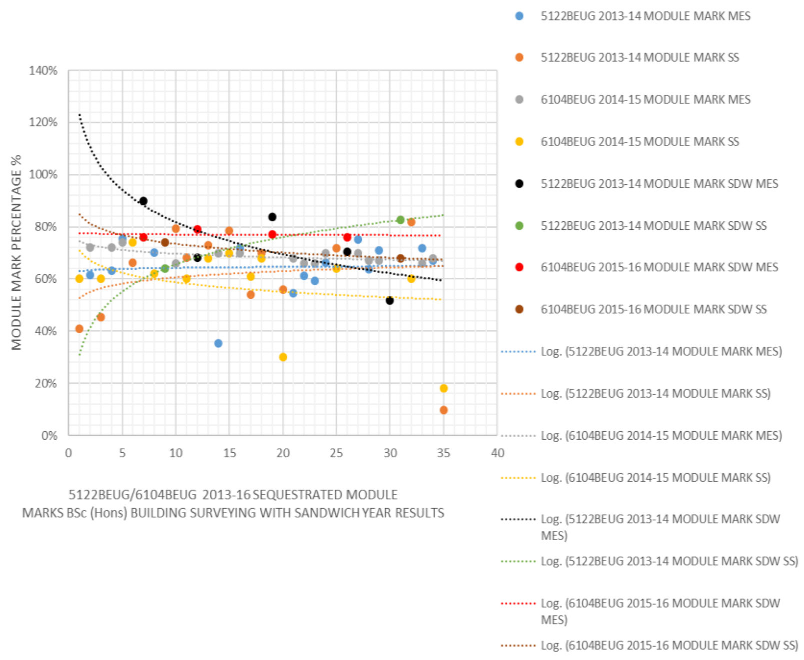
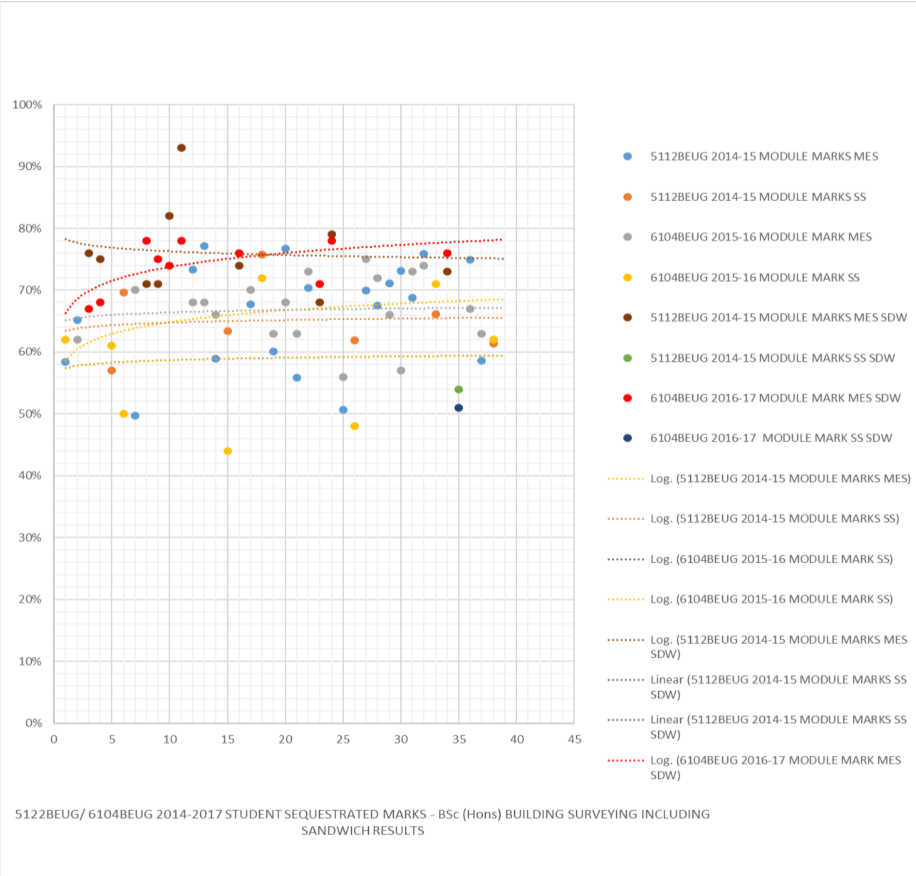


TABLE 9. Graph showing the 2013-17 Level 5 and Level 6 sequestrated marks in BSc (Hons) Building Surveying – Sandwich Year. LJMU



6. Conclusions and Recommendations

It is clear from the previous research and literature published on the subject of the benefits of International Exchange Programmes that there is a benefit in taking part not only to students' grades but also to student's development to the World of Work. Having completed an International Student exchange it is more likely that students will put into practice in the Global market what they have gained from their experiences as well as what they have learned. A quantitative survey has been completed in order to prove this matter, but it has been decided not to publish the results because the body of work would bring the word count above that recommended for a conference paper. A survey was completed from a sample of 12 students who had completed the University of Malaya exchange programme. The questions were based on three major themes, specifically Academic Gains (vocational knowledge, vocational experiences, and professionalism), Cultural Gains (learning about different cultures, education training in multi-cultural environments, and attitude toward different cultures), and Personal Development Gains (foreign language learning and self-confidence). Overall, the results were positive and proved that the students thought that the programme gave them all three benefits. This aligns to the theory of G. Gutiérrez Almarzaa, R. Durán Martínez and F. Beltrán Llavador (2015) concerning the 'Third Space' of intercultural communication. By these results, there was some indication that students thought that they should have more training in foreign language and this may be a route for future design of curriculums within the Built Environment in that Spanish and Mandarin are now the major languages in the world and will become more important by 2030. It is forecast that, by 2030, construction output worldwide will grow by 85% to $15.5 trillion and China, India and the US will account for 57% of this growth. With this in mind, it might be a benefit to bring some language studies into the Built Environment courses.

With respect to the results of the sequestrated marks form Level 5 and Level 6; they clearly shows that there is an increase in performance by those students who took part in the University of Malaya Exchange Programme. The large differential gap between these marks, up to 10% in some cases, also could indicate that there is not only an academic improvement but also one of attitude to learning. There is a danger that the improvement could isolate students who could not afford the £600 extra for the programme. Although this figure is subsidised there may be an argument for applying for sponsorship funds such as the NSS Improvement Funds that are available for students who can prove exceptional financial hardship. The other option could be to provide International Studies as a part of the curriculum. The introduction of this pedagogy could become part of the Entrepreneurship modules that are new to the Department of Built Environment. This would have the effect of focussing the student on the positive world economies in construction and engender confidence in the subject. This could give students the chance to dream about a positive future, which improves self-efficacy and self-motivation to study.

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A TRULY INDUSTRIALISED HOUSE BUILDING SYSTEM

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Abstract. The increasing number of participants in the design and construction of buildings requires comprehensive coordination and a flow of information between the relatively independent actors. Meanwhile society is occupied with the great costs to be paid for decent buildings due to the many working hours required and is looking for a miracle to happen to lower the prices. The answer from the construction industry is the so-called BIM strategies that should ease the flow of information between the participants. This article points at industrialisation as the requested miracle and gives an example of how a truly industrialised building system could look. As a means to draft such a system, it asks what a true industrialist would suggest as an answer to all the performance requirements society has for its buildings. Henry Ford is quoted to have said that had people been asked what they wanted for their transport in the time before the cars they would have asked for "faster horses" (Quoteinvestigator, 2011). The author finds that BIM is just an attempt to make 'faster construction' but that construction at any time will be quite as time consuming and expensive as tailored dresses are in comparison with the manufactured dresses people mainly buy today.

1. The present stage problem and what to do about it

Because todays buildings are made or assembled on site, they are relatively expensive, and the development of the construction industry is stuck in an outdated tradition and therefore far behind all other major industries (Kristensen, 2011). This is a bit strange because the building industry early began to utilise techniques practised in other advanced industries like for example cast iron elements in the Crystal Palace in 1851 (Gideon, 1966; Frampton, 1980; Kielland, 1920; Barrow, 2004).

The construction industry is the only mayor industry that is not yet really industrialised. It still has clients and consultants as key actors whereas the industrialised industries have producers, sellers and buyers as their key actors (Kristensen, 2015).

Thus, it is logical to ask, which changes of technical nature it will require to change the industry to one that manufactures buildings for people just as most of the clothes people wear are manufactured and not tailored (Barrett and Kruse, 2016). The clothes people wear today are no more uniformed than tailored dresses were in the preindustrial period and the buildings people desire might be quite as individual in order to suit them. The first generations of buildings made by prefabricated components uniform people and their families, but other industries have shown that there is no need for such a "stalinistic" uniformity (Barrett and Kruse, 2016).

The new trend in the construction industry is to enhance the cooperation between the increasing number of participants in the design, planning, and execution of buildings by the help of the so-called BIM procedures. This recognition is strongly underpinned by the significant number of articles about the subject in journals and conference proceedings. At the latest ICAT conference one could notice the following articles about BIM: Hayes and Saleeb (2016); Loveday, Kouider and Scott (2016); Shaw, Leon and Scott; Kouider, Paterson and Harty (2016); Mellon and Kouider (2016); Renata and Saleeb (2016); Dearlove and Saleeb (2016); Cusack and Saleeb (2016); Comiskey et al (2016); Galiano-Garrigos, Iribarren and Fernandez (2016); Harty (2016).

The ICAT conference in 2016 was symptomatic of the belief that the way forward for the industry is "faster horses" as Henry Ford was assumed to say (Quoteinvestigator, 2011). In a truly industrialised sector however, communication and required kinds of action stay mainly inside the individual producing company and do not need special common tools for the whole sector to provide its plans and procedures. This means that the producers of whole buildings can design their own systems based on their own ideas and that BIM is mainly useful for more traditional tailored buildings. The industrialised manufacturing procedure can, by using already existing advanced electronic techniques like newest CAM-tools, take place without manpower by using a fully automatic computer driven procedure. Instead of having the aim to copy what is done already in construction it will accept that its own way of production will have its impact and lead to a new kind of aesthetics for houses. Cars do not look like old fashioned carriages as in their first stages of existence. As people got used to the situation without horses and with a higher speed, cars got new functional and aesthetic characteristics. They ended fully based on decent requirements to the result in combination with the requirements to its production methods.

When it comes to whole buildings, it is hard to say how close we are to a breakthrough as to real industrialisation, but still more building parts become industrialised products as nails, screws, and bricks were for centuries. Similarly, tailors have used threads, manufactured fabrics, and buttons in a longer period before industrialisation took over and became successful by delivering dresses to an extent and quality that was no less flexible and suitable to people's requirements than what the tailors offered.

The producers of attempted completely industrialised buildings delivered in so-called modules to be assembled at the building site have typically entered the traditional market and tried to adjust to what consultants are asking for on behalf of clients (Nadim and Goulding, 2009). Typically, they have a background as master carpenters, base their techniques and procedures on what is common in the construction industry, and buy their materials from the same sources. Therefore, their products are (even if a bit cheaper) still expensive like tailored clothes (Kielland, 1920; Kristensen, 2011).

The following is an attempt to find an answer to the question of what kind of building system a real industrialist could develop to begin a mass production of buildings that would suit people's individual taste as the manufacturers of clothes have done for so long. As its main method, the article asks several critical sub-questions and suggests answers to them. The answers are visualised in technical drafts.

2. Requirements to a truly industrialised building system

An industrialist might in the first place want an industrial company with a production section, a research and development section, **a** sale and service section and a marketing section as in other fields (Barrow, 2004).

Initially, the research and development section has to develop a system based on basic initial ideas. Such a package of initial ideas fitting each other is presented in the following as answers to the basic system requirements.

2.1. REQUIREMENT ONE: A FLEXIBLE AND PORTABLE SYSTEM

To meet this request, it is necessary to secure a basic load carrying system or frame that is stable enough to carry multiple common loads and multiple surfaces to satisfy people's requests. Initially, an industrialist could go for buildings of four levels above ground plus one basement as the limits for the building height. For transport, one could see the 4.5-metre wide units that is the practised maximum width in Denmark as a general maximum and 3 metres as the usual height of stores. The minimum height from floor to ceiling is 2.5 metre in the Danish building regulation for buildings produced for sale or rent. When people ask for a building for themselves, which might become quite common with the proposed industry, 2.3 metre is the minimum. The height matters because it influences the consumption of materials and the necessary space for the staircases (Hansen, 2012).

To be flexible, the system should be adjustable to a variation of sizes within certain limits so that almost all kinds of rooms for living and/or office activities are possible (Barrow, 2004). Here, it is estimated that a floor area of around 30 m2 or less per unit or module will give the desired flexibility and portability. For the flexibility it is an idea to use the principle of an aquarium frame for a load-carrying carcass in each unit to secure the stability and allow units without load carrying walls but completely open to neighbouring units.

A carcass supposed to be sticking to the above-mentioned requirements is shown below together with an example of a "column" of five modules.

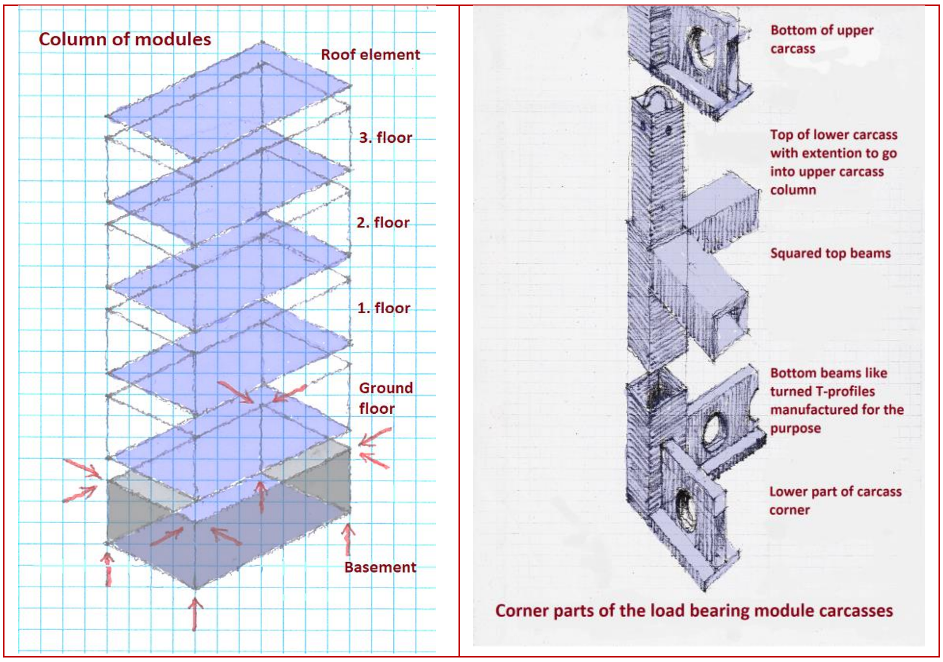

Figure 1. Column of modules and corner of a carcass (Barrett, 2016)

The carcass consists of columns of 160 x 160 mm steel profiles, top beams of the same profile and in the bottom a special I-profile of steel. If the span exceeds a certain limit the top beam of the lower carcass can, on site, be connected to the bottom beam of the upper carcass thus to make them act as one high strong beam. The illustration shows how an exceeding squared steel profile topped with half circular stirrups for crane lifting and guiding the upper unit to its position is welded on top of the corner column.

In such a flexible system walls and horizontal divisions (floors and ceilings) must be installed in the factory and not require any treatment on site. How could this take place with as little effort as possible?

2.2. REQUIREMENT TWO: LOAD CARRYING HORIZONTAL DIVISION

An industrialist might ask what performance requirements he should stick to live up to what is common in buildings and not what is the common solution in construction due to its rather different way of execution. The following list indicates the resulting major requirements:

1. Sufficient load bearing capacity
2. Minimum own load
3. Sound insulation
4. Fire insulation
5. Pleasant surfaces
6. Easy montage in carcass

2.2.1. Sufficient load bearing capacity

In construction, the common solution is beams or slabs spanning in one direction. In theory, this is only the most sufficient because buildings are designed as individual as the tradition requests. If only relatively few are requested, the investment in machinery and research has to be equally limited, and simple solutions become the result.

If, on the contrary, the scenario allows a capacity to invest in both research and machinery because a vast number of units of the type are requested, other principles will apply. It would be logical to minimise the consumption of material by utilising the capacity of the chosen material in the most efficient way. A stressed skin design fits this idea (Page, 1961).

2.2.2. Minimum own load

This requirement likewise leads to the thought of a stressed skin design with the same argumentation as above. Today’s requests for ventilation, heating, water supply, and electricity, which in ordinary construction is solved by the help of a suspended ceiling with its additional layers for ceiling and an additional wall height, points at the possibility of utilising the cavity in a stressed skin solution for the purpose.

2.2.3. Sound insulation

There are two known principles available to meet this request and they are heavy constructions not to be moved by sound energy and/or a separation of surfaces with acoustic insulation between. A combination of the two principles might also stick to the requirements (Mollerup et al., 1991).

2.2.4. Fire insulation

A chosen stressed skin element must consist of fire resistant materials to satisfy the building regulation requirements and must participate in insulation of the load bearing columns and beams as well.

2.2.5. Pleasant surfaces

For the ceiling, a nice smooth white surface is the most common choice everywhere. For floors, a variety of solutions are available on the market but the simple concrete floor to be covered with carpet or floor boards is perhaps the most common simple solution people can think of. Combined with an earlier mentioned consideration this could lead to the idea of a stressed skin element of fibre concrete that could have different colours and textures but very often might be smooth and white. Such a surface would also be acceptable as the cheap basic choice in many countries.

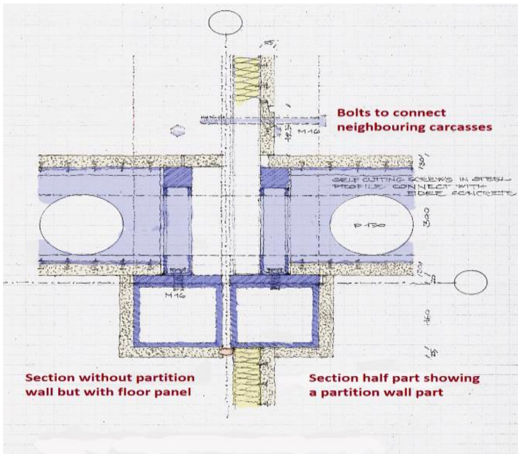

Figure 2. Horizontal divisions and meeting between four carcasses showing a half part internal wall and half a cover board (Barrett, 2016)

2.2.6. Easy montage in carcass

When to be mounted in the shown carcass, a stressed skin element the size of the whole floor within the carcass needs to be lifted in diagonally through the opening between the columns and beams.

Thin plate steel profiles create space between the two skin slabs and provide a rigid connection between the two. There are circular holes in the profiles and the carcass beams to allow 150 mm ventilation tubes to pass and to be connected in the accessible space between the two carcass beams next to each other. To bridge the gap of this space when not filled with wall parts a board of fibre concrete is prepared and ready in the one module.

The connection between steel profiles and fibre concrete is here shown with a row of self-cutting screws put into the profiles before they are sunken into the wet concrete. Another possibility is to have a perforated top and foot of the profiles so that they can be sunken and integrated into the concrete themselves. Below, a section of the lowest floor with foundation mounted beneath the carcass beams and transported together with the lowest modules.

Figure 3. Foundation of fibre concrete and crawl space to access through a cover below the main door matt (Barrett, 2016).

The idea is that only excavation and a compressed and levelled layer of stabile gravel are needed preparatory works for the support of the manufactured foundation beams that come bolted to the ground floor units.

2.3. REQUIREMENT THREE: GOOD PERFORMANCE OF EXTERNAL WALLS

The requirements to the external walls are in principle the same as for the horizontal divisions but with certain additions:

1. Sufficient load bearing capacity
2. Minimum own load
3. Wind and water resistance
4. Good thermal insulation
5. Sound insulation
6. Fire insulation
7. Pleasant surfaces
8. Easy montage in carcass

If made in two parts with an external and an internal part each consisting of fibre concrete and thin plate steel profiles to stand wind load, own load, and accommodate insulation each part might perform quite well.

Shown below are two wall parts mounted from external side and internal side respectively. This enables a sufficient coverage of the carcass and keeps it inside most of the insulation.

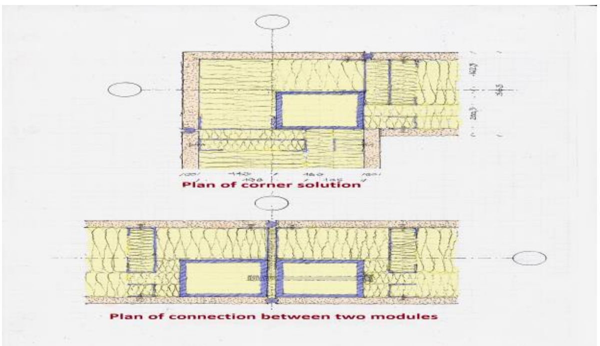

Figure 4. External wall where two units meet (Barrett, 2016)

Notice that a bolt behind the movable skirting board connects the two carcasses in figure 4.

Regarding wind and water closeness, a minimum of two characteristics of the external surfaces are always required, namely that the main material chosen is tight enough and can stand the influence of water plus that the joints between the main material units are tight and resistant enough for the purpose. Not bound by the primitive conditions construction on building sites gives, an industrial company has much better possibilities to reach advanced and much more satisfactory final solutions.

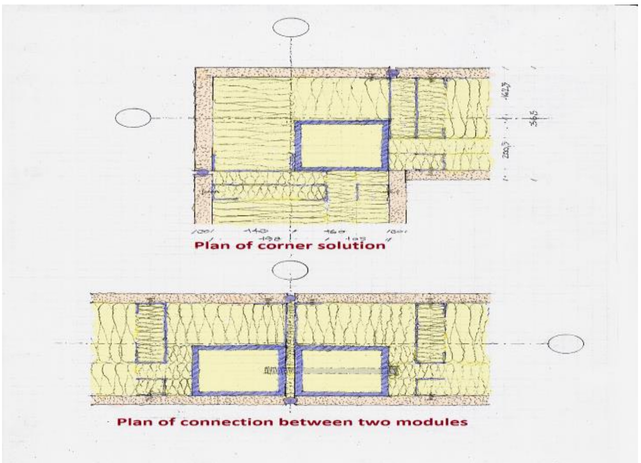

Figure 5. Corner of external wall as a separate component (Barrett, 2016)

The simplest version of the external wall has a fibre concrete surface outside but there can be different pattern impacts and different colours if desired. To get a tile stone surface or masonry like surface the tiles can be casted into the external fibre concrete leaf. The same counts for natural stones but of course, a heavy layer of traditional masonry can also be placed when a strategy for mounting and transport is developed.

2.4. REQUIREMENT FOUR: GOOD PERFORMANCE OF ROOFS

Most kinds of roofs for the proposed system are going to be placed on the top carcasses. The only example shown is a flat roof of fibre concrete. The top carcass can also be shaped as a roof itself with dormers or skylights and this requires a further development of the system, but the author possesses certain drafts of such possibilities.

The requirements to the external roofs are in principle the same as for the walls but with an extra stress on closeness to wind and water:

1. Sufficient load bearing capacity
2. Minimum own load
3. Wind and water resistance
4. Good thermal insulation
5. Sound insulation
6. Fire insulation
7. Pleasant surfaces
8. Easy montage in carcass

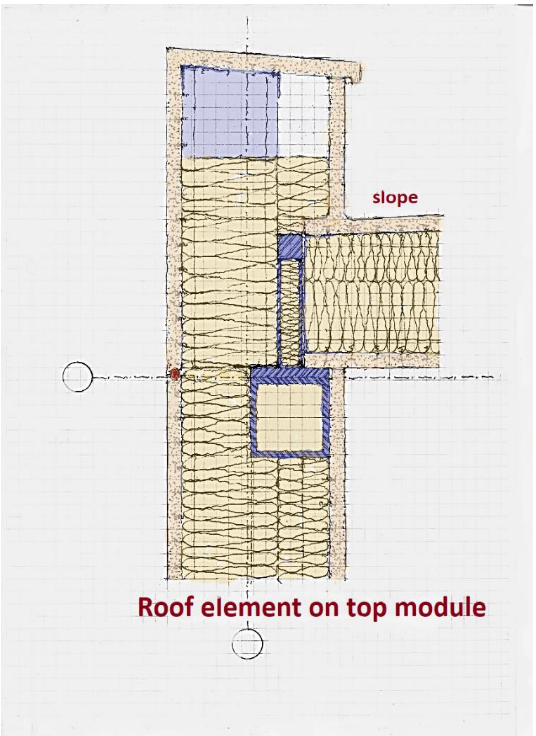

Figure 6. Flat roof unit mounted like an ordinary module but could also be delivered already mounted to the carcass below it (Barrett, 2016).

The shown roof solution sticks sufficiently to all eight requirements

2.5. REQUIREMENT FIVE: WELL PERFORMING BASEMENTS

The requirements to the external basement walls are in principle the same as for the other external walls but with an extra stress on closeness to moisture:

1. Sufficient load bearing capacity
2. Minimum own load
3. Water closeness
4. Good thermal insulation
5. Sound insulation
6. Fire insulation
7. Easy montage in carcass

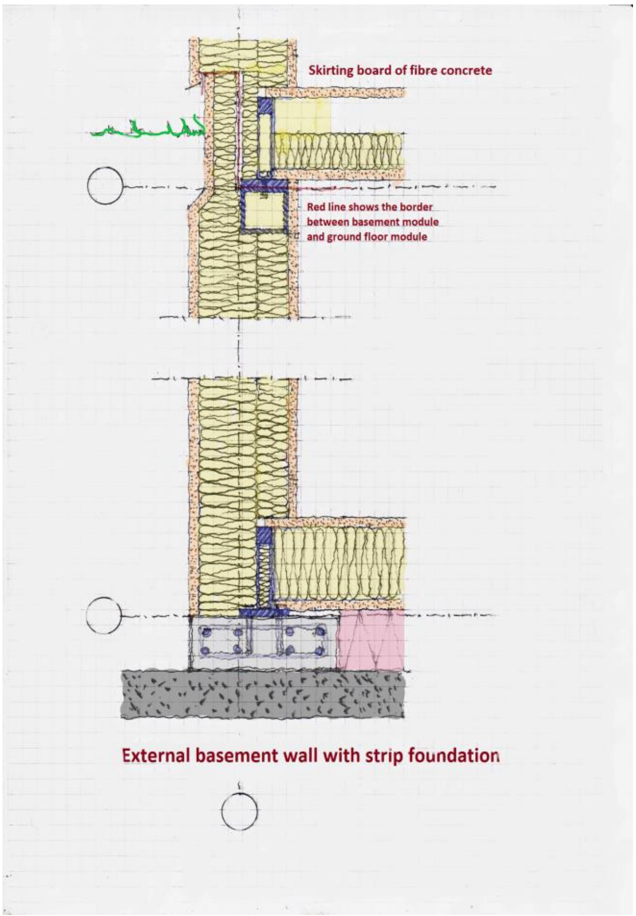

Figure 7. An ordinary carcass carrying a basement wall and foundation (Barrett, 2016)

Basement modules can be prefabricated like ground floor units with additional foundation mounted and can be placed the very same way only a level deeper than the crawl space below a ground floor. The illustration shows how this principle can be applied. One can rely on good performance from an external fibre concrete leaf that can stand both moisture and soil pressure (Mollerup et al., 1991). The external leaf of the illustrated basement wall continues up to create a decent plinth for the meeting with the upper wall.

The basement wall might in urban contexts border to neighbouring basement walls. Thus, it needs to provide both a good sound insulation and a good fire insulation.

To be lighter, a strip foundation under the basement carcass could be made as a hot dip galvanised hollow steel beam instead of the shown concrete solution. The carcasses for basements are exactly the same kind as the carcasses of the upper levels.

3. Requirements to the producer of the drafted system

The producer of the system should possess two different major production lines plus an assembly line. The production lines should be an advanced flexible steel and welding line plus a fibre-concrete-thin-plate stressed element line. Detailed drawings to meet individual requests from customers who have accepted the designs of the service department could via CAD-CAM systems direct robots to "tailor" both carcasses and fibre concrete elements to the specific design that always has to respect the degree of flexibility of the developed building system. Other producers from the building industry might deliver the smaller supplying components.

The producer need to invest in both factory and staff for all the above-mentioned departments. Transport and shipping is a challenge, but solutions are well known from numerous other industries. Especially the shipping requires special developed solutions.

4. Conclusion

It is possible to take the full step to industrialise the whole building production when it comes to the more ordinary and common needs for housing. Done the right way it will not lead to uniformity but incline individual buyers to request the degree of individual performance any decent local plan might allow.

There is no reason to believe that the unit price will not end at the same low level in comparison with construction as for example cars and clothes have reached in comparison with the traditional handicraft products. Some of the saving potential might already be achieved by industrialised components but much is still to be gained when real industrialisation is introduced with producers and customers instead of the traditional client and consultant relationship (Kristensen, 2011; Phillimore, 1989).

Naturally, this will be beneficial for society but what about the existing professions of the industry? They have to adjust to the new situation with new roles as leaders of companies, department leaders, developers and service agents. BIM might still be useful in relation to tailored and more outstanding buildings society might request. The industrial firm will use advanced 3D modelling corresponding with equal advanced CAM-systems, but it will not need a lot of troublesome communication with other parties about individual buildings. The firm has its own systems to develop and update continually (Barrett, 2014).

It will require a considerable investment to establish a successful manufacturing business of the described kind but the first at the international market will have a significant advantage and a potential to grow world-wide.

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UTILISING LEGACY DATA FOR PROJECT RISK IDENTIFICATION, ANALYSIS AND MANAGEMENT

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Abstract. Existing research provides evidence that the construction industry is susceptible to risk. The HSE places Construction second, below agriculture, forestry and fishing in workplace injuries. The literature suggests that current practice regarding risk identification within the construction industry has a significant potential for subjectivity and that this constitutes a considerable shortcoming. To determine the extent to which this is the case, both Qualitative and Quantitative data collection in this research was undertaken over several phases, and detailed analysis, including the application of grounded theory, was applied in order to generate a well-rounded theory. These phases were interviews, questionnaires, observations and secondary data sources. The data sources were then analysed to understand the construction industry's processes, attitudes and exposure to risk. The research process revealed that construction companies rely on intuition, judgement and experience to identify the risks to a significant extent, and also revealed some restraints within this situation. However the industry has available a potentially substantial pool of data in that captured by mobile devices (e.g. SnagR, 360 Field, and Field Supervisor), but does not make use of it to any great extent, with only 15% of all historical data being analysed coming from mobile applications. The proposal to overcome the above issue is the introduction of a new framework. This framework will undertake using this source of mobile captured legacy data to increase the portfolio of quality risk data that is available to project teams to assess risk more efficiently, and also to reduce the potential for subjectivity within the risk identification process. This was aimed to ensure that the use of historical mobile data is streamlined through a framework structure and that any amendments to the data structure are essential in improving the risk identification process. It was also intended that the new framework will aim to increase the participation of staff at all levels, in risk decision-making by project teams.

1. Background, Rationale and Problem Statement

Change is inevitable within the construction industry and the industry suffers from a poor reputation for dealing with change, with projects being unable to meet construction deadlines, cost overruns or low quality standards. With better risk management principles, engineers may be able to improve how effectively this change is managed (Smith et al., 2014).

Risk management plays a key role when planning construction activities such as the creation of a construction programme, the quantifying of cost and managing the quality of the final deliverables. The importance of risk management for construction companies is highlighted by Smith et al., (2014) who state that "the need to manage risk is important to them because of the need to limit professional indemnity costs and to protect the organization's reputation".

The concept of employing effective risk management analysis techniques to reduce or control risk is widely acknowledged throughout the construction industry. These analysis techniques include the risk premium, subjective probability, decision analysis, sensitivity analysis, Monte Carlo simulation, stochastic dominance, Caspar and intuition risk adjusted discount rate (Akintoye & MacLeod, 1997). It is clear that the concept of effective risk management is not new to the construction industry, and this research was designed to investigate whether any possible improvements could be achieved through the use of legacy data. There is a drive within the construction industry to digitise the creation of data such as issue data, e.g. quality non-conformances, programme delays, design issues, H&S and environmental issues, captured onsite with mobile devices. This research also considered whether this data is structured to allow for use within risk identification and decision making processes for project teams, and consequently whether this pool of data could be a valuable source for risk identification and analysis.

2. Literature

According to ISO 31000, risk is explained as the consequences of an organisation setting and pursuing objectives against an uncertain environment, this uncertainty arises from both internal and external factors and influences that the business does not completely control (Purdy, 2010). Whereas the PMI Project Management Institute, 2013 defines project risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality". It seems clear from this definition that exposure to risk arises where events have an uncertain outcome. This uncertainty may come from a number of sources, including an organisation's lack of information or knowledge/experience of the type of project being constructed; insufficient time to make an informed decision; inadequate 'lessons learned' processes, resulting in the new projects being subjected to the same potential risks as previous projects

The research undertaken revealed that the construction industry is particularly susceptible to risk, as the industry has to deal with constant situations where changes including client changes and design changes occur (often on a daily basis).

When comparing the construction industry to other industries such as the automotive or manufacturing industries, which potentially have an opportunity to reduce risk through continual improvement by producing the same products in a controlled environment, the construction industry, even when producing the same product like a housing estate where the designs are often duplicated, may find that ground conditions, weather and material quality vary from project to project. This is highlighted by (Nadeem, et al., 2010) who state that "the construction industry, perhaps more than most other industries, is overwhelmed by risks". Problems that arise in construction projects when compared to many other industries are complicated, usually involving massive uncertainties and subjectivity (Taylan et al., 2014) and construction companies are exposed to risk at a greater level because of their involvement in numerous contracting parties, technological challenges, and difficult working environments (Hanna et al., 2013). These risks can affect many different areas; these include Health and Safety, contractual, environmental, quality and reputational risks.

Not only is the construction industry highly susceptible to risk, but the consequences are greater. The Health and Safety Executive records for 2016 to 2017 put the industry second highest for workplace injuries, only below agriculture, with 2940 workplace accidents. In addition, data on rework costs identified by Burati et al., (1992) showed that deviations on projects accounted for an average of 12.4% of the total project costs. In extreme situations risks that bring about time and cost overruns can nullify the economic case for a project (Smith et al., 2009).

2.1. CURRENT PRACTICE FOR THE IDENTIFICATION AND MANAGEMENT OF RISK

It could be said that the success of any risk management process hinges on being able to identify the risk in the first place, risks that are not recognised cannot be considered as part of the risk management process (Smith, et al., 2009). These statements make it clear that without effective methods for identifying the risks that could affect the project, the project will not only fail to mitigate these risks, which could bring about all of the consequences discussed above, but also these unidentified risks have the potential to be repeated on future projects.

If risk identification is key to any risk management process, how the construction industry currently undertakes this exercise is very important. The literature suggests that the most common approach for the identification or assessment of project risk is gathering key project personnel together to undertake risk identification sessions. Smith, et al. (2009) state that personnel will discuss in groups or as individuals and determine the project risks. One issue with this method is that individuals may bring bias to the risk analysis and the results, so it is important to minimise this bias by ensuring that sufficient numbers of people are involved in the process (Smith et al., 2009). Within construction almost all companies rely on intuition/judgement/experience to manage their risks (Akintoye & MacLeod, 1997).

The individuals tasked with carrying out the risk identification activities may include project team members, project manager, risk management team (if assigned to the project), subject matter experts (from outside the project team) and clients (PMI Project Management Institute, 2013). It should be noted that the previously mentioned personnel are key to risk identification, however all project team members should be encouraged to identify potential project risks (PMI Project Management Institute, 2013).

Within the risk management process there are a number of documents, including Project Management Plans, Risk Management Plans and Probability and Impact Matrix. However the core document in the risk management process is the risk register (Weaver, 2008). This register is where the results of the risk analysis and risk response planning are recorded (PMI Project Management Institute, 2013). During the lifecycle of the project the register will be managed and updated to ensure it reflects the risks at different project stages. For the risk register to bring value to the project team it must contain the correct data categories that highlight all aspects of the risk (Ehsan et al. 2010).

2.2 LEGACY/HISTORIC DATA USE WITHIN CONSTRUCTION

There is much recognition of the untapped value of historic project data to identify and manage risk Smith et al., (2009) state that “The examination of historic data from previous, similar projects helps to utilise corporate knowledge.” But also that “*An organisation may not have carried out a similar project, or the data from a previous similar project may not have been recorded…..Database systems that actively manage and report the progress of projects may be a useful source of information. However, such systems are often limited in terms of the usable or relevant data being stored*.”

Wood & Ellis, (2006) go further and state that facts and statistics utilised for risk assessment do not include much use of historical or recorded data from previous projects. There is also a recognition that this is a missed opportunity, as stated by Lyons & Skitmore, (2003).

2.3 UPTAKE OF MOBILE DATA COLLECTION APPLICATIONS

The use of mobile technology to capture and manage site information, such as quality and Health and Safety records, has increased within the construction industry. Sattineni and Schmidt, (2015) comment that the use of mobile devices during different stages of a construction project is on the increase, then going on to state that the construction industry has taken a large stride forward with companies accepting mobile devices and deploying them on construction sites. In a survey conducted by KPMG International, (2016), a high percentage of contractors and owners were either deploying the technology on selected projects or on all projects.

2.4 RISK PROCESSES IN OTHER INDUSTRIES

Within some other industries the concept of risk analysis using large amounts of historical data or as it is known “big data analytics”, is well established. Infragistics.com, (2017) state that within these industries the insurance industry is currently perhaps the most advanced data driven industry, with each business group of an organization producing a unique set of complex data. This data can include policy sales, claims, and payouts. With this level of data available, equations can be created that enable analysis of trends to set premiums and monitor fraud and risks. The extent to which the insurance industry has advanced the analysis of historic data to inform risk is demonstrated by Russom (2011) who state that “insurance companies use text analytics to parse the mountains of text that result from the claims process, turn text into structured records, then add that data to the samples studied via data mining or statistical tools for risk, fraud, and actuarial analyses". In the same way, the construction industry may be able to create a workflow to take data relating to project issues, and structure it so that it can be analysed more effectively.

3. Methods

The literature review indicated that current risk identification practice might be a subjective process, which could lead to unidentified or non-prioritised risks due to lack of experience. The research sought to establish this extent, and gain insight into possible routes to improvement using mobile and legacy data, including identifying the essential elements of a risk register. Data collection was conducted across the industry sectors as follows:

Phase One. Questionnaire. An online questionnaire, using Google Forms sent via hyperlink to identified industry professionals, and distributed more widely to specialist BIM groups using Linked-in. These established a wide spread of industry positions and experience of risk processes, and then sought details of current risk management practices.

Phase Two. Interviews. Conducted with individuals with specific experience relevant to the subject matter, identified prior to Phase One, or as a result of their responses to questionnaire. The results were analysed using a Grounded Theory mind map.

Phase Three. Observations. Conducted on risk workshops for three projects. An analysis of the relative importance of each activity measured through time spent on this as a percentage of the whole exercise.

Phase Four. Secondary Data Collection. Examples of Risk Registers from six AEC organisations. Analysed for commonality using Grounded Theory.

Phase Five. Statistical Data analysis using ANOVA test. An ANOVA test is a method to investigate if survey or experiment results are significantly different to each other (i.e. there might also be a relationship between them and not random results). This will help rejecting an initial null hypothesis put in place (that there is a relationship between 2 or more factors) and accept the alternate hypothesis. In ANOVA, groups are tested to find if there's a difference between them (Cuevas et al., 2004). If the resultant p-value of conducting the ANOVA test is <0.05, then this means that less than 5% of the data can be attributed to random results between the variables and hence there could be a significant difference between the results (refuting the null hypothesis) and hence maybe a correlation between the variables tested. This test is used and explained subsequently. An example of using ANOVA test:

- A contractor has two different processes to make concrete. They want to know if one process is better than the other in reducing time.

4. Data Analysis and Results

The points highlighted below summarise the key findings from the literature review and the data collection phases. These findings formed a significant part of the development of the risk framework proposed in this study:

- The literature review emphasised that the construction industry is particularly exposed to risk whilst the interviewees all stated that their organisations placed a high level of emphasis on the reduction and management of risk. This indicates that the construction industry is likely to be receptive to a new development that facilitates better risk management.
- The construction industry relies heavily on the use of meetings/discussions to identify risk – see Figure 1 below.

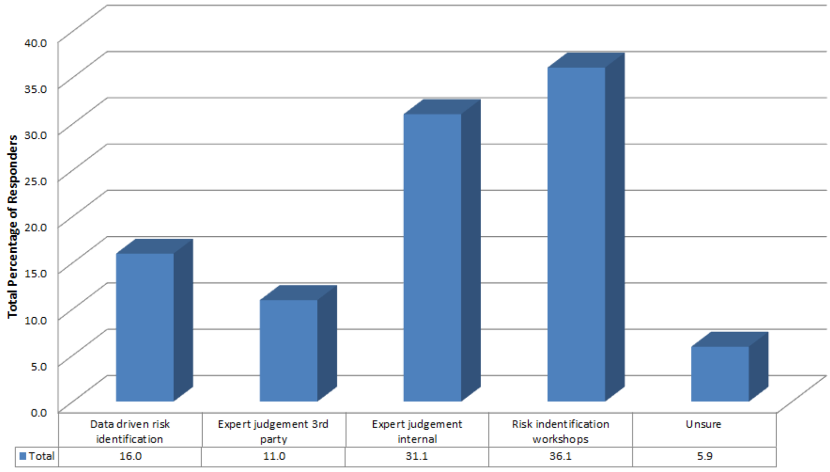
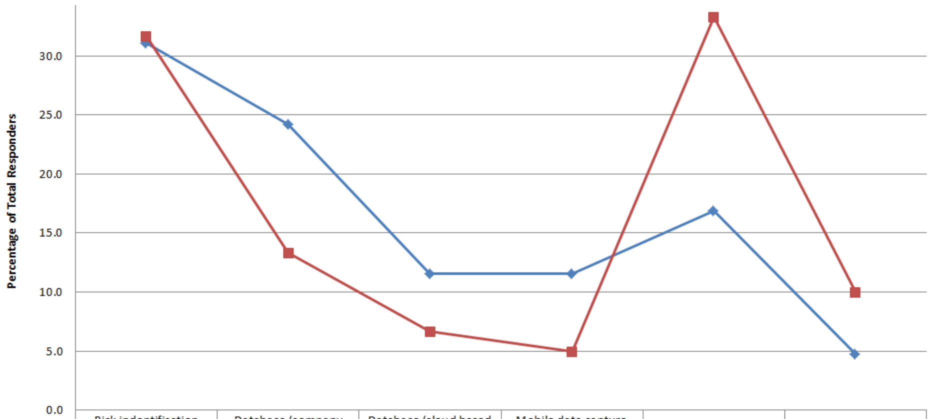


Figure 1: Methods used to Identify Project Risks within organisations

The proposed framework will supplement the risk analysis process through the use of historic mobile data thereby reducing the potential for mistakes through subjectivity or lack of experience. It is not intended to overhaul a system in widespread use, but rather to supplement the current system with the addition of a new source of data, as this will not require as much change and allow transitioning as opposed to implementing a new system.

- Although there is an increasing use of mobile data capture devices in the AEC industry as detailed in the literature review, currently only 22% of respondents stated that collected data comes from mobile applications, and only 15% of respondents stated historical data which is analysed comes from mobile applications; meaning that the data captured is not exploited to a great extent to add value to risk processes as they are in other industries, particularly the insurance industry. It is intended that introduction of the proposed framework utilises existing mobile data for the purpose of risk analysis. To be effective data needs to be well structured and accessible. This should increase both the level of data captured and its use as a risk management tool. Techniques from the insurance industry were considered to assess where they could add value to the framework.

- Larger organisations (those with more than 500 staff) tend to store data in more sophisticated databases than smaller organisations – see Figure 2 below. Added to this is the fact that those organisations, which store historic data in sophisticated databases tend to utilise this more for risk analysis than those where it is stored in less sophisticated paper-based or spreadsheet formats – see Figure 3 below. In designing a new framework, concentration on ease of use is likely to particularly benefit these smaller organisations/projects.



	Risk indentification workshops	Database (company server based)	Database (cloud based server)	Mobile data capture system	Spreadsheet	Paper based system
More than 500 Staff	31.1	24.2	11.6	11.6	16.8	4.7
less than 500 staff	31.7	13.3	6.7	5.0	33.3	10.0

Figure 2: Multi-dimensional Chart showing the Risk Data stored and collected option categories by the size of company.

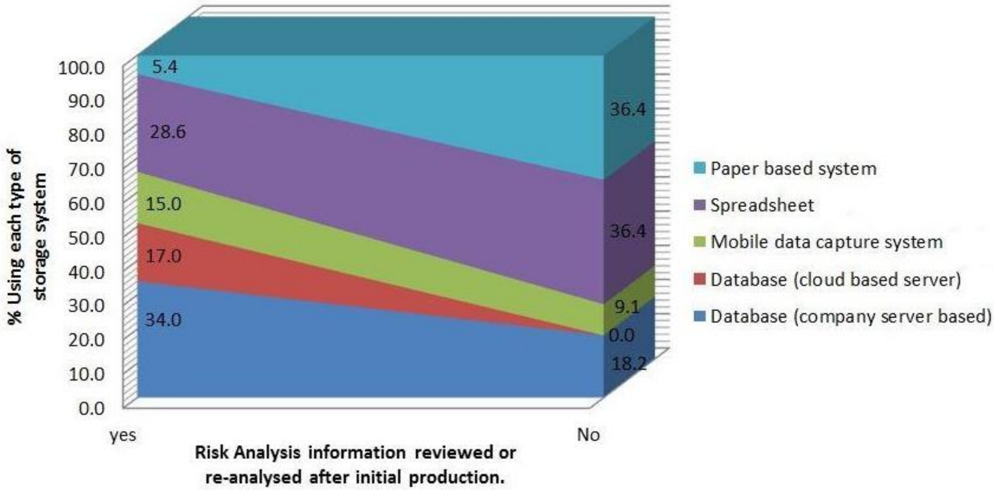


Figure 3: Multi-dimensional Chart showing the Risk Data stored and collected option categories by whether the risk data was reviewed or re-analysed after initial production.

A null hypothesis was assumed for a relationship between the data storage system (a) and whether the risk data was reviewed or re-analysed after initial production (b). To provide evidence for it, an Anova test was undertaken and this demonstrated a p-value of 0.006 which is <0.5. Hence this result refutes the null hypothesis. This suggests that there might be a relationship between the data storage system and whether the risk data was reviewed or re-analysed after initial production, and that the data pattern between them is not random. The reason for this could be or indicate that having data stored in a database with advanced search functionality allows easier analysis because the data is easier to access and manipulate and that the Meta data fields imbedded within the data enable easier categorisation and analysis.

• All phases of the data collection confirmed that the risk register is the primary document/tool for the management of risk. Integration of the risk register into the new framework was a key element of the proposals in order to facilitate adoption of the new process. The application of grounded theory to the collated Risk Registers resulted in the identification of the common items of data needed to manage risk - see Table 1 below

Table 1: Commonly Used Risk data fields

Unique Risk ID Number	Commonly required data fields
Risk Category	
Risk Description	
Risk Ownership	
Risk Creation Date	
Risk Status	
Risk Likelihood or Occurrence	
Risk Impact	
Risk Mitigation Action	
Risk Cost	

- All data collection phases identified that risk management activities were particularly undertaken during the earliest stages of a project. The new proposed framework should be able to evaluate risk through the earliest stages.
- All interviewees and workshop observations noted that risk processes currently involve senior staff. Mention was made in interviews and the literature review that this would benefit from input from team members at all levels. Given that data capture is undertaken by all site team members using mobile tools, the proposed framework involves all levels within a project team considering and having input to project risk.
- In order to ensure that this framework does not involve additional workload, all proposed data and processes were streamlined and combined with those existing.

5. Proposal

To reduce the amount of input required by the site teams and to provide the best chance of the framework being adopted, fields were added to the Autodesk 360 Field project issue definition template – see Figure 4 below. These corresponded to the data items identified through the grounded theory analysis of Risk Registers – see Table 1 above. For the purpose of demonstrating the new framework, sample risk data was created by importing the content of an existing project risk register – see Figure 5 below.

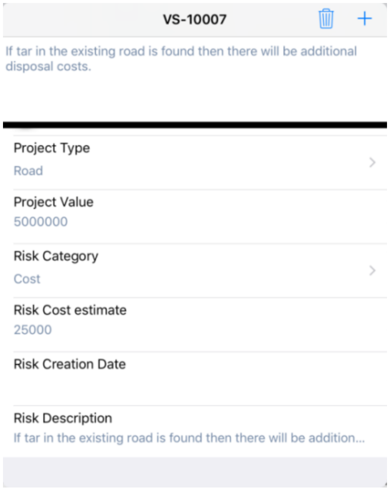


Figure 4: Proposed Mobile Data Capture Risk issue Sample (shown from IPad application).

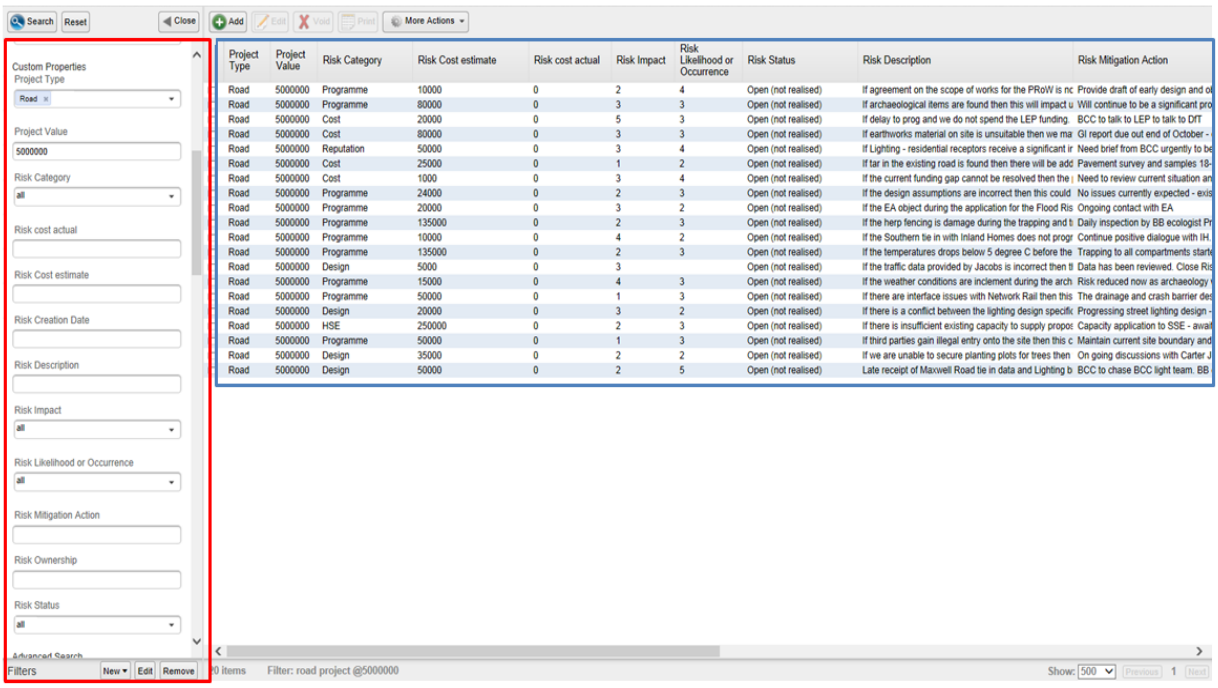


Figure 5: Proposed Mobile Data Capture Risk Analysis Framework - Example of Autodesk 360 field on the Web Browser Interface (Internet Explorer).

The addition of these fields, including the text fields allow for the utilisation of data already in existence, applying appropriate search filters to find risk trends and highlight risk areas. Whereas the ability to search for key words within a database is not a new function, the framework data structure, with the use of risk specific text data fields ('risk description' and 'risk mitigation action') provides a potentially powerful technique to allow for key-word search in a similar way to the insurance industry undertakes data-mining. This will become more powerful as the historic data within the database is expanded. With the introduction of this framework, smaller companies/projects could benefit by having a new source of historic data for the analysis of risk.

5.1 FRAMEWORK WORKFLOW

At the first stages of a project the initial risk meeting would involve a search of the data contained in the risk framework database (e.g. Autodesk 360 Field Cloud) based on project parameters, such as the 'Project Type', 'Project Cost' and 'Risk Impact' fields. By defining the required project parameters it is possible to focus the search to the risk items that are specific to the current project requirements. The Excel based risk register was identified as the most commonly used tool, therefore the completed search will generate a new project specific Excel spreadsheet risk register by exporting the search data from the mobile data capture application using the in-built export functionality within 360 Field, this project specific Risk Register will be added to and improved during all subsequent project stages. This risk framework search and risk register export could form the starting point for the on-going risk workshops.

As required, a project will, during later project stages as more information becomes available, increase or change the search fields to focus better on specific requirements enhancing the project risk register as necessary. As the project proceeds, the risk register is developed by the Project team with any new items that are documented, either through a newly identified risk, or an issue being recorded using 360 Field. These items will be manually validated by project team members with relevant experience (e.g. Risk Manager, project manager or Quantity Surveyor). Although validated by senior staff, this connection to 360 Field issues involves site staff at all levels in risk management processes. As shown in the Framework Workflow Diagram Fig 6, these new risk entries will be fed back into the cloud database to increase the effectiveness of future searches. In this way a potential for systemic continuous improvement is created.

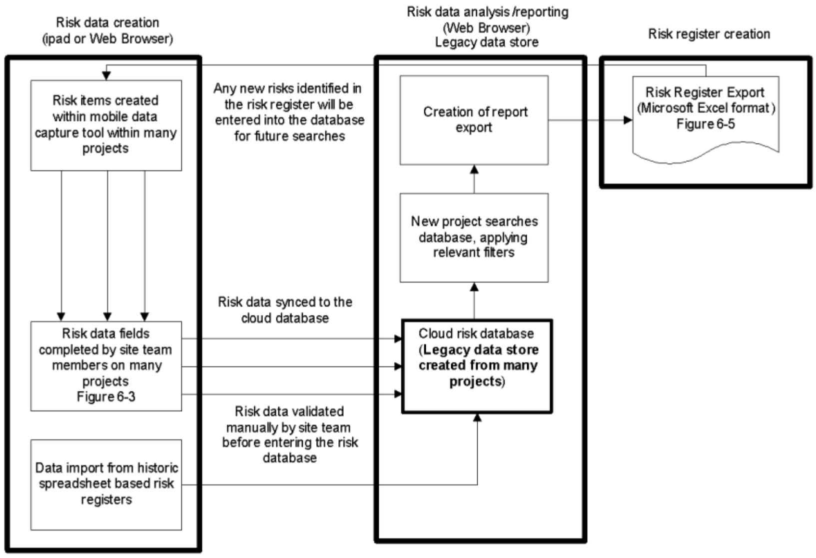


Figure 6: Workflow Diagram for the Mobile Data Capture Risk Analysis Framework.

6. Conclusion

With ever more sophisticated technology available, the construction industry is constantly updating its processes. As better, more thorough and efficient practices are possible, risk management cannot be left behind. Indeed, the evidence regarding accidents, cost and programme over-runs indicate an existing need for improvement. The capture of mobile data on legacy construction projects means that there is an untapped pool of data which should be considered for analysis. This work could be taken forward and developed in future using other data sources such as Cost Management Plans and Quality Management Plans.

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DEVELOPING AND EMBEDDING A BIM CURRICULUM IN BUILT ENVIRONMENT COURSES, THE RGU EXPERIENCE

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Abstract. Among The ambitions regarding BIM uptake across the built environment sector in the UK and arguably beyond may be tempered by a realpolitik shaped in part by interactions between Higher Education (HE) and professional practice. In September 2013, Education for the Built Environment (E4BE) was constituted as a strategic UK industry group by the Construction Industry Council (CIC) and Construction Industry Training Board (CITB). E4BE's strategic remit was to encourage professional institutions to extend their engagement with HE in collaboration with other stakeholders to add value to Higher Education's contribution to industry.

The BIM Academic Forum (BAF) comprises around 50 faculty members from UK universities and was formed to promote academic aspects of BIM, in particular, a "BIM Academic Framework". (HEA, 2013) BAF's articulated vision was to embed BIM learning within undergraduate and postgraduate Higher Education. BAF published an academic framework indexing BIM skills, knowledge, competencies and capabilities together with learning outcomes for BSc and MSc education levels in the UK.

In 2014/15 this framework, combined with research on international BIM curricula development, was used to develop a strategy to integrate collaborative BIM in the curriculum of all BE courses at RGU to be implemented over a 4 year degree cycle. This paper focuses on 4 key areas, namely:

- Presenting the BIM curriculum strategy, its rationale within the context of 4 professional accredited programs
- The implementation strategy of this curriculum to date and lessons being learned
- Reporting on 2 multidisciplinary collaborative BIM projects including feedback from tutors and students

- Presenting the outcomes of a survey conducted as part these 2 multidisciplinary projects focused on multidisciplinary collaborative working through BIM.

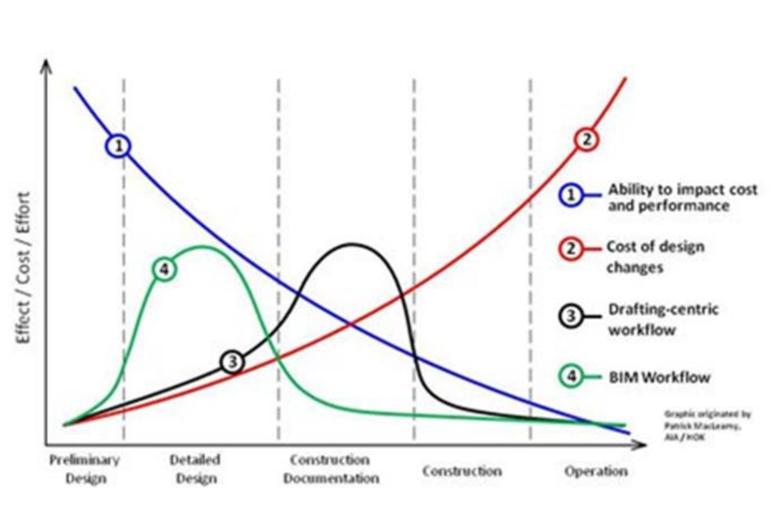
Keywords: Curriculum, BIM, Multidisciplinary, Collaboration, Workflow, Data.

1. Introduction

When this project was initiated in 2013 the debate on Building Information Modelling (BIM) had been steadily growing over the previous few years, especially following the British Government's intervention with its BIM Report and Government Construction Strategy (GCS) both published in 2011. The impact of these two documents on the construction industry had been and continues to be significant, and ultimately meant that all public sector spending will be channelled through a supply chain that is compliant with BIM level 2, now a reality. The Bew-Richards maturity diagram defines 'level 2' as file-based collaboration and library management. The drivers behind the Government 'push' are to achieve significant improvements in cost, value and carbon performance, as has been cited by the industry for some time (see Latham (1994), Egan (1998), Wolstenholme, 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. (BAF 2013) The BIM Workflow diagram in Figure 1 illustrates the savings in terms of time, cost, and efficiency of workflow through the design and construction stages of a project. In addition, it is recognised that Higher Education Institutions (HEI) will have to work with professional bodies in addressing new requirements in the accreditation of courses. It is important to note that all BE professional bodies have endorsed this view with the RIBA taking the lead with the new plan of work 2013 mapped against BIM workflows. (RIBA 2013) Since 2013 a series of BIM related standards have been published by the UK and Scottish governments to facilitate full implementation by the 2016/17 deadlines. PAS1192 versions 2,3,4,5 are examples of these standards to govern project data within the context of BIM and whole life cycle of an asset.

Since the publication of its construction strategy report in 2011, the government has set up a number of task groups to promote the implementation of its BIM strategy. This includes, amongst others, the training and education task group which has representation covering HEI, training organisations and bodies such as construction skills and Construction Industry Council (CIC).

The aim has been to bring together education and training stakeholders to debate how to best support upskilling and industry graduates of the future.



-Better ability to impact cost and performance
-Solving potential construction issues at design stages
-Potentially seamless collaboration
-Better workflows and project documentation
-Better communication

Figure 2. BIM v traditional workflow

2. Context

The Scott Sutherland School of Architecture and Built Environment (SSSA&BE) is one of few schools in the UK where most of the Built Environment (BE) disciplines are taught side by side sharing both human and physical resources. The question of Interdisciplinary teaching has been debated for a long time and occasionally attempted but with little real lasting effects. The debate remained theoretical, limited to some shared teaching, and largely a wish arguably reflecting the state of the BE professions.

In 2013/14 part of the preparation for its 5 yearly Institution Lead Subject Review (ILSR) coupled with the forthcoming move to a newly purpose built accommodation, the school decided to put multidisciplinary collaborative teaching on the agenda as one of the main goals. A key parameter used to drive the structure of the debate and guide the outcomes was that each discipline taught should maintain its identity and professional integrity. Any multidisciplinary curriculum would be implemented on a collaborative basis to add strength to each discipline and enhance the relationship between the disciplines.

The ongoing debate, nationally and internationally, on BIM coupled with the recently implemented UK government legislation have lead most education institutions to rethink at least the relevant parts of their BE courses curricula. The objective is to explore how to integrate collaborative BIM in their curricula. Given the importance of the impact on both teaching and graduate employability, the debate on multidisciplinary collaborative teaching has used BIM as a catalyst to try to achieve tangible outcomes and respond to the needs of the professions and the market in the spirit of breaking the silos and increase collaborative working. This project is driven by the following objectives:

- Collaborative working as an industry goal
- Government legislation mandating collaborative BIM from 2016/17
- Buy in by all relevant professional bodies
- Keep up / lead in ICT/BIM understanding and skills
- Tangible results that are meaningful to our courses and graduates

3. Mind the Gap: BIM implementation strategy and course curricula

3.1. BIM AND THE PROFESSIONS

The BIM Framework, a collaboration between the Higher Education Academy (HEA) and BIM Academic Forum (BAF), published an index of BIM skills, knowledge, competencies and capabilities with the endorsement of all BE professional bodies. (Fig. 1) The operation category's focus is on learning the necessary skills to operate collaborative BIM software; developing awareness and data file exchange standards. The management category's focus, however, is on professional and middle management issues to include BIM awareness, collaboration, standard methods and procedures, value and industry challenges. All these points could be easily described as of a multidisciplinary nature as they cut through professional boundaries.

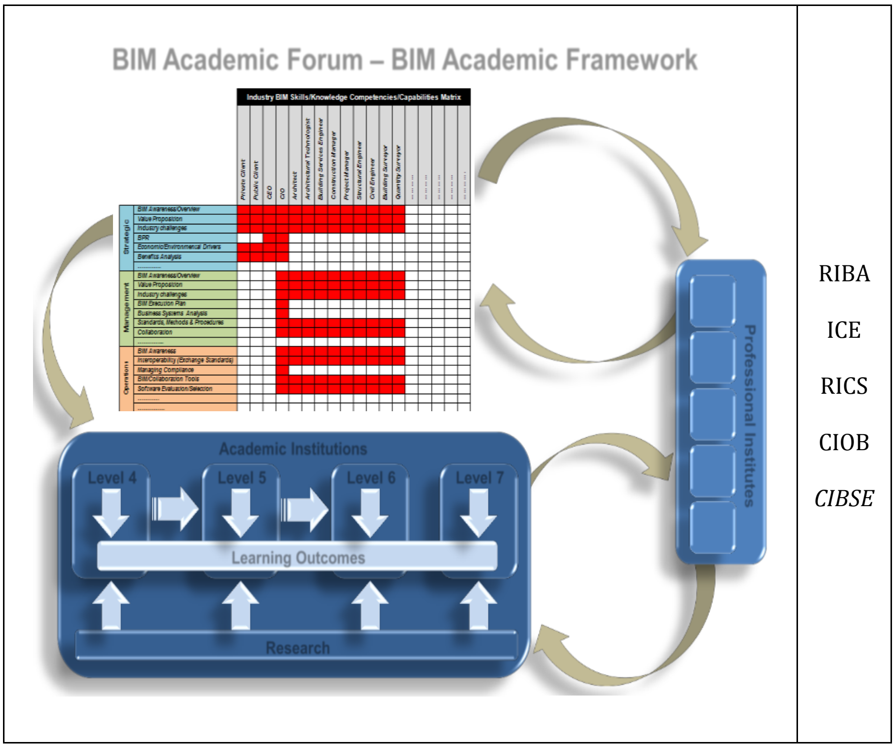


Figure 1: BIM Academic Framework

A quick examination of SSSA&BE courses revealed that they all fall under the operation and management categories, the former for the lower years (1 to 2-3) and the latter for the upper stages (3-4 to 5). In session 2013/14 Architecture and Architectural Technology (AT) students largely met the operational category and were taught the software skills with a good degree of application in the first 3 years of their respective courses. Surveying and Construction Management (CM) fell short on these skills. Overall awareness was very briefly introduced with limited theoretical underpinning and hardly any instructions were provided on data exchange and interoperability. BIM awareness was covered at an introductory level on AT and Architecture courses. Industry challenges were invariably covered by all courses at varying degrees in a number of Professional Practice and Management modules.

3.2. BIM TEACHING STRATEGY AND IMPACT

The IT tools and CAAD skills taught within the various curricula at the SSSA&BE in 2013/14 are summarised in Table 1.

TABLE 1. IT / CAAD provisions in 2013/14

Tools	**Theoretical underpinning**	**Year & Course**	**Modules**
Introduction to IT and basic software (AutoCAD 2D /Photoshop…)	Yes (basic)	Surv1 / AT1 / BS1 / Arch 1	Scholarship skills I. Studies (AT) Intr. To B. Design
Revit	Minimum	AT2 / Arch 2	Design Studio I. Studies
Environmental Analysis software: IES / SAP / Green studio… (2D, 3D)	Yes (limited)	AT2 / Arch 3 AT3 / AT4	I Studies Design Studio
Construction Management software (2D) Asta Power Project	Minimum	QS/BS 4	Project Management I Studies
Surveying estimating software (2D) BCIS	Minimum	Surv2 / Surv3	Bill of Q
Introduction to BIM	Yes (basic)	Arch stage 6	P Practice & Management

It is apparent that the tools taught have a direct correlation to the area of the curriculum within each discipline e.g. Autodesk Revit for AT and architecture, BCIS for surveyors and Asta Power Project for Construction Management etc. This correlation can be interpreted as singular in that it only focuses on the discipline and very little is done cross-disciplines such as an integrated module or integrated delivery of these skills. Information gleaned from course leaders and tutors suggested that although the practical skills are being taught, the relevant Knowledge and understanding is in need of major improvement. For example, the shift from AutoCAD to Revit was implemented in 2009 but very little if any lectures on BIM and the wider context of 3D modelling and data management were coherently taught. Limited teaching using some aspect of collaborative BIM had been attempted by the AT course.

4. Bridging the gap: strategy and Impact

The methodology used in this project was based on a number of sources of information and tools of analysis both internal and external. Focused discussions with course leaders and key teaching staff were used to glean discipline specific information and explore the concept of collaborative learning from each discipline's view point together with aspirations and most appropriate methods of delivery. Literature sources were used to provide context, legal framework, professional bodies' requirements and professional practice trends in the area of BIM and associated skills.

BIM curriculum and associated mapping and impact assessment tools developed by BAF in association with HEA were used as a guide to assess current provisions and future requirements within the school.

Table 2 uses the HEA Index to map the impact of the proposed BIM curriculum on current and target provisions within the school. Yellow indicates a level either already achieved or could be easily achieved by all disciplines in the School. Red, however, indicates the level to be attained by all disciplines within the next 3 years to meet the target date of government BIM mandate (2016/17).

The impact on curricula in 2013/14 was minimal in the first instance and any minor adjustments could be accommodated with existing IT/CAAD provisions except for Surveying and CM. The latter courses needed to be brought up to the minimum threshold already achieved by AT and Architecture. To meet the BIM level 2 target, however, substantial adjustments needed to be done to key modules which may include embedding assessments in projects, delivery of a knowledge and understanding programme and practical interdisciplinary sessions. Course structure was not affected except minor key module adjustments of teaching plans or instruments of assessments. The biggest impact identified was on staff development and IT infrastructure. The curriculum research gap was found to be adequate within the school as many research active staff in this area were already embedding most of their research into teaching, mostly at master level (MSc courses).

TABLE 2. BIM Teaching Impact Index 2013/14

	BIM Level			
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	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.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should be enabled by the BIM model.

Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.
Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
Staff	No change	Staff in the key modules will need an understanding of BIM and how it impacts on industry.	All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.	All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.
Infra-structure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery
Yellow: current status Ref: Williams and Lees, 2009		Red: to be reached by 2016/17		

5. Making it work: implementation and other stories

BAF/HEA published a level learning mapping of a BIM curriculum that would meet the requirement of level 2 BIM and beyond. This mapping was utilised to map SSSA&BE disciplines provisions in 2013/14 (Table 3) indicating levels already being met and any deficiencies. It also suggested the method of delivery, method of application / assessment and the vehicles of delivery. Collaborative teaching was also highlighted where applicable.

It is clear from this mapping that only the practical skills (green font) were being taught with some minor shortfall at upper stages. The practical skills (red font) were not delivered in any coherent manner although some disciplines may have covered some aspects in isolation within particular modules. Knowledge and Understanding (red font) was also not taught in any coherent way also the concept of collaboration may have been applied elsewhere such as group work but within the same discipline.

The delivery vehicles column (blue font) identified the modules within each discipline where teaching could take place including common teaching. It was identified that within these modules that collaborative links could be achieved through theoretical lectures, skills workshops, projects and integrated assessments.

TABLE 3. Mapping of BIM curriculum

Level	Knowledge and understanding	Practical skills	Transferable skills	Delivery vehicle
4/7	***Undergraduate***			
	- importance of collaboration - the business of BIM -common lecture	Introduction to technology used across disciplines -AutoCAD/Revit/ Photoshop workshops	BIM as a process/technology/ people/policy - A common lecture with a workshop collaborative task	- Communication skills module (BE) - IT workshops (All) - Design studio (Arch)
5/ 8-9	-BIM concepts & construction processes -stakeholders' business drivers -supply chain integration - Series of lectures to accompany workshops	-use of visual representation - BIM tools and applications - attributes of a BIM system - Revit workshops for all courses	- value, lifecycle and sustainability - 'software as service' platforms for projects - collaborative working - communication within interdisciplinary teams - short inter-disciplinary collaborative project -Application in a project	- Design studio - Design Technology - Bills of quantities - Environment and Services
6/ 10	-BIM across the disciplines -contractual and legal frameworks/ regulation -people /change Management	Technical knowhow: -structures and materials -sustainability -Application workshops: -Environment assessment software - Costing software	Process/management: -how to deliver projects using BIM -information and data flows -BIM protocols/EIR - Lectures followed by an interdisciplinary	- Design studio (Arch stage 5) - Design Tech / Int. studies (AT & BS) - QS?

	- A series of lectures on topics with demonstrations	- Modelling	project using a central/federated data model	
Colour coding: - Black font: BAF / HEA mapping - Red font: method of delivery & method of assessment (partly/not met) - Green font: Delivery being met or could be easily met next session - Blue font: vehicles of delivery (modules) where learning could be embedded. - Level: English and Scottish education levels				

The above mapping of the school's undergraduate courses curricula together with an assessment of physical and human resources culminated in a BIM curriculum proposal which was approved by the school for implementation. Knowledge and Understanding, Practical Skills and Transferable skills were mapped against methods of delivery, course relevance and vehicle of delivery as illustrated in Table 4.

TABLE 4. Summary of proposed curriculum

Year		**Delivery method**	**Program**	**Delivery modules**	**Observations**
1	Knowledge & Understanding	shared lecture on: - importance of collaboration - the business of BIM	All	Communication skills module - Design studio (Arch)	
	Practical skills	Existing AutoCAD/ Revit/ Photoshop workshops on: -Introduction to technology used across disciplines	All	- IT workshops (All)	
	Transferable skills	A common lecture with a workshop collaborative task on: -BIM as a process/ technology/people/ policy	All	- Design studio - Intr. to B Design	
	Knowledge & Understanding	- Series of lectures on -BIM concepts -construction processes -stakeholders'	All	Part of Revit workshops	
	Practical skills	Revit workshops		- Design studio	Customised tasks within

2		-use of visual representation -BIM tools and applications -attributes of a BIM system	All	- Design Technology - Integrative Studies - Environment and Services (IES)	the relevant module for each discipline
	Transferable skills	A short interdisciplinary collaborative project -collaborative working -communication within inter-disciplinary teams	All	- Design studio - Design Technology - Integrative studies	
	Knowledge & Understanding	Lecture(s) on: -business drivers -supply chain integration	All	-Management -P Practice	
3	Practical skills				
	Transferable skills	-Application in a course specific project -'software as service' platforms for projects -value, lifecycle and sustainability	All	-Design Studio -Integrative studies	
	Knowledge & Understanding	A series of lectures on topics with practical demonstrations -BIM across the disciplines -contractual and legal frameworks/ regulation -people /change Management	All	-Integrative studies -Building Technology -Design Studio (Tech support)	
4/5	Practical skills	Advanced application workshops on - Environment assessment software - Costing software - BIM Modelling on Technical knowhow: -structures and materials -sustainability	All	-Integrative studies -Building Technology -Design Studio (Tech support)	Customisation by discipline to provide context to each course
	Transferable skills	Lectures followed by an interdisciplinary project using a central/federated data base to demonstrate: Process/management:	All	-Integrative studies -Building Technology -Design Studio (Tech support)	An elective may be used for advanced learning of BIM process

-how to deliver
projects using
BIM
-information and data
flows
-BIM protocols/EIR

	Colour coding: - Black font: BAF / HEA mapping - Red font: method of delivery & method of assessment (partly / not met) - Green font: Delivery being met or could easily BE met - Blue font: vehicles of delivery (modules) where learning could be embedded.

A colour coded tracking methodology has been used to monitor progress of implementation over the last 3 years as summarised in Tables 5. Green indicates over 90% completion, yellow over 50% completion and red not attempted as these levels are perceived as not appropriate to non-BIM dedicated courses and will have a detrimental effect on professionally accredited course if fully implemented.

TABLE 5. BIM Teaching Impact Index 2016/17

BIM Implementation level: 2016/17				
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	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.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should enabled by the BIM model.
Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.

Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
Staff	No change	Staff in the key modules will need an understanding of BIM and how it impacts on industry.	All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.	All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.
Infra-structure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery

Yellow: over 50% complete   Red: Not started for strategic reasons
Green: over 90% complete
Ref: Williams and Lees, 2009

As of 2016/17 the level of BIM Curriculum implementation may be summarised as follows:
- All courses now complete a minimum threshold of Revit training including BIM awareness
- All courses complete a practical skills in data and file manipulation / management within a central model
- 2 BIM modules (BIM theory and BIM Practice) are delivered at postgraduate level to achieve awareness and application of level 2 BIM
- 50% of staff have full BIM awareness and practice BIM partially within the context of their discipline
- Investment in hardware and software completed to level 2 BIM requirements and further investments still needed for level 3 and beyond
- Integration of BIM level 2 knowledge and Understanding within Professional Practice and Management modules is complete

- BIM process management theory is delivered where appropriate but application remains an ambition.

6. The common thread: collaboration, collaboration, collaboration

This section summarises 2 BIM multidisciplinary projects carried out over the last 2 academic sessions part of the implementation of the new BIM Curriculum seeking collaborative learning amongst the various BE disciplines.

6.1 BIM COLLABORATIVE PROJECTS 1 AND 2

The aim of these 2 short projects was to start developing collaborative working skills through BIM in anticipation of UK/Scottish government legislation and to reflect ongoing changes to work practices in the BE professions. These pilot projects were run over two consecutive academic sessions 2015-16 and 2016-17 to test how it could be inclusive of all cohorts. The projects were open to a selection of students from the 4 disciplines within the school to work in groups on an existing BIM model. Each group had to undertake a number of tasks including making design/construction decisions then incorporating them into a central model. The tasks per discipline were as follows:

Architecture team (years 2 & 3): redesign the external envelop (facades, roof) of the building i.e. materials, colours, textures; redesign the landscaping of the site including access, green and hard surfaces, steps, ramps, etc.

Architectural Technology (years 2 & 3): Procure new doors and windows (both internal and external) to improve the thermal performance of the building, carry out an energy assessment of the building, and carry out a lighting assessment.

Surveying and Construction Management (years 2, 3 & 4 AT in a supporting capacity): embed unit cost in the following materials/ components: doors, windows, furniture; using the 3D model produce a material schedule of the above components.

A workshop was designed to host 20 interdisciplinary students to collaborate on one project; the project was modelled to an extent using Revit. The workshop started by briefing the students on the workshop aim and objectives, the organisers gave a short talk about collaboration and BIM, what are the benchmarks of UK industry with a rough plan for the workshop.

Then students were asked to work in groups of 5, each group has a title of Architecture, Architectural Technology or Surveying. Each group has to achieve a specific task. Each group worked on one model, and then at the end of the workshop the models were merged and presented to the students with a brief discussion on the result, their experiences and technical difficulties.

6.2 STUDENT SURVEY AND FEEDBACK

Each BIM project programme included a student staff feedback session then followed by a questionnaire to all participating student. A questionnaire was designed to ask participants to reflect on their specific experience within their group and other groups.
A summary of the feedback is given below.
Student feedback

- All students enjoyed working in a collaborative multidisciplinary groups
- Architecture students identified their lack of practical experience using BIM models and would like a practical element be embedded in their design studio projects
- AT students seemed to some extent familiar with the practicalities of BIM software but struggled with performing environmental analysis due to network failure in the first iteration due to firewalls
- Surveying students were to a disadvantage since only recently they had started learning Revit/BIM software but with the support year 4 AT they saw the relevance to their disciplines
- Stage 4 AT had sufficient expertise to help all other students and staff set up the protocols of the collaboration
- All students agreed that similar projects should be repeated and extended to bigger cohorts.

Staff observations

- An experienced BIM coordinator (AT graduate)
- The project was a good taster for a limited number of students
- Students had, in the first iteration, very limited awareness of design management, BIM standards and protocols. In the second iteration, better understanding was clear and a number of students, particularly AT and Architecture, had a handle on basic BIM protocols such as synching of models and federated model rights
- The University IT network had major technical limitation in setting up a Common Data Environment (CDE) in the first iteration. In the second, however, with the support of IT engineers who created a special area on a University server and modification to access rights and security set up, the BIM project run smoothly.
- Limitation of staff expertise in the practicalities of BIM i.e. setting up protocols and manipulating project data in the first iteration which were remedied by an external BIM coordinator in the second iteration.

7. Post-Workshop Questionnaire

A BIM multidisciplinary project questionnaire was designed to understand the academic context whereby three multidisciplinary groups of students used BIM workflow in order to reflect back on their experience despite the fact that BIM was not an integrated part of their project model as yet. The questionnaire was structured into two main sections; the reflective part, and the active part of experiencing BIM.

7.1 FINDINGS

The reflective part focused on the workshop advantage and disadvantages by asking them multiple questions. Students agreed that the main advantage of such workshops was having a better understanding of how Revit (3D modelling software) would work with multiple users simultaneously.

Most of the students agreed that the workshop's disadvantages were mainly: its (short) duration, intensiveness in terms of its tasks, new software program for some, and technical and network constraints. It is possible that the students' prior knowledge of Revit detracted them from the collaboration aspect. Conversations were mainly focused on how to complete certain tasks rather than using the model for designing or testing ideas.

The participating students responded that their working flow they had used was mainly influenced by the studio tutors (22%), equally influenced by their personal skills (19%), and studio skills (19%). They were also equally influenced by their own approach to BIM (16%), and the type of task undertaken (task characteristics) (16%), with less influence from the systematic evaluation of the model (5%), or any previous placement skills (5%).

The participating students' answers revealed that using BIM workflow was useful to them in looking at more than one aspect (options) of the task and collaborating with other students more effectively (23%). Speeding up the systematic evaluation of their group work (16%) and looking at more than one way or method to solve the task (16%). However; overcoming the design task uncertainty and prompting peer learning (11%) contributed poorly.

Revit experience influenced one or more of the following design tasks. It has influenced the way students communicate through design (27%), the way they document design solutions (19%), the way they make decisions (19%), and the way they solve design problems (19%), nonetheless; some of the students indicated that using BIM workflow influenced the way they think about design (16%).

Most importantly, students were asked which way they would prefer to learn BIM. A significant percentage stated that they prefer to learn BIM integrated within their existing courses (37%), with an equal percentage of participating students stating that they prefer the combination of learning BIM within existing courses and within multidisciplinary modules (37%). However; some of them responded that they prefer to learn BIM in an independent training course (26%).

Students' responses were very positive about the workshop and the gained skills; some of them mentioned 3D modelling techniques, energy and lighting assessment through Revit programme without the use of any external (specialised) programs. They also learned about the synchronising of models. The general consensus of the results show that students found the workshop very useful in terms of getting the actual experience of using Revit in a collaborative workflow. Peer discussions were also mentioned as a significant gain that has significantly improved their knowledge.

Finally, the participating students made some suggestions on how to improve and plan for the next workshop. These included more practical hands-on experiences, and to make the outcomes a worthwhile part for the learned skills. Some also suggested having more than one workshop (a number of sessions) across all courses, as they felt that the exercise was short in its nature. The students also mentioned the value of having people from industry who have experience working with collaborative models to guide everyone through the workshop. Other students suggested having more defined tasks with a product library with deep specification, especially thermal properties in order to be ready for an environmental analysis. One other suggestion was to structure the workshop in a way that is similar to simulated practice.

8. Conclusions

The following conclusions are drawn from the various discussions and data presented above. The implementation of a BIM curriculum at SSSA&BE was successful as far as raising awareness of BIM and raising BE students' BIM practical skills to a near level 2 threshold. Courses like Architecture and AT demonstrated better engagement and reached advanced levels of skills and understanding given the design / technical design nature of the courses relative to Surveying and CM. Acquiring a common BIM threshold helped interdisciplinary and multidisciplinary collaborative working beyond these 2 pilot projects, particularly in design studio and integrative studies projects. Furthermore, increased engagement with BIM enabled specialist software such as Asta Power Project for CM, IES for AT and Architecture etc. was noticeable.

Embedding the proposed BIM curriculum fully was not practical mainly due to professional bodies mapping requirement which tended to lag behind their public discourse. However, stepped and contextualised integration across curricula was possible but required adjustment.

Two major difficulties were encountered, namely staff resistance to change and appropriate infrastructure. A good number of teaching staff perceived BIM as another CAAD tool and failed to appreciate its extent both academically and in practice. A BIM CPD programme was devised for staff with less than 50% take up over 3 years. The IT infrastructure obstacles needed to be tackled. First large data, processing power and annual software updates put increased demands on hardware which very quickly started to struggle and needed an upgrade which does not often fall within the replacement schedule of the University nor the high costs involved. Moving beyond level BIM requires serious investment not IT hardware and appropriate IT specialist support both at school and University level.

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A COMPARATIVE STUDY ON THE ENERGY PERFORMANCE OF TRADITIONAL DESIGN PRINCIPLES WITH COMMON REFURBISHMENTS USED IN TRADITIONAL BOSPORUS HOUSES

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Abstract. Traditional Bosporus houses are known for their unique architectural character, comprising different detail solutions for dealing with the harsh micro-climates of the Bosporus. Geographical conditions, such as climate, sun and wind orientations, slope and soil texture; and social conditions which dominate the planning of these houses in different scales. Organization of gardens, rooms, structural systems, window/door openings, materials and furnishings are all effected by the place they are located in. Wooden structural system, many large area windows and shutters are three important traditional passive low energy design attributes of Bosporus houses. Today, in order to better the energy performance of these buildings various methods are used. Implementation of thermal insulation materials in the opaque parts of the walls, usage of double glazing, usage of aluminium roller shutters, are some of those methods. Unfortunately, instead of bettering the passive low energy design attributes, almost all of the new implementations and changes focus on active systems and energy intense materials. Within this framework, this paper is part of a continuing research which aims to question and analyse the performance of the envelope of the original details of Bosporus houses and compare them with new details used for renovations, and reconstruction of the ruined ones. At the end tentative proposals are presented in relation to the refurbishments of these type of houses.

1. Introduction

The Bosporus, with lots of different micro-climatic regions, is a harsh geography for buildings to provide satisfactory envelope performance. One of the significant things about the wooden mansions of the Bosporus is about the surprising performance of their building envelopes. The typical original architectural features of the envelopes are very simple. The opaque parts are made as timber stud walls, the transparent parts are made of single glazed timber windows, and to better the thermal and visual performance a timber shutter are added to the windows. The rooms are individually heated with stoves. To better the heat gains in suitable periods, the area of the windows is kept high and the shutter decrease the heat losses in cloudy and cold days. These briefly explained original details have worked pretty well for over 100 years. But starting with the 1980s, the tremendous increase on the population of Istanbul has also increased the demand for larger and/or better buildings. Hence, although the legislations in Istanbul ban the owners to demolish an original historic building, and promoting the refurbishments of them, instead of refurbishing the original buildings, pulling them down and reconstructing them from scratch became a more preferred option. And as after a certain age timber buildings need careful, continuous, and sensitive maintenance, naturally demolishing the buildings and getting a permission for reconstruction have always been easy for the owners.

Efficient usage of energy is one of the most crucial matters of this time because of the various direct and indirect costs of energy. Energy is a convertible concept, and it can be converted to CO_2 emissions. The embodied energy, which is basically the sum of all CO_2 produced to manufacture an industrial product and it is an evolving criterion for buildings. There are several researches which studies building materials in terms of energy and emissions. For example; Kus, H. et al. studied the embodied energy of masonry wall units regarding manufacturing process (Kus, 2008). Another example is a detailed study of Schmidt, A.C., about rock wool thermal insulation (Schmidt, 2004). The operational energy, which is basically showing the energy usage of an industrial product when it is in use, is another long recognized criterion for buildings. The study of Maile, T. et al. is a good example for operational energy usage in buildings (Maile, 2012). They studied the energy used in a building and compare it with simulated energy usage which was obtained in the design processes. Suleiman, B. M., studied the operational energy usage in buildings using the U-values of the external walls (Suleiman, 2011). The positive effect of insulation materials on the U-values of the external envelopes is significant. Friess, W. A., studied the effect of appropriate usage of thermal insulation on the building's energy consumption (Friess, 2012).

Neither embodied, nor operational energies are enough to assess the environmental performance of buildings. Buildings are complex structures with life cycles. There are also several studies assessing the environmental performance of buildings. The study of Hacker, J. N. et.al. is a good example for these kinds of studies (Hacker, 2008). They studied the embodied and operational CO_2 emissions of housing.

This paper presents an ongoing study about the environmental performance of the original Bosporus mansions and their reconstructions. The embodied CO2 emissions of the typical reconstruction details used for Bosporus mansions of external walls, and windows are being analysed, energy losses from them are being calculated and the data obtained is going to be compared with the data are being calculated for the original building details.

2. Method

The method adopted for this research consist of 3 parts. In the first part detailed literature review has been realized to find out the original and reconstruction architectural details used in the Bosporus mansions. The architectural details found from the literature is supported by the authors long-term site visits to the reconstruction studies realized in the Bosporus since the year 2004. All these acquired information is used to generate model architectural reconstruction details, one for each different type explained in the third part of this study, and model original/historic architectural detail.

In the second part inventory analysis is being realized to determine the embodied CO2 levels of the model details. All the materials used in the unit area of the envelope of the model details are listed and the amount of CO2 produced to manufacture and assemble those materials are listed and the average embodied CO2 values are calculated.

In the third part the U-values of the model details are being calculated. By using the U-values, the yearly heat losses occurring from unit area of different model details are derived.

In the fourth part, the data obtained from the second and third parts are going to be compared and contrasted to determine the best reconstruction alternative in terms of passive low energy design principles.

3. Architectural Style of Bosporus Mansions

Along the Bosporus, there are several former villages, which now expand until each other’s borders, and became almost a whole. The typical geographical specialties of these villages are sloped with trees. Usually a stream in these villages meets with the sea from a small flat space. The typical mansions of the Bosporus are two or three storeys high with wooden structural systems. Because of the sloped topography, there may be a semi basement, which was used to be a storage house for firewood or coal. The semi basement and the footings were built as masonry. The timber superstructures evolve on top of the masonry walls. It has a common living space (sofa) at the centre of each floor and four rooms surrounding this sofa. The front façades, if possible, are usually directed to the Bosporus. Almost all of the mansions have a small garden with some fruit tree. As the villages used to be far away from the urban areas, the clean water grids did not exit. Hence usually a water well and/or an underground cistern connected to the gutters exit.

Figure 1. An anonymous photograph of Bebek village in 1900s.

3.1. ORIGINAL DETAILS OF BOSPORUS MANSIONS

The traditional mansion buildings are built up with load-bearing platform walls having lightweight timber structural system, which can also be seen in particular places around Turkey and the Balkans. The main structural components of the wall system are; posts/studs, bottom and top plates, braces/diagonals, headers and sills for window and door openings. The space left inside the walls are left empty. The roof form is gable with wooden structural system usually having a 33% slope with mission clay roof tiles.
The main façade characteristics of the Bosporus mansions are the large ratio of window openings and the projections on the upper floors. Usually the external wall openings are about 30% of the total façade area, are dominated by the window sizes of two-to-one, and are many in number. The windows are almost always vertical slider type with single glazing and counter balances which are operated with a pulley system. Another common component used in the façade are vertical pivoted timber shutters with two sashes. The louvres of the shutters may sometimes be moved up and down to control the amount of natural light. The openings are usually smaller on the ground floors, because of the privacy needs at that period. When possible cantilevered floors were very popular at the front façade of the buildings, if not possible in the

front façade, cantilevered floors exist on the side or back facades. The opaque wall finishing was wood siding on the exterior side and lath and plaster in the interior.

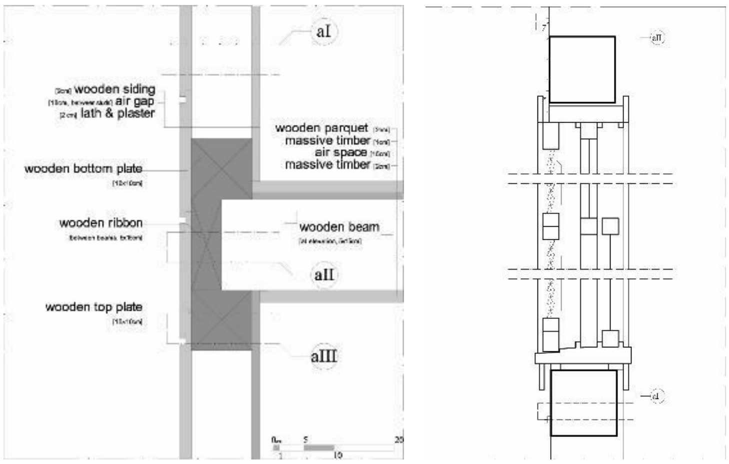

Figure 2. The typical detail of a historic Bosporus mansion.

In figure 2 a typical ruined Bosporus mansion may be seen, the first image gives an idea about the overall appearance of the ruined buildings, and the second image shows the ruined lath and plaster used on the inner surface of the external walls.

Figure 3. A typical ruined Bosporus mansion, exterior view and the condition of the external walls from inside [author archive].

3.2. RECONSTRUCTION DETAILS OF BOSPORUS MANSIONS

There are two different reconstruction alternatives. The first alternative, is realized with reinforced concrete structural system. In these reconstructions, the external wall core was built of perforated bricks or autoclaved aerated concrete blocks. Gypsum plastering was applied internally and a wooden siding externally. The entire facade was constructed similar as the original façade visually, in terms of the type of the main material, which is wood. Double glazed glass, new lock systems, and new counter balance systems were preferred for windows, as the primary differences from the original details. The usage of motor powered aluminium roller shutters are very popular in these alternatives. The structural system of the roof can be made of timber or usually in steel in order the attic to be used. Typical details and an exemplary photo of a building constructed with similar details with this alternative may be seen in Figure 4.

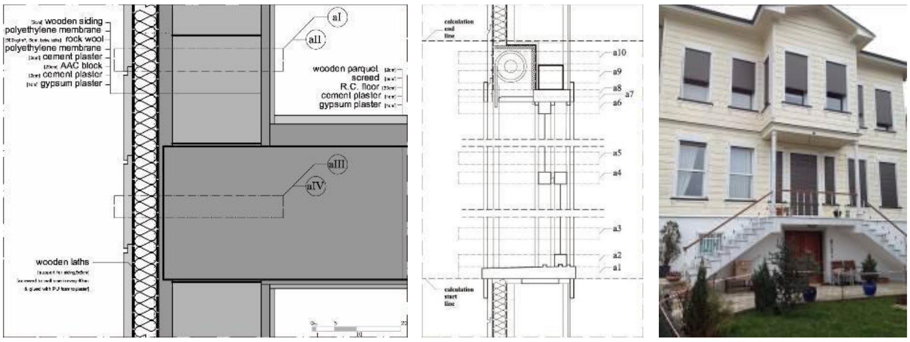

Figure 4. Detail section drawings of; the floor external wall knot, and the window used in R.C. reconstructions.

The second alternative is realized with timber structure. Hence, the details used in this alternative looks more like the original details. The major difference is the thermal insulation placed in between the studs of the walls, and the polyethylene foils. The windows are the same with the first alternative but the instead of aluminium roller shutters original timber shutters are used. Typical details and an exemplary photo of a building constructed with similar details with this alternative may be seen in Figure 5.

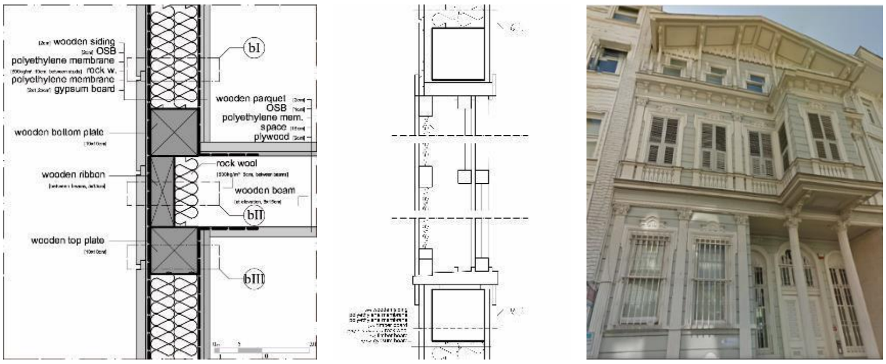

Figure 5. Detail section drawings of; the floor external wall knot, and the window, used in timber reconstructions.

4. Performance Assessment

The performance of the details is still being studied in this research. Below, the assessment method developed for this study is presented and early raw results related with the performance of the original and reconstruction details are presented.

4.1. REVIEW OF THE EMBODIED CO2 OF THE ORIGINAL AND RECONSTRUCTION DETAILS

The total mass of embodied carbon dioxide per unit mass or volume of material is called as the embodied CO2. It is usually expressed as kilograms of CO2 per tonne or m3 of material [8]. Basically it can be said that, if a building material or element has a low embodied CO2, it will be more sustainable. The total CO2 values of all materials used in the original and reconstruction alternatives are examined and the total CO2 released from the external walls and window system will be calculated in this research. The challenging thing about this part of the study is the determination of the unit embodied CO2 values of the materials used in the details. The unit embodied CO2 of the materials used in the details are compiled either directly from the manufacturer’s data sheets or from the most appropriate references. If the embodied CO2 of a material is found different in different resources either the average or the most logic one is chosen. Once all the embodied CO2 values of the materials used in the original and reconstruction details the total value for the unit area of the external walls and windows are going to be calculated. Below the table generated for this study is presented.

TABLE 1. The table prepared to calculate the total embodied CO2 of the unit are of the windows and walls of the original and reconstruction details.

Materials	Density kg/m^3	Emission CO^2e	Original window / wall detail		Reconstruction window / wall detail 1		Reconstruction window / wall detail 2	
			Total Usage	**Total CO^2e**	**Total Usage**	**Total CO^2e**	**Total Usage**	**Total CO^2e**
Material 1								
Material 2								
Material n								

4.2. REVIEW OF THE U-VALUES OF THE ORIGINAL AND RECONSTRUCTION DETAILS

The U-values of the original and reconstruction details are being calculated according to the details given in Figures 2 and 4 and the lambda values obtained from the standard TS825. The challenging thing about these calculations are the complexity of the details. The original wall detail has 6 different parts, the first reconstruction detail has 5, and the second detail has 6 different parts. The U-values are going to be calculated for all different parts and the total average U-values for unit areas of the details are going to be calculated. The windows are even more complex and there are 10 different parts for each of the original and reconstruction details. The effects of the air space between the shutters and the window frames/sashes are calculated according to the standard ISO-10077-2 2012. The equations used to calculate the U-Values are obtained from TS825 and given below.

$$R = d1/\lambda 1 + d2/\lambda 2 + \ldots + dn/\lambda n \quad (1)$$

$$1/U = Ri + R + Re \quad (2)$$

R : Heat transmission resistance (m2K/W)
dn : Width of the material (cm)
λn: Heat conductivity value (w/m2K)
Ri : Heat transmission res. of the internal surface (m2K/W)
Re : Heat transmission res. of the external surface (m2K/W)

5. Expected Outcomes and Results

The expected outcomes related with this ongoing research study can be grouped in two at this stage; the outcomes related with the; embodied CO2, and U-values. Below these outcomes are listed.

5.1. EMBODIED CO2 RELATED RESULTS

The early results related with the embodied CO2 are listed below:

- Structural system components, reinforced concrete and wood are the most CO2e intensive components in both alternatives.
- As concrete (used in aerated, plaster, RC.) is very CO2 intensive the embodied CO2 of the first reconstruction alternative is more.
- Although it is believed at the beginning that the total embodied CO2 emission for the window system with wooden shutters is going to be low, it seems like due to the extra paint used on the wooden shutters they are going to be almost equal.
- The calculations are realized as if the aluminium shutters are manually operated. If automatic/motor powered aluminium shutters are used the embodied CO2 of the system will increase accordingly.
- Wood, water-based paint, double-glazing, and autoclaved aerated concrete are the most CO2e intensive components in both alternatives.
- Paint, is one of the most CO2 embodied material and as more wood is used in the window system with the wooden shutters more paint and so CO2 is embodied.

5.2. U-VALUES RELATED RESULTS

The results related with the U-values are listed below:

- The U-value of the reconstruction alternatives is around 0.5 W/m2K which a satisfactory value
- Although the spaces between the wooden structural studs are filled with excessive amount of thermal insulation material, the continuity of the insulation was cut with the studs which results many thermal bridges
- As the wooden reconstruction’s external wall does not have any kind of material having heat storage capacity, it is not suitable for the dwelling function of the building
- The R.C. structured reconstruction also has thermal bridges at the intersection points with the wooden studs carrying the wooden siding. But as the number and amount of the structural components are small in RC, it doesn’t affect the mean U-value much

- The U- value of the window system with the wooden and aluminium shutters are almost 0.7 W/m2K which is a very satisfying value
- The air space between the aluminium shutters and the window sashes are slightly ventilated. As there is a gap of about 8 mm width and 800 mm length in the window frame for the aluminium louvers operation which make the thermal conductivity of air cavity increase twice.
- The air space between the wooden shutter and the window sashes are slightly ventilated. There isn't any significant opening or gap measured in the shutter but some spots at the connections of the wooden louvers with the shutter sash leaks small amount of light which made the airspace be counted as a slightly ventilated
- The glazing is the weakest link in terms of U-values of the window systems.

6. Conclusion

The embodied CO2 emissions of the typical reconstruction details used for Bosporus mansions' external walls, and windows are being analysed, energy losses from them are being calculated and the data obtained is going to be compared with the data calculated for the original building details. Although the exact values haven't been determined yet the early results show that keeping the original structural system, and using the details similar with the originals are going to be the most environmental friendly alternative for reconstructions considering the embodied energy. However, in the long run, considering 30 years of Life Cycle of the building, usage of the more sophisticated details will be more environmental friendly choice considering the operational energy usage.

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DESIGN FOR MENTAL WELLBEING

Developing an Audit Tool to Assess a Building's Effect

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Abstract. This research investigates the impact of a building's design on the mental wellbeing of the occupants. The main factors that affect mental wellbeing were identified through a review of current literature relating to the topic. Weightings were applied to the factors based on previous research to allow them to be used to assess a building's influence. The factors were then compiled into a tabular audit tool that may be used to score a building out of 100%. This audit tool was then tested on three buildings of varying types and sizes to assess its usability. A detailed interview was carried out to obtain the opinions of a professional working within the subject area. The paper concludes by highlighting the need for further research in this area and suggests fine tuning of the audit tool.

Keywords: Mental Wellbeing, Mental Health, Occupancy Wellbeing, Building Design, Audit Tool

1. Mental Health in Construction

Mental health has become a more prominent issue in recent years. According to the Office for National Statistics (2017), 5,965 suicides were recorded across the United Kingdom in 2016. This represents a 3.6% reduction from 2015 figures. This reduction in statistics may be partly due to work carried out be organisations such as Mind (www.mind.org.uk) and Anxiety UK (www.anxietyuk.org.uk). The Architects Benevolent Society (www.absnet.org.uk) specifically helps people employed currently or previously within the architectural profession. Another organisation which focuses on the mental wellbeing of individuals within the construction sector is Mates in Mind (www.matesinmind.org) which was launched in January 2017.

While architectural technology advances the quality of our buildings with regards to economic impact, function and aesthetics, the effect a building has on an individual's mental wellbeing is an increasingly important topic. A wealth of research has taken place since the turn of the century which investigates the impact of the built environment in general on mental wellbeing, however, this has not always been linked directly to architecture and architectural technology. A solid link between the two is vital in ensuring the progression and development of architectural methods that promote mental wellbeing for end users.

A positive correlation exists between the quality of housing and psychological wellbeing (Evans, 2003) and this has been confirmed by multiple research articles, for example Bond et al. (2012), Chu, Thorne and Guite (2004), Guite, Clark and Ackrill (2006) and Mazuch and Stephen (2005). This paper investigates published material linked to the effect of architecture on mental wellbeing. The review includes articles focusing on the built environment in general which may be related back to architectural decisions. There is a particular focus on residential architecture, with articles on other building types reviewed in less detail and only referred to where appropriate.

2. Objectives and Methodology

The purpose of this investigation is to create an audit tool to help designers consider mental wellbeing when designing a new building and during the assessment of existing buildings. A review of relevant existing literature was undertaken to identify the main factors that influence mental wellbeing relative to the built environment. These factors were then evaluated and compared to establish a hierarchy of significance and appropriate weightings were then applied.

This information was then adapted to create an audit tool to facilitate the assessment of new and existing buildings with regards to the mental wellbeing of occupants. The tool was developed in conjunction with a treatment method known as design prescription (Mazuch and Stephen, 2005) where the location for a patient's recovery is decided by assessing the environmental factors that would be most beneficial for their recovery. As outlined by Huang and Brubaker (2006), good audit tools provide consistency and accuracy.

Therefore, the proposed audit tool was tested on three different buildings to assess its usability and accuracy in a variety of scenarios.

A structured interview was used to validate and refine to the tool. Gray (2014) states that interviews are suitable for restricted research contexts. While the limitations of this method are acknowledged it was deemed suitable for the context of this investigation.

The audit tool was adapted by addressing issues that arose during testing and consideration of feedback from the structured interview. The final audit tool complements design prescription (Mazuch and Stephen, 2005) and proposes a methodology appropriate for use in architectural practice.

3. Factors Influencing Mental Wellbeing

The effects that buildings have on an individual can be split into two categories: physical and psychological. A relationship exists between the two, meaning that one reaction may be caused as a result of a factor relating to the other category, and vice versa. The psychological factors that are examined in this investigation can further be broken down into direct and indirect factors (Evans, 2003). Direct effects are experienced specifically due to one factor, for example noise causing stress, whereas an indirect effect could be where an individual has less social support, leading to social withdrawal and therefore reduced mental wellbeing.

3.1. DIRECT EFFECTS

Direct effects on an individual's mental wellbeing tend to be more short-term issues. However, their effects can be long-term, especially in situations where the effect is repetitive. While a lot of these factors have different effects on mental wellbeing, depending on the individual's own perception, the following factors have been repeatedly researched and are found to be the most prevalent direct effects on mental wellbeing.

3.1.1 Noise

Noise can be described as unwanted sound. In the built environment, unwanted sound is usually the result of traffic, aircraft, or loud neighbours. Perception of noise differs widely between individuals. Noise properties are also influential, for example, the characteristics, unpredictability and meaning of the noise (Chu et al., 2004).

Research into the effect of noise on an individual strongly suggests that unwanted noise causes symptoms closely linked to stress and discomfort (Chu et al., 2004). This is further backed up by Evans (2003) with results indicating that there is an increase in psychotropic drug use in adults exposed to airport noise. Evans also asserts that even in a noisy home, if children have a room in which they can spend time alone, the negative effects decrease significantly. Guite et al., (2006) also found an association between poor mental wellbeing and noise, specifically from neighbours. Bronzaft (2000) points out that a noise doesn't have to be loud to have a negative effect, giving the example of a dripping faucet causing stress over time. The author also points out that a noisy household will impede a child's learning.

3.1.2. Light

Light can refer to either artificial light or natural light. While natural light is usually stated as the more important of the two types, artificial light can sometimes provoke certain feelings or states of mind in an individual. Different effects can be produced through different colours of light while artificial lights can also be used to replicate natural light in spaces that do not receive any.

Another key area that was referred to in multiple articles was lighting. Chu, et al., (2004) pointed out that 2/3 homes in the UK are inadequately lit. The power of well-lit areas is highlighted by Evans (2003) who found that patients who are hospitalized with depression recover quicker in well-lit rooms compared to dimly lit rooms. While levels of lighting have an effect on mental wellbeing, the type of light produced is also an important consideration. Viola, James, Schlangen and Dijk (2008) found that an exposure to blue-enriched white light in workers during the working day increased their alertness and performance while also decreasing fatigue in the evening.

Publications such as The SLL Code for Lighting (Raynham, 2012) should be referred to when designing the artificial lighting for a building, to ensure that a building is sufficiently lit. Maximising the natural light within a building is also important, with the many effects of natural light on the internal body investigated by Edwards and Torcellini (2002).

3.1.3. Air Quality

Many factors can affect air quality within a building. These factors include toxic elements within construction materials. Toxins within a building have become more problematic over recent decades with increased air tightness in buildings allowing toxins to build up within the environment (Jones, 1999). Such toxins may even lead to negative behaviours like aggression. Additionally, problems with indoor air quality may be caused by heating and cooking systems (Evans, 2003).

Sick building syndrome is a term commonly used when referring to indoor air quality. According to Jones (1999), sick building syndrome can have many negative effects on an individual. The effects that directly influence mental wellbeing include difficulty remembering and concentrating, an increase in depressed feelings, tension and nervousness.

Air quality is an important consideration when designing the heating, ventilation and air conditioning systems for a building. A well designed system should meet the standards provided by local building control departments such as, Technical Guidance Booklet K in Northern Ireland (Department of Finance and Personal, 2012). Air quality can also be altered to provide different effects on the building's occupants, for example releasing certain aromas to increase productivity or relaxation, as commonly found with sense sensitive design (Mazuch and Stephen, 2005).

3.2 INDIRECT EFFECTS

The results of indirect effects on mental wellbeing are not immediately apparent. These effects tend to build up over time, sometimes resulting in exacerbated symptoms.

3.2.1. Control of Internal Environment

Many aspects of an internal environment contribute to the comfort of individuals. When these factors cannot be controlled, they may have a negative impact on comfort. This can lead to diminished quality of life and mental wellbeing if it becomes a long-term problem. This lack of control can also lead to problems related to sick building syndrome, as investigated by Jaakkola, Heinonen and Seppänen (1989).

When an individual lacks the ability to control internal environments, then this often becomes a dominant factor related to mental wellbeing, resulting in feelings of helplessness (Evans 2003). The control of noise, ventilation, and damp contribute to the maintenance of internal environment. Guite et al. (2006) adopted internal environment as one of the six factors affecting mental wellbeing in their research.

3.2.2. Fear of Crime

Fear of crime is essentially linked to the perception of an individual. People who have fallen victim to crimes may have a higher fear of crime than those who have not. The built environment can help to moderate these fears through the incorporation of security as well as better separation between public and private spaces. Another factor associated with fear of crime is the building location, but this cannot be directly addressed in most situations.

McManus and Mullett (2001) identified two elements of the fear of crime: direct effects and indirect effects on the health of an individual. Effects of crime on mental wellbeing broadly fall within the indirect category. These affect people's mental wellbeing through stress, sleeping difficulties, depression, loss of appetite and loss of confidence. Unhealthy coping mechanisms, e.g. smoking and alcohol consumption (Chu et al. 2004) also contribute to reduced wellbeing. Weich et al. (2002) found that rates of depression were higher in areas where crime is more likely to occur. These areas were also characterized by a prevalence of graffiti, open public spaces and little distinction between public and private spaces. Furthermore, Bond et al. (2012) found a higher level of mental wellbeing among those who had an aesthetically pleasing front door with incorporated security provision.

3.2.3. Occupant Density

Occupant density is defined as the number of residents within a certain area or within a structure. Some maintain that occupant density relates to social support, but Evans (2003) argues against this as detailed in the next section. Population density affects mental wellbeing through overcrowding, lack of green spaces as well as a lack of entertainment (Guite et al., 2006). The direct effects of overcrowding on mental wellbeing include aggression, increased vulnerability, confusion, disorientation and isolation. According to Chu et al., (2004) the effects of overcrowding can be alleviated through the provision of escape facilities, for example cafés and parks.

At the design stage, green spaces should be incorporated to minimize the effect of occupant density. This closely relates to 'Biophilic Design', which involves the integration of plants and natural elements within a building (Kellert, Heerwagen and Mador, 2011). Where this is not possible, transport links should be provided to allow occupants to easily escape their surroundings when necessary.

3.2.4. Social Support

Occupant density and overcrowding is closely related to social support. It has been found that a positive relationship exists between social support and mental wellbeing. Social support involves the incorporation of social spaces which encourage the development of social connections. Conversely, crowded residential settings result in social withdrawal (Evans, 2003).

Many studies have been conducted to investigate the psychological effects of social support. Cobb (1976) found that social support can protect people from pathological states, for example depression. Buildings can be designed to foster the development of social relationships and social support.

Incorporating communal spaces within building contexts helps maximise social support. As it has been proven that people at higher levels within high rise buildings tend to feel isolated, residential buildings should be kept as low rise where possible. Other considerations that can also increase feelings of social support include suite arrangements rather than corridors and closer proximity to other building entrances.

3.2.5. Physical Activity

While taking part in physical activity is a personal choice and cannot be directly influenced by a building, passive design measures can be implemented to help make physical activity as accessible as possible. Physical activity has many positive results including an improved mental wellbeing. Depression, for example, is much less common in individuals who are physically active (Fox, 1999). Architecture can be used to provide people with more opportunities for physical activities. Incorporation of green spaces and convenient placement of attractive stairs are two typical examples (Rao, Prasad, Adshead and Tissera 2007).

3.2.6. Insufficient Space

Space in this case primarily refers to personal space within or around a building. Personal space must be considered vertically as well as horizontally (Cochran, Hale and Hissam 1984). A lack of space can also produce the direct effect of claustrophobia which may affect certain individuals.

While associated to overcrowding, lack of space is a distinct issue. It is particularly problematic in families with young children, where it has been found that parents with insufficient private space are more reluctant to engage with their children. In this situation, parents also tend to control the activities of their children more. Evans (2003) maintains that providing outdoor play space benefits parents and children.

3.2.7. Aesthetics

Perception of building aesthetics is subjective and transient, and input from the end user is vital. Notably, the designer's perception of aesthetics is not the same as the general population's (Guite et al., 2006). It is often believed that colour affects mental state however, Evans (2003) states that there is no clear evidence that colour has an effect on mental wellbeing.

3.2.8. Humanistic Architecture

This approach is becoming more established when designing for mental wellbeing. Humanistic architecture is a combination of psychology, sociology, biology and physiology relating to the effects of an environment on a person's health. Mazuch and Stephen (2005) researched design work by Nightingale Associates, an architectural practice in the UK specialising in creating healing environments. Three specific design methods were identified that can be used to create a healing environment: sense sensitive design, emotional mapping and design prescription. These three methods may be used together as part of the design process, to ensure the creation of a positive environment that helps to promote mental wellbeing.

3.3. SUMMARY

It has become clear that significant consideration is required during the design process to achieve a positive effect on mental wellbeing. Mental wellbeing can be potentially enhanced when various factors are correctly addressed. Traditionally, aesthetics has been the main consideration when changing or upgrading existing buildings, but clearly a more holistic approach is needed.

4. Audit Tool Development

Guite et al., (2006) applied weightings to six factors: Noise, Density, Internal Environment, Fear of Crime, Social Participation and Design. This study has identified: Lighting, Air Quality, Space and Encouraged Physical Activity. It has been assumed that these additional factors are less significant. Appropriate weightings have been applied based on the literature review as shown in Table 1.

TABLE 1. Adapted Overall Weightings out of 100% extrapolated from Guite et al. 2006.

Factor	Result	Position	Percentage
Noise	1.48	1	16.80
Density	1.14	2	12.94
Internal Environment	0.97	3	11.01
Fear of Crime	0.88	4=	9.99
Social Participation	0.88	4=	9.99
Design	0.86	5	9.76
Air Quality	0.80	6	9.08
Lighting	0.70	7	7.95
Space	0.60	8	6.80
Encouraged Physical Activity	0.50	9	5.68

4.1. CREATING THE AUDIT TOOL

The audit tool was arranged in a tabular format. The distinct sections aid easy interpretation and consistency of assessments. Each section has an associated rating to help auditors identify issues that may need greater attention.

Questions have been incorporated to ensure all the relevant issues are identified and suitably addressed. Some questions require a yes or no answer, while others require a numerical rating. A tick box has been used for the yes/no answers to save time. Questions that require a rating are scored out of 5, as commonly used on other forms. A 10 point system is generally considered more time consuming due to user indecision.

4.2. CALCULATION OF RESULTS

To determine an overall score for a building out of 100 each answer has been given a value. The maximum score for each section was indicated in the percentage column of the table as shown in Table 2. Values for answers were calculated by dividing the overall maximum mark for each section by the number of questions in that section. Where an answer was a rating, the value for that question was divided by 5, providing a value for each point out of 5. A positive or negative sign was applied to questions depending on the positive or negative effect on mental wellbeing. For example, answers with a negative sign have a negative effect on mental wellbeing.

Each question was assigned a number that corresponds with the numbers assigned in the form itself to help prevent any confusion when marking the form.

TABLE 2. Answer Values

Question No.	**Sign**	**Value**	**Result**	
Noise				
A1	-	1.866		
A2	-	(x0.373)		
A3	-	(x0.373)		
A4	+	(x0.373)		
A5	-	(x0.373)		
A6	-	(x0.373)		
A7	-	(x0.373)		
A8	-	1.866		
A9	+	1.866		
			Total =	/16.80
Density				
B1	-	(x0.518)		
B2	+	2.588		
B3	+	(x0.518)		
B4	+	(x0.518)		
B5	+	(x0.518)		
			Total =	/12.94
Internal Environment Control				
C1	+	1.573		
C2	-	(x0.315)		
C3	+	1.573		
C4	+	1.573		
C5	+	1.573		
C6	+	1.573		
C7	+	(x0.315)		
			Total =	/11.01
Fear of Crime				
D1	+	(x0.500)		

	D2	-	(x0.500)		
	D3	+	2.498		
	D4	+	(x0.500)		
				Total =	/9.99
Social Participation					
	E1	+	(x0.400)		
	E2	-	1.998		
	E3	+	1.998		
	E4	+	(x0.400)		
	E5	+	1.998		
				Total =	/9.99
Aesthetics					
	F1	+	(x0.651)		
	F2	-	(x0.651)		
	F3	+	(x0.651)		
				Total =	/9.76
Lighting					
	G1	+	(x0.530)		
	G2	+	2.650		
	G3	+	2.650		
				Total =	/7.95
Air Quality					
	H1	-	(x0.454)		
	H2	+	(x0.454)		
	H3	+	2.270		
	H4	+	2.270		
				Total =	/9.08
Space					
	I1	+	1.362		
	I2	+	(x0.272)		
	I3	+	1.362		
	I4	+	(x0.272)		
	I5	+	(x0.272)		
				Total =	/6.81
Encouraged Physical Activity					
	J1	+	(x0.379)		
	J2	+	(x0.379)		
	J3	+	(x0.379)		
				Total =	/5.68

4.3. TESTING THE AUDIT TOOL

The audit tool was tested on three residential buildings of varying scale, age and layout. This provided a range of results and assisted with the discovery of issues which may not occur in all building types. Residential buildings were chosen since the majority of the existing mental wellbeing research focus on residential buildings and related literature review provided the basis for the audit tool.

Testing the audit tool will identify areas that have been overlooked or that need to be improved. One major limiting factor of the audit tool is that it does not measure the mental wellbeing of individual occupants to compare it with the audit rating. However, the nature of this research did not facilitate such considerations.

4.3.1. Building One

The first building is a detached two-storey Edwardian house in Bangor, Northern Ireland. This building was chosen to help identify any problems that may arise when assessing an older building. Currently there are three adults residing in the house. It was anticipated that due to single glazing, inadequate ventilation and a closed floor plan that the overall score for this house will be lower than the other buildings, particularly for noise and indoor air quality.

4.3.2. Building Two

The second building is another detached house located in Donaghadee, Northern Ireland. This house was chosen because it was built within the past five years and therefore provides insight into how the audit applies to recent construction scenarios. The current residents are three adults and one child. As building two is much newer than the first building, it is expected that a better score will be achieved.

4.3.3. Building Three

The third building is a flat located in Bangor, Northern Ireland. When examining a communal building there are other issues that may be investigated that would not otherwise be present in a single dwelling. One adult resides in this flat. It was felt that the building characteristics would result in a lower overall score, but not for all sections.

5. Building Test Results

Table 3 gives a summary of results for each of the test buildings. Some of the main observations are subsequently highlighted.

TABLE 3. Summary of results for the three buildings

Category	**Building 1**	**Building 2**	**Building 3**
Noise	-2.238	-3.357	-0.372
Density	6.732	5.696	4.142

Internal Environment Control	2.516	5.349	3.776
Fear of Crime	3.998	6.496	7.494
Social Participation	7.992	5.596	5.596
Aesthetics	4.557	4.557	5.208
Lighting	2.120	2.120	0.530
Air Quality	-0.908	4.540	1.816
Space	6.536	5.716	4.628
Encouraged Physical Activity	5.306	5.680	1.516
Total	36.61%	42.39%	34.33%

5.1. BUILDING ONE

The test took around half an hour to complete. The audit tool was straightforward to use, but some issues were identified. On reflection it was realised that repetitive noises are most easily identified by speaking to residents themselves. Other issues are discussed in section 7.2. Building one performed best with regards to space and encouraged physical activity but scored negatively in air quality and noise.

5.2. BUILDING TWO

Building two took around 25 minutes to assess. Residents were briefly consulted to more accurately assess certain factors, particularly relating to noise. It had originally been expected that this building would perform better than the first dwelling in terms of noise, however, it actually achieved a lower score. This may be due to the close proximity of a busy road which results in constant road traffic noise throughout the day. The rest of the scores are what had been expected, with a much higher score achieved for air quality.

5.3. BUILDING THREE

Testing the audit tool on the flat took around 15 minutes due to its smaller size compared to the first two buildings. The final results for this test fell within a close range of the other two results. This means that the average result from the three tests was 37.78%, with all results falling within a range of 8.06%.

The results for building three show the expected differences. The space available within the flat is much smaller than the other two buildings as evidently shown by the contrasting percentage scores. Another key difference between building three and the other two buildings is the density value. As this percentage is lower, it means the higher density level within the block of flats has a more negative effect on mental wellbeing.

6. Interview

The interview took place on the 19th of April 2018. The individual who was interviewed was from an environmental health background, having extensive experience as an environmental health officer, primarily within the private rental sector. Their current role is in education in which they also focus on noise relating to housing.

The interviewee firmly believed that the built environment significantly affects the mental wellbeing of individuals. They also indicated that while related research is growing, particularly with regard to noise, significant gaps still exist. The top factors affecting mental wellbeing according to the interviewee were noise, security, control of the environment and safety. The housing health and safety rating system (HHSRS) (DCLG, 2006) was referred to in this case as being important when considering a building's safety. Regarding noise, the problem of public demand rather than individual needs was brought up in relation to road improvements.

After showing the interviewee the audit tool, they stated that it would probably be most useful when relating it to design prescription or if used as a tool during the design process of new buildings. Difficulties with changing existing buildings were considered to be inhibitive. Some of the questions were considered to be subjective, for example regarding air pollution, which may fluctuate depending on diurnal activities in a dwelling. The audit tool was commended for going beyond current practice by considering aspects that are not normally considered.

Overall, the interview validated the need for such an audit tool, provided key feedback to improve it and confirmed the necessity of further research of the topic. The audit tool was considered to be more viable during the design of new buildings rather than assisting with existing buildings.

7. Discussion

7.1. EXISTING LITERATURE AND INTERVIEW

The aim of this research was to create a design tool to help designers to design buildings that will positively affect the future resident's mental wellbeing. The first step towards achieving this was to identify key factors that affect mental wellbeing, through a review of the existing literature. This literature identified a wide range of factors which had a direct or indirect effect on mental wellbeing.

Reviewing the existing literature also helped to determine the methods for controlling the effects of the different factors on mental wellbeing. The majority of these methods would be most helpful during the design process and could be adopted as guidance notes to supplement the audit tool.

Design prescription, a method of choosing the most appropriate location for recovery from mental health issues, was also discovered. The developed audit tool could be used in conjunction with design prescription to assess possible locations for recovery. This idea was also discussed during the interview as being one of the possible uses for the tool.

The previous research by Guite et al., (2006) was particularly helpful in deciding the weightings for each factor. In this research each factor was tested to determine which has the greater effect on mental wellbeing. This research however did not directly test four of the factors that were identified from other sources.

It was repeatedly mentioned throughout existing literature that there are many gaps in the current research. This was confirmed during the interview, but this was balanced with the recognition that new work is being carried out. Undoubtedly, further research would be beneficial and should lead to a better understanding of mental health and how buildings may be appropriately designed.

The interview specifically highlighted the significant effect that unwanted noise can have on an individual's mental wellbeing. This corroborates the results of research that was examined as part of the literature review, in which Guite et al., (2006) found noise to be the principal factor. The relationship between physical health and mental health, and how building design can impact on both is documented by Chu et al., (2004). This was supported by comments made during the interview. A measure of triangulation is discernible through the comparison of various sources on a variety of issues related to mental health.

7.2. AUDIT TOOL ANALYSIS AND DEVELOPMENT

The purpose of using test buildings was to determine the usability of the audit tool and identify areas for improvement. The interview also used to establish if the tool is fit for purpose. A revised version of the audit tool takes account of these factors and has been included at the close of the paper.

In testing, it took a maximum of 30 minutes to undertake the audit. This confirms that the tool could be easily used, at least in the majority of situations.

During the test audits, several issues were identified. The form lacked a section to record building details including the address and date of the audit. This has now been rectified. Some questions were partially repetitive and have now been combined. Other questions were not always relevant (for example when none of the occupants were children). An additional option, "not applicable" has been added to account for such scenarios.

Initially the use of negative marking was thought to be beneficial. However, following testing the scoring requires adjustment since a score over 50% would be difficult or impossible to achieve. One possible method would be to apply a baseline score. The impact of positive and negative marks would then be more consistent and reliable. This particular aspect requires further testing to perfect the scoring system.

During the testing of the audit tool, it was found that some questions were quite subjective. This was also pointed out in the interview. These questions have been reworded to help minimise the likelihood of misleading results.

Further testing of the revised audit tool would be beneficial, particularly to aid with the overall scoring aspect. A larger selection of buildings should be tested, including building types not covered in this study. The tool could also be tested by a select number of relevant professionals and feedback documented to further enhance the tool.

8. Conclusions

This research focused on the development of an audit tool to be used to assess a building's effect on the residents' mental wellbeing. It was developed through reviewing existing research into the built environment's effects on mental wellbeing and the specific factors that were mentioned were included in the audit tool itself. The audit tool was then tested on three buildings to determine its usability and efficiency. Finally, an interview was conducted to obtain professional insight on the nature of on the audit tool.

Through reviewing the existing literature, ten factors were identified which had a major effect on mental wellbeing. While other factors do exist, they have not been found in previous research to have as significant an effect. The selected factors were given weightings in order to obtain a percentage rating for the building's overall effect. This system could be further improved to provide easily comparable scores for each factor.

This research provides a platform for further research into the prediction and assessment of a building design's implications on mental wellbeing through the use of an audit assessment method. As highlighted in the interview, this is an area that has been increasingly researched over the past few years. The revised audit tool is a good base point for any future developments, with the three tests providing recommendations for improvements which have been incorporated (see Table 4).

Developing the audit tool highlighted the complexity and extensive number of factors that could have an effect on mental wellbeing. Furthermore, the importance of personal perception of the factors became apparent. With this being hard to determine, the audit tool provides a more general rating of the most likely effects on mental wellbeing.

Assessing the resident's mental wellbeing and comparing it to the findings of the audit would open up an entirely different aspect and improve integrity of the results. This, however, could not be completed as part of this research due to ethics implications.

As stated in the interview, this tool has the potential to be used in several different ways, for example during the design process or on an existing building to assess possible spaces for recovery. It could therefore be used by Architectural Technologists, Architects and other design professionals or by occupational therapists working with people recovering from mental health problems.

TABLE 4. Revised Audit Tool.

ASSESSMENT DETAILS

Building Address: ____

Date of Assessment: ___/___/___

Assessor: ____________________

INSTRUCTIONS

- **Answers should be provided in the white boxes with greyed out boxes left blank.**
- **Questions that are not applicable should be marked with a line through the answer boxes.**

No.	Question	✓	Rating /5 (1=Lowest, 5=Highest)
	Noise		
A1	Are there children living within the residence?		
A2	Is there a lot of constant noise within the environment on a daily basis?		
A3	Is there a lot of repetitive noise within the environment on a daily basis?		
A4	How predictable are these noises?		
A5	Is there much aircraft noise present on a daily basis?		
A6	Is there much road traffic noise on a daily basis?		
A7	Is there much noise from neighbours on a daily basis?		
A8	Does the present noise signify something?		
A9	Do residents have a private room to themselves?		
	Density		
B1	Is there a high residential density within the building?		
B2	Do residents have access to a garden/outdoor green space?		
B3	Are there many cafes/green spaces within the surrounding area?		

B4	Are there many entertainment facilities within the building & surrounding area? (e.g. common rooms, bars, cinemas etc.)		
B5	Are there many plants within the building?		
	Internal Environment Control		
C1	Can windows within rooms be opened?		
C2	Is there much damp visible within the environment?		
C3	Do the windows have shutters/blinds/curtains?		
C4	Do doors within the residence have locks?		
C5	Can the temperature of the internal environment be controlled?		
C6	Can the layout of the internal environment be changed easily?		
	Fear of Crime		
D1	Does the building incorporate security measures? (e.g. cameras, security personnel, gates)		
D2	Is there a lot of vandalism present in the surrounding area?		
D3	Is there a transition space between public/private spaces?		
D4	Does the building provide much visual surveillance of the surrounding area?		
	Social Participation		
E1	Does the building provide many shared spaces? (e.g. common rooms, gardens)		
E2	Is it more than 7 storeys tall?		
E3	Is the entrance to the building near a main pedestrian thoroughfare?		
E4	Are there other residential buildings nearby?		
E5	Does the building use a suite layout for residences as opposed to corridors?		
	Aesthetics		
F1	Are there many escape facilities nearby? (e.g. public transport links, green spaces)		
F2	Is there a lot of vandalism on the building itself?		
F3	Is the building in a good state of repair?		
	Lighting		
G1	Does the internal environment receive a lot of natural light?		
G2	Can the colour of the artificial lights be controlled?		
G3	Can the levels of the artificial lights be controlled?		
	Air Quality		
H1	Is there much apparent air pollution within the internal environment?		
H2	Does the environment have good natural/mechanical ventilation?		
H3	Do cooking and bathroom areas have extraction fans?		
H4	Does the ventilation system provide any aromatherapy options?		
	Space		
I1	Do children have access to outdoor space?		

I2	Does the building have high ceilings?		
I3	Do residents have their own space away from children?		
I4	How spacious does the internal environment feel?		
I5	How spacious do areas outside the residence feel? (e.g. circulation space, communal areas)		
	Encouraged Physical Activity		
J1	Are stairwells made obvious and in convenient places?		
J2	Do stairwells within the building look physically appealing?		
J3	Does the surrounding area incorporate much green space?		

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WHICH VERSION™?

Exploring the digital modelling of architecturally important sites and the implications on the understanding of the historical narrative the model reflects.

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Abstract. The preservation of architecturally important buildings and monuments takes on various forms, with the reasons for the need to retain them varying from region to region, nation by nation. The parameters and criteria for this preservation can be informed by politics, economic considerations, the prevailing zeitgeist etc. Similarly, the wanton destruction of architecture can be influenced by numerous agendas, with recent examples including the destruction of the monumental Buddha statues in Afghanistan by the Taliban and the damage to the ancient city of Palmyra by daesh during the ongoing Syrian civil war.

With the destruction of architecturally important buildings and monuments, the photographic, archaeological and academic studies related to them have been used to restore as much of the original form as possible. With the advent of digital methods of recording and creating Computer Aided Design models, with the capacity for producing virtual immersive versions, the capacity to both preserve and then share remotely those buildings expands. With particular reference to Palmyra, a city very much on the front line with no guarantee Daesh will not recapture it and recommence their deliberate, targeted cultural destruction, digital models may be the only way to study the city, and preserve it, for the foreseeable future.

Cultural vandalism, the destruction or modification of architecture and monuments, the wanton eradication of buildings considered important to some but inconvenient blocks to further development to others, are part of architectural history's long story. Other instances, such as the destruction of buildings associated with the Nazi regime, can be seen as part of a cathartic exercise of renewal and understandable revenge.

However, versions of these buildings exist in fiction and museum models and are likely the source of veneration for those of a particular political perspective.

With the range of complexities surrounding what is preserved and why it is preserved, there are questions which arise as to who has control over the preserved model, what time period does it cover, how is 'Disneyfication', or the 'Vegas' version avoided etc. These will be explored as part of this paper with its aim being the examination of the themes set out here to begin a conversation on how sites like Palmyra can be preserved and recorded. For example, the restoration of Palmyra to a pre-daesh state could arguably include the Tadmur prison, a notorious site for alleged torture since the Assad family came to power. Is it an honest reflection of modern Palmyra, a site made up of influences from civilisations across a 2,000-year period, if its modern reflection as an example of the failure of civilisation is not also recognised and preserved? As will be set out in the emerging conclusions of the paper, the importance of establishing a multifaceted context, and engaging in an inclusive dialogue with all the affected parties is key to attempting to establish What Version™ eventually emerges.

1. The Historical Perspective: An Introduction

The ancient city of Palmyra and its associated inhabited town of Tadmur are part of the troubled modern state of Syria and have been an interest of mine for 20 years. Ancient Palmyra first came to my attention through the epic work of historical record and commentary produced by Edward Gibbon in: The History of the Decline and Fall of the Roman Empire, published in six volumes between 1776 and 1789. Gibbon described Palmyra as:

Amid the barren deserts of Arabia, a few cultivated spots rise like islands out of the sandy ocean…situated at a convenient distance between the gulf (sic) of Persia and the Mediterranean, was soon frequented by the caravans which convey to the nations of Europe a considerable part of the rich commodities of India…It was during that peaceful period[1]*, if we may judge from a few remaining inscriptions, that the wealthy Palmyrenians constructed those temples, palaces and porticos of Grecian architecture, whose ruins scatter over an extent of several miles, have deserved the curiosity of our travellers. (Gibbon, 1776, pg.317)*

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[1] The 150 years following the victories of the Emperor Trajan over the Parthians in 116 CE.

The ancient city became a symbol of the meeting of cultures, arguably the clash of cultures and its ruins, internationally identified as a UNESCO[2] World Heritage Site since 1980 (UNESCO, accessed 20th of July 2017). Further, the site encapsulates in its history links to some of the most famous figures and states of the ancient world, perhaps best embodied in the Palmyrene Queen, Zenobia[3]. Zenobia claimed lineage from the more famous last Pharaoh of Egypt, Cleopatra VII and echoed the Egyptian Queen in her attempt to wrestle the Eastern Roman Empire from the control of Rome.

More recently, the advent of daesh, the so-called Islamic State of Iraq and the Levant and its targeted campaign of ideologically driven destruction of what it perceives as idolatry has seen Palmyra, which it captured, lost and recaptured briefly, bear the brunt of what can be reasonably argued as cultural vandalism. The UNESCO assessment of the current state of Palmyra notes:

The mission asserted the deliberate destructions that were reported by aerial images and propaganda images when the site was inaccessible, namely the destruction of Cella of the Temple of Baal-Shamin, the Cella and surrounding columns of the Temple of Ba'al and the Triumphal Arch…The funerary towers and the temple of Bel could only be seen from a distance, as demining operations were still underway. (UNESCO, April 2016, pg.3)

Because of this deliberate destruction, Palmyra and Tadmur are once again in the forefront of the minds of those concerned, professionally or personally, with all this site represents. It is an insignificant consideration, in light of what daesh has wrought across the region, and in the terrorist attacks perpetrated by affiliated cowards, twisted by daesh's social media campaigns, but access to Palmyra for most people with an interest in the city is likely to be difficult for years, if not decades to come.

Not being able to fulfil a professional or personal wish to visit the city of Zenobia could be considered a selfish though within the context described above; making the previously described 'insignificant consideration' even smaller in its pettiness. However, the shared anger at this wanton destruction is one widely reported and shared across the globe. As a student of these subjects and a lecturer in the Built Environment, it seems reasonable to consider how the technologies associated with architecture and education can be used to counter the cultural vandalism of daesh as some small means of recovering something from their legacy.

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[2] United Nations Educational, Scientific and Cultural Organisation. World Heritage Site status is applied to sites considered to have special significance requiring recognition and protection. These range from the Pyramid at Giza, Egypt to the waterfront of the city of Liverpool, England.

[3] Septimia Zenobia, ruled with her husband, then regent for her son, and finally Empress with her son in the final year of the period 260-272 ACE.

With the considerations described in mind, this paper will consider three areas relevant to ancient Palmyra and other similar historical and contemporary instances where the deliberate destruction of architecture has been deployed for ideological purposes. In the first instance the example of destruction and subsequent reconstruction relating to World War II will be considered as examples of pre-digital projects reflecting on the core consideration of this paper, Which Version™ are you creating/recreating and for what purpose?

Secondly the paper will examine the current digital technologies available to those tasked with restoring what has been destroyed in Palmyra and the implications of these methodologies, particularly where virtual/immersive environments are a possibility.

Finally, the paper will consider the historical narrative these technologies could have on the story of Palmyra going forward from the removal of daesh as a governing entity in the region. How will the ancient city reflect recent events? It is an oft repeated truism that history is written by the victors, and this continues to be the case when considering Which Version™ of Palmyra will be restored.

Methodologically, this paper is the culmination of the gathering of various published sources of material, ranging from literature specifically examining the deliberate destruction of architecture as a means of control and domination, to a review of recent broadcast documentary and news reports charting the actions of various groups in the Middle East. As such the aim of this paper is to examine the three areas detailed above in the interest of beginning a conversation as to how sites like Palmyra can be preserved and recorded.

1.1. HISTORICAL PERSPECTIVE: WHAT VERSION™ REMAINED AFTER WORLD WAR II?

Robert Bevans's 2006: The Destruction of Memory: Architecture at War, describes the deliberate destruction by Nazi Germany of the Polish capital Warsaw, from the initial damage caused in its capture in 1939 to the calculated retribution in 1944 for the Warsaw Uprising of the same year:

Of the official pre-war list of 957 historic monuments in Warsaw, 782 were completely demolished and another 141 were partially destroyed. Only 34 survived because the Germans did not have time to set the charges once the Soviet advance resumed. (Bevan, 2006, pg.97).

As an ideologically driven movement, the Nazi Party, once in power used the deliberate targeting of cultural buildings, as well as associated commercial and residential properties, as a means of both propagating terror and, arguably as attempting to architecturally clean Germany in a violent prelude to their ethnic cleansing of Europe during the Holocaust. Their most notable act on German soil, the Kristallnacht (Night of the Broken Glass) between the 9th and 10th of November 1938 saw the burning of a thousand synagogues alone. Their destruction arguable acted to wipe these Jewish centres of worship and learning off the German landscape and cityscape in order to produce a version of Germany more akin to the Nazi ideals. When considering What Version™ of Germany they sought, Kristallnacht, like the destruction of Warsaw in the creation of a greater Germany, expressed in the destruction of architecture a future without Jews and without the Slavic races Nazi ideology considered inferior to their Aryan ideal.

The response to the defeat of Nazi Germany and how the restoration of what they destroyed was handled is an interesting assessment of how Palmyra may be restored, as well as other historical cities and monuments destroyed by daesh. The most recent act of destruction perpetrated by the group has been at the 12th century Great Mosque of al-Nuri in Mosul, Iraq, including a famous leaning minaret, on the 22nd of June. This occurred as Iraqi forces, backed by the United States of America, continued the battle to take control of Mosul, the second city of Iraq. On the day the story was reported John Darlington of the World Monuments Fund Britain[4] was interviewed on Radio 4's World at One programme and discussed the options for the Great Mosque once Mosul was back under the control of the Iraqi government and the potential for recovering the complex was possible. Prompted by the question of the options 'Restoration or Commemoration', Darlington raised the restoration example of Warsaw, Poland which, on being asked his opinion of the project, he noted "…personally I think it's an extraordinary achievement, but there is a certain sort of antiseptic nature to it that doesn't actually tell the story of what happened to it." (BBC Radio 4, June 2017)

The range of options discussed during the BBC interview included operations where buildings and monuments were partly restored from the remaining fragments, left as ruins to commemorate the events, and adaptations of ruins into new forms; all of which will be considered against various examples in this paper. With regards to Warsaw, Bevan goes on to state, regarding Chrystian Piotr Aigner's 1826 Neo-Classical Church of St Alexander: "*Like so much of the historic city centre, it was rebuilt in close facsimile in the post-war period but it lacks the finesse of the original. The reconstructed city has been described as a 'Disney operation.'" (Bevan, 2006, pg.182)*

The restoration of the centre should be considered as an extraordinary achievement, as noted by Darlington. An article from The Guardian series 'Story of cities' described the process of rebuilding the city, recycling materials from buildings across the city to create bricks and reusing surviving

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[4] A UK charity concerned with supporting conservation in the UK and abroad. https://wmf.org.uk/

architectural details on new buildings. Assisted by surviving inhabitants of the city, international experts began work on the restoration, with particular attention to the 22 cityscapes painted by Venetian Bernardo Bellotto[5]:

Bellotto's paintings, along with the expertise of Polish architects, art historians and conservators, enabled the reconstruction of the Old Town to take place in an impressively short period of time. Most of the work was finished before 1955 – although additional construction continued into the 1980s… (Mersom, April 2016)

Before the advent of the digital technologies which will likely aid in the restoration projects at Palmyra, any analogue source, be they photographs, paintings or descriptions of the existing buildings were (and continue to be) a vital source of original materials where plans, sections and elevations do not exist. With regards to the use of artistic or descriptive/academic sources, there is naturally some scope for discrepancies. Bellotto, for example used a camera obscura[6] to trace the buildings he was seeing before transferring to canvas to paint them. (Mersom, 2016) Therefore the version of modern Warsaw is not exactly that of the pre-WWII city.

The version of Warsaw now standing can reasonably be seen as the antiseptic one described by Darlington. This might also be extended further to the actual materials and construction methods. While arguably the partial destruction of an historic building is an opportunity to study the archaeology and technological/material science realities of its construction, the socio-economic realities of trying to restore a city following a World War are likely more pressing than restoring like-for-like as might be expected under usual conservation regulations and requirements. When considering the premise of this paper What Version™, from a construction perspective, Warsaw is a Soviet Era project. Indeed, taken further, as Bellotto was dead by 1780, the Old Town of Warsaw of 2017 is a Warsaw of the mid to late 1700s, conceivably leaving an architectural developmental gap of 160+ years.

Nothing in the Old Town stands to commemorate the Nazi invasion or the subsequent destruction in response to the Warsaw Uprising of 1944. Arguably, 'stands' is perhaps the wrong word for it is precisely what does not stand, or partially remains as a ruin which the Old Town does not have. This lack of acknowledgement, even in some small way, is part of the antiseptic argument laid at Warsaw. However, across Europe there are a number of sites who use ruins or an absence of buildings to commemorate the absence of inhabitants due to violence and war, recognising the destruction was human as well as to

[5] 1722-1780

[6] A method where an image is projected through a small hole. The projection is inverted but does allow for the transfer of that image on to the projected medium.

the built environment. The French village of Oradour-sur-Glane, site of a Nazi Waffen-SS massacre in 1944 was set aside by the French post-war state as a permanent memorial to the event and the atrocities of the whole conflict. Nothing has been rebuilt or cleared away.

Coventry Cathedral in England and the Kaiser-Wilhelm-Gedächtniskirche[7] in Berlin, Germany are further examples of buildings partially destroyed by the bombing raids of the German and Allied air forces respectively. The 14th and 15th century St. Michael's Cathedral was destroyed in 1940 with a modern Cathedral being completed in 1962 as a contrast to the ruins of the old building as a symbol of reconciliation with the past. Similarly, and during the same period, modernist contrasting new structures were built around the remaining spire of the Gedächtniskirche, recognising within it the martyrs created by the crimes of Nazi Germany.

If Warsaw is an attempt to forget WWII, these French, English and German examples are evidence of a desire to remember, to commemorate and in the last to look to the future. Germany in particular, for anyone who has visited its cities, Berlin especially, will see architectural and monument-orientated interventions that do nothing to disguise the awareness Germany has of the horrors perpetrated by its leaders and citizens during the Nazi period. In particular, they seek to remember crimes against other Germans and especially those Germans, Jews and other peoples who were the victims of the Holocaust. When considering What Version™ is the correct one, and how this may assist in the work to be carried out in Palmyra, the answer is; there is no correct approach. We may all have opinions on what we consider right and, as will be explored in the final part of this paper with regards to historical narrative, there are ideological reasons, either deliberate or possibly paternalistically naïve which offer a context for What Version™ eventually wins out.

As a final consideration with this regard, the descendants of participants in the German army and state may consider commemoration and remembrance is the correct approach. The descendants of Poles who resisted or fled the destruction of Warsaw in 1944, might want to see restoration and the eradication of what the Nazis did. Context and consultation with regards to defining this context is everything and represents a considerable challenge to those tasked with a conundrum like Palmyra.

[7] Kaiser Wilhelm Memorial Church, built in the 1890 and damaged by an Allied bombing raid in 1943.

2. The Digital Opportunities

Continuing to use Europe as an example, there are numerous historical sites where the passage of traumatic history can be seen left on display. The 16th century Gothic Basilica of Notre-Dame d'Alençon, France has a number of religious and royal figures around the portal, all decapitated. A simple assumption of a link to the French Revolution of 1789-1799 and the guillotine would be reasonable, however in this instance the destruction was related to events of the Wars of Religion two hundred years earlier.[8] To restore those heads would be to ignore a formative part of French and Norman history, and the revelation of this history is part of the educational opportunities architecture bearing some acknowledgement of past destruction offer. Similarly, in the Church of Saint-Sulpice, Paris, France made recently more famous by Dan Brown's 2003 novel (and subsequent film): The Da Vinci Code, the Gnomon, an astronomical measurement device featured in the book also bares the mark of upheavals in French history. The French inscription on the French/Latin plaque had the names of the King and his ministers deleted, much in the same way the Egyptians would remove the names of Pharaohs from monuments and buildings to erase their memory; literally and figuratively.[9] A simple modern plaque next to the original reinstates the missing text and offers explanation, restoring the information while maintaining the historical relevance of the events of the Revolution.

Such physical elements in the architectural record as those in Alençon and Paris are evidence of the power buildings and their decorations have in telling multiple stories of the existence of those structures and the context they have survived in. Hampton Court Palace, England offers a similar contextualisation opportunity while also presenting a challenge to the concept of What Version™ should be preserved. Much of Cardinal Thomas Wolsey's[10] original Tudor palace of the early 1500s was extensively demolished and remodelled during the reign of the Stuart monarchs William III and Mary II in the late 1600s and then finally remodelled by the first two Hanoverians, George I and II. Following its abandonment as a royal residence by the later Hanoverians, the Palace became a grace-and-favour home for various Court, Military and Government personages. The opportunity/challenge regarding the Palace was one raised in programme about the building a few years ago. Whilst attempting to remove some Victorian wall paper to restore one of the

[8] French religious civil war between the Roman Catholics and the Huguenots, a sect of Reformed Protestants.

[9] A famous example being that of the female Pharaoh Hatshepsut of the 18th Dynasty who ruled from 1478-1458 BCE. On her death her Cartouches were chiselled off monuments and it is only modern archaeological finds that have restored her to the recognised chronology of Pharaohs.

[10] Henry VIII's Chief Minister and Roman Catholic Prelate of England.

remaining Tudor apartments, the conservationists discovered rare Georgian wall paper, with even rarer Stuart wall paper beneath that. What should they do now? Destroy two layers of historically important material in order to reveal an older one, having already destroyed one historic layer in the removal of the Victorian paper?

For conservationists, architectural historians and the many other related professionals and interested armatures, the advent of digital systems offers a range of possibilities beyond what pre-digital experts had. This can be seen directly in the main subject of this paper, Palmyra. UNESCO staff "…undertook a damage assessment of the site and the museum, identified some first-aid measures, documented the damages with aerial photos and 3D scanning, and conducted rapid interventions for the safeguarding of the museums objects." (UNESCO, April 2016, pg.3). UNESCO proposed, in the 2016 report considered earlier, a number of short, medium and long term recommendations for damaged sites such as Palmyra. Understandably the short term measures relate to 'first aid' based on a systematic documentation of the remaining fabric, particularly relating to those monuments damaged during the occupation through a form or architectural triage. Ominously they also include recognising the need to protect the site from further military activity or infrastructure, assumedly aimed at the Syrian government forces but they are not specific, recognising the ongoing instability of the region.

The example of Warsaw demonstrated what can be achieved from archival information, dating back a few hundred years. UNESCO recognise the importance of the scanning and digital methods available to it in addition to existing information, in this case going back millennia. The first point relating to its medium goals state: "Gathering of documentation, archives, and studies in an exhaustive manner, involving all relevant expertise, archaeological missions, historians, restorers, and conservationists who have studied the site before the conflict." (UNESCO, April 2016, pg.3). The potential of the use of Drones and 3D capture, of using Computer Aided Design in conjunction with these to create models of the site and its structures is vast. Considered further, they can also be adjusted to produce immersive 3D environments where the study of the structures, their materials and construction can be considered by experts as well as those who are simply interested. These remote access possibilities represent opportunities for study and conservation never before available to the degree of quality currently achievable. Arguably Palmyra could be left as a ruin for many years, as Syria perhaps continues to struggle, allowing for a comprehensive plan for restoration and/or commemoration to be developed in anticipation of the end of conflict.

2.1. ENHANCEMENT AND THE POTENTIAL FOR THE HYPER-REAL

Returning to the Hampton Court wallpaper, pre-digital methods would have left the conservationists with a conundrum. Options may have included leaving examples of all the period paper on the walls, or physically recreating the rooms elsewhere to show the Victorian, Georgian and Stuart layouts while restoring the Tudor apartment. However, the digitisation of elements of this process could see the wallpapers digitally recorded and scanned and recreated virtually, accessible from the Palace or anywhere with an internet link to view it, or the relevant immersive technology to experience them in 3D. Augmented reality devices already exists which allow for what cannot be physically seen to be virtually appreciated. Take for example The Shard in London, England where digital pads allow people on the observation deck to still see the cityscape even if the deck is shrouded by cloud. Cloudy or not, those devices, when pointed at a particular landmark can, at the press of the screen, detail the key information and facts for each of the important buildings visible from the Deck.

With regards to Which Version™ there is naturally a consideration of control with the creation of digital environments, including, in the case of the Shard, what visible buildings should be considered landmarks and worthy of highlightable information. However, the scope for amendments or the creation of multiple versions of the same space are theoretically infinite in this environment. With regards to historical sites such as Palmyra, it would be possible to not only create the pre-daesh site virtually, but also to use the other information mentioned in the UNESCO recommendation in order to achieve a recreation of Zenobia's Palmyra. These could all be achieved without the necessity of the Warsaw approach and could allow for a further strategizing over what to actually do with the site once recovered.

As noted earlier, Bevan identified a 'Disney operation' to the Warsaw project, linking this to comments made by the American critic and Marxist theorist Fredric Jameson. The notion of a Disneyfication of cities is an area Jameson has explored in a number of essays and the term has been used by other commentators to reflect on a theme-park style airbrushing of history, architecture and science in a style reminiscent of Walt Disney and the Disney Corporation's Theme Parks around the world. An examination of the term in a different context, in this case towards the representation of animals generally, not just specifically with regards to Disney products states: "Disnification (sic), it seems to me, is a specifically visual thing…the basic procedure of disnification is to render it stupid by rendering it visual." (Baker, 2001, pg.174) While architecture is significantly concerned with the visual, it is also vitally important not to forget, in the rush to restore those visuals, the importance of understanding what has been restored and what the reason for that restoration may itself represent. As an example of another project from the same period, the regeneration of the Victorian era Albert Docks in

Liverpool, England during the 1980s saw an opportunity for commemorating the impact of the bombings of WWII missed when the one corner of the docks damaged by a bomb was restored. The corner was internal facing and therefore only visible form within the dock complex. It showed the depth of the walls and the vaulted brick ceiling construction and supporting iron work. In the desire to restore the docks to a 'whole' structure, the exposure of the construction technology of the Victorian dock, and a chance to commemorate the damage of WWII and the contribution it had on the decline of the city, was lost. Were the docks being renovated now, what opportunities could digital capture and modelling allow for with regards to this element of the Dock's history?

Continuing with the example of WWII, some architecture and monuments relating to Nazi Germany in particular, have been deliberately destroyed in order to prevent them becoming sites for veneration by individuals and groups who support the ideology of the Third Reich. These include Nuremburg where mass rallies were held by the Nazi Party, and the demolition can also be seen as a cathartic act on the part of victorious parties to see the destruction of your enemy's works. Even as recently as December 2016, the decision was made by the Austrian Government to demolish the building in Braunau am Inn where Nazi Leader Adolf Hitler was born. Architecture and monuments can have a destructive power beyond the positive need to remember the horrors of the past. A recent example of how digital technology can be used to augment this is the creation of a virtual reality version of the Auschwitz concentration camp in order to assist in the prosecution of war criminals. To, physically, recreate the gas chambers of a concentration camp would be distressing and could also inadvertently create those very sites of veneration authorities are still trying to supress.

It could be argued, at the extreme end of the concept of Which Version™ that such a suppression of sites such as Hitler's birth place is a form of control through destruction and is on a part of the spectrum where (much) further along, the destruction of Warsaw sits. It is also easy to dismiss those arguments by contextualising those events and their outcomes against the weight of evidence and the general ethical code most societies abide by. However, there is a potentially dark side to digitisation relating to concepts of the hyper-real achievable in digital renderings, immersive technologies etc. It is no longer necessary to have the Nuremberg of the late 1930s and early 1940s physically present in Germany in order to appreciate in 2017 the grandiose footage of German filmmaker Leni Reifenstahl's 1935 propaganda film: Triumph of the Will. The film used aerial footage of the architecture of the city and Nazi parade ground of Nuremburg to glorify the achievements and power of Hitler and the Nazis. The awesome, awful horror of this and indeed Albert Speer, Hitler's architect's vision of a new Berlin, Welthauptstadt

Germania[11] can be seen in full hyper-reality in current TV shows such as The Man in the High Castle[12]. The physical buildings, considerations of how to build them, materiality etc. do not exist as concerns of restrictions in these immersive digital realities. Thus as with any technology, its application can be varied. How it can be applied to strike a balance between the various forms of architectural restorations detailed in this paper is a task for those concerned with what to do with Palmyra. Whether it can also be used to reflect the most recent horrors inflicted on the historical site, the wider region and peoples is another difficult conversation, particularly as the likely future custodians of the site is the Syrian regime whose legitimacy nations such as the United Kingdom question.

3. The Historical Narrative

The task facing UNESCO and its associates in Palmyra is daunting, though recent examinations suggest the damage has not been as extensive as first thought. However, as noted in this paper, the challenges around the site are significant. With regards to restoring what has been damaged by daesh, it is obvious what monuments should be restored in the archaeological city. But in neighbouring Tadmur, the first building daesh destroyed was the notorious Assad[13] regime prison where enemies of the state have been held, allegedly tortured and executed. If you seek to achieve a full reset of the site, does the prison go back up? From our perspective, the answer is a simple no. However, the likelihood is Palmyra will be governed again by the current Assad regime and those decisions rest with the victor.

Who controls a recovery is important. Returning to Warsaw, Bevan pushed Jameson's point further: "…there needs to be a 'careful disassociation between the categories of historicity and authenticity.' The deaths of millions of Germans and Poland's own Germanic heritage have been lost in the narrative of Warsaw's celebrated rebuilding.' (Bevan, 2006, pg.182) The visual recreation of Warsaw does not truly reflect the history of the city that existed before 1939 or the one that suffered under the occupation. Even considering the current example of Mosul, daesh have blamed the US air force while the Iraqi Government sees the destruction of the Great Mosque as the last gasp of a defeated force. Both narratives serve the propaganda purposes of each side without really reflecting reality.

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[11] World Capital Germania

[12] Based on Philip K. Dick's 1962 alternative history novel where the Axis powers of Germany and Japan won WWII and vie for control of a divided United States.

[13] Syria has been ruled since 1971 by the Assad family.

Palmyra is an example of an architectural palimpsest[14] where layer upon layer of history and civilisation has been built up and can be pulled back to reveal elements of a shared past. The simple reconstruction of a pre-daesh Palmyra misses an opportunity to mark how this site, the repository of so much evidence of different civilisations' rise and falls should also reflect the modern failure of our civilisation and the regional powers. Gibbon commented on attempts by Rome to rebuild the city "But it is easier to destroy than restore." (Gibbon, 1776, pg.319) In this modern instant, it is now possible to do more than just restore with the careful, evidence based creation of virtual versions of the site. These could be invaluable for future education and, should cultural vandals ever damage the site again, useful for restoration.

UNESCO's second medium term recommendation states: "Elaboration of a comprehensive approach and an overall conservation plan for Palmyra after the end of the conflict, to achieve international standards and high-quality scientific methods, and establish an inclusive and participatory process." (UNESCO, April 2016, pg.3) As with the Darlington interview with regards to Mosul, a key consideration is to make whatever restoration is undertaken an inclusive one with the people of Palmyra. What Version™ of their city do they want reflected when the experts have finished their work? While it is clear history is written by the victors, it is also a truism oft repeated that those who ignore or forget history are doomed to repeat the mistakes of the past. Palmyra, like the village of Oradour-sur-Glane, Coventry Cathedral and the Gedächtniskirche should be more than just a reconstructed relic to the past. It should be a statement in stone and a digital record recognising its past, acknowledging the impact of the present, and acting as both a warning and a hope for the future.

Drawing a conclusion from a paper aiming to begin a conversation around What Version™ the possibilities of digital modelling provide in the setting of a future historical narrative for a site like Palmyra, it is evident context will be everything. Establishing a context acceptable to all in calmer times can be seen in this paper as potentially fraught with difficulties arising from cultural, social, historic demands, as well as those arising from a need to see the final result reflecting recognition of the need to both memorialise while also remaining part of a living history. The paper demonstrates any outcome, regardless of its eventual aesthetic merits, be they charges of Disneyfication or otherwise, can only be achieved through dialogue which is inclusive of these varied demands. Reflecting again on Palmyra, sitting as it does in the middle of the ongoing Syrian crisis, it is difficult to envisage how this particular, inclusive conversation can start, or how contextual issues can be guaranteed and respected. As such, a remote, digitised Palmyra may be the only fair place to start.

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[14] A page where previous text has been scraped away or washed off for reuse, often leaving some residual marks from its previous use.

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MIND THE (PERFORMANCE) GAP

Embracing Technology to Enhance On-Site Performance

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Abstract. The demand for low energy buildings is something which will only increase over the coming years due to both a top down approach from government, in terms of legislation, and a bottom up approach from clients who are becoming more informed in relation to performance related aspects. Low energy design calls for a reconsideration of how buildings are designed and constructed, with materials and detailing being a key part of the process. A performance gap in the sector has been identified between the predicted performance of buildings at the design stage and how they actually perform once constructed. This can occur for a variety of reasons including poor workmanship and on-site practice, substitution of materials from those originally specified and a lack of inspection and validation in terms of what is being constructed. This is an area requiring urgent consideration to ensure clients are getting the buildings they pay for and projected carbon emission targets are accurate. This study highlights the performance gap from a Northern Ireland perspective, investigating issues with low energy design via a case study methodology. The study identifies issues in relation to on-site practice, verification and lack of communication between design team members before investigating how technological advancements and BIM processes can assist. The paper concludes by proposing a scaffolding approach which could allow for a more robust system, potentially closing the aforementioned performance gap.

Keywords: *Building Performance, Technology, BIM*

1. Building Typology Evolution and Low Energy Design

A case could be made for the strong correlation between early architectural design traits and the low energy design we know today. Vernacular buildings were a low energy building type of their era, using compact forms, building mass and carefully placed openings to assist with controlling the internal environment. Early cottages (Figure 1) were commonly single storey with a relatively small footprint, allowing the building to be heated quickly and the heat to be retained within. Buildings were designed to meet the essential needs of the inhabitants, with both local materials and workers used to construct the buildings. Thatched roofing was common, this was not only sustainable, but a natural insulator. The thick external walls also helped to reduce heat loss. Local knowledge in relation to wind direction, sun path and weather trends were also considered during design along with building form and position of openings.

Figure 1. Vernacular Style Building in Maghera, Northern Ireland

During the Renaissance period, Scheer (2014) outlines that the architect's primary concern was building form, with the builder taking responsibility for construction. Whilst Scheer (2014) rightly alludes to the separation of design from construction in this process, it was not a major issue in early architectural designs due to the expert knowledge of the builders and the limited range of materials from which to build, therefore high performing buildings, in relative terms, were achieved. On a related point, Barrett (2013) highlights the role of the Master Builder who historically prepared drawings and executed construction work. The building design process has evolved to become more focused on science and materials. However, the principle of separation between design and construction still exists (Scheer, 2014). This separation, combined with more complex construction forms, the vast array of available materials, builders lacking knowledge of new methodologies and intermittent inspections is contributing to a performance gap in the industry between intended performance at the design stage and achieved performance in constructed buildings. "*Investigation into the Performance Gap is therefore a priority for government and a wide spectrum of groups across the sector*" (Zero Carbon Hub, 2014).

Whilst building typology has evolved to be more performance driven, the process by which buildings are designed and inspected has not kept pace. Outdated forms of drawing communication via two-dimensional representational plans (see Harty, 2016) are still the main method of conveying design intent, coupled with an over reliance on human inspection to ensure they are constructed as intended. If higher performing buildings are to become the norm this needs to change; more intelligent design and more robust regulatory and validation processes are required. This assertion has been validated recently in the United Kingdom (UK) by the publication of the Independent Review of Building Regulations and Fire Safety Interim Report in the aftermath of the Grenfell tragedy (HMSO, 2017) and the Independent Inquiry into the Construction of Edinburgh Schools (City of Edinburgh Council, 2017). These publications highlighted issues with current regulatory processes and quality assurance respectively. Findings from a 2018 survey from the CIOB highlighted serious issues in relation to management of quality for the aspects of supervision, sign-off and workmanship (Construction Manager, 2018). It could be argued that current processes have allowed for bad practice to occur on-site in relation to aspects of building details, with this not being picked up in many instances due to the nature of the current inspection process (Comiskey et al, 2018).

2. Historic Problems in the Quest for low energy Design

Within Northern Ireland, whilst traditional construction methods are still the norm, designers are beginning to embrace new construction methodologies as an awareness of the benefits of low energy design becomes apparent. Some modern construction methods, such as Super Insulated Masonry Systems (Quinn Building Products, 2018), are reverting back to solid wall systems to maximise thermal performance, whilst there is also an increased interest in modular construction forms as the benefits of such systems become more widely recognised. New design approaches can pose challenges, especially the standards and regulations designers are required to become familiar with if low energy certification is to be achieved. Over recent years Passivhaus (BRE, 2018) design standards have become more widespread, and the Nearly Zero Energy Building (NZEB) requirements as set out in the European Performance of Buildings Directive (EU, 2010) are looming. Irrespective of BREXIT, it is anticipated that similar standards, albeit potentially in a different guise, will be introduced. This all means that designers will increasingly be faced with new technologies and processes and contractors will be tasked with implementing these on site.

A fundamental issue on construction projects is key technical details and materials decided during the design stage being changed during construction without the input of knowledge of the wider project team (Comiskey et al, 2018). For buildings to be truly low energy, on-site practice must be addressed. There is an expectation by clients that buildings will be constructed and perform in alignment with the as-designed plans. However, anecdotal evidence would suggest that this is not always the case. This assertion is supported by findings from a study highlighting that carbon emissions from new homes can be up to three times in excess of design stage estimates and issues with the building fabric in relation to actual performance compared to original design targets (Innovate UK, 2016). This would suggest that not enough is being done to monitor what is being built, resulting in numerous knock on effects. Firstly, the as-designed building plan or model is no longer accurate; and secondly, clients are then moving into or purchasing buildings which do not perform as expected in terms of their energy performance. This leads to the situation whereby a design may be highly energy efficient on paper, but not in reality. These issues can be traced back to a breakdown in communication between the design and construction teams and a regulatory process which lacks sufficient rigour and enforcement due primarily to the absence of a standardised and robust methodology to obtain compliance.

2.1. TECHNOLOGICALLY DRIVEN SOLUTIONS

As already alluded to, a change is required in the design and verification of low energy dwellings. This change is beginning to happen thanks to the Building Information Modelling (BIM) approach and introduction of digital technologies into the design and construction process. "*With BIM and computational design, architects have, for the first time since the codification of architectural drawing in the Renaissance, a truly new medium with a different epistemological basis*" (Scheer, 2014). In this new digital enabled world, what is required is a detailed digital simulation (see Scheer, 2014), something which can be delivered through BIM. BIM does not simply comprise of using authoring or analysis software, it is a process change. It has opened the door to new working methods in the construction sector and expanded into something bigger in the form of digital construction possibilities. BIM has moved on from simply being a process for designing and managing built assets by instigating a host of related technological innovations linked to the broad BIM process. In short, advances in technology have a lot to offer the construction sector and BIM and associated technologies can potentially create a more intelligent and cooperative relationship between the project team. Whilst not a panacea, technological advances may facilitate a virtual link between the designer, inspectors and contractors.

3. Research Methodology and Data Analysis

This study aims to complement the findings emerging from the review of literature with primary data in the form of structured interviews recording the views of industry experts on the current issues in relation to low energy building design and the potential for technological approaches to assist. The study is an example of real world research (see Robson & McCartan, 2016), with a qualitative methodology deemed most appropriate for this study due to the area under investigation. That said, there is an element of a mixed methodology approach due to the use of NVivo for the purposes of analysis. A case study was selected as it allows the researcher to "focus in-depth on a 'case' and to retain a holistic and real-world perspective" (Yin, 2018). Such an approach has been found to be especially valuable in practice-orientated fields, providing a not only a spectrum of valuable information, but also in-depth analysis of the topic being addressed. The case study consists of structured interviews; Gray (2014) suggests that interviews are appropriate for a small scale study, supported by a scoping review to identify existing technologies and processes which may assist in proposing a new workflow. Structured interviews were deemed the most appropriate data collection method as they tend to reinforce reliability within the answers given. It was also deemed an appropriate data collection method due to the researcher having some background knowledge of the research area. As outlined by Wilson (2013).

"Structured interviews are most appropriate when the product team is aware of the major issues in the project and wants to collect detailed and consistent information about those specific issues."

To add a further degree of rigour, NVivo software was used to assist with data analysis, allowing the written interview transcripts to be more easily evaluated and emerging themes identified. Hilal & Alabri (2013) outline that the use of such software "*may significantly improve the quality of the research*." Due to the research involving human participants in the collection of data, ethical approval was sought and obtained.

Those interviewed were purposively selected (Silverman, 2010) due to their expertise, coming from backgrounds in Architectural Technology, Architecture, Surveying and Construction Materials. This selection methodology aimed at obtaining knowledge from a diverse group to identify common themes. In total six professionals were interviewed. Although the length of interview was shorter than that recommended by Rowley (2012, cited by Gray 2014), this was justified by the level of study and the interviewer having knowledge of the area under investigation.

4. Case Study

The interview responses were divided into two main areas, the performance gap and use of technology. Due to the limitations of this paper only a summary of the main findings are presented.

4.1. THE PERFORMANCE GAP

The main issue resulting from the interviews was in relation to communication, or lack of, between designers and contractors, with interviewees giving examples of instances on projects where details and materials were changed on-site without the prior knowledge of the designer. This becomes an issue once the problem is identified, as the change to the material or detail makeup may mean that the said detail does not perform to the same standard as the original design. On many occasions such aspects are only identified long after the change has taken place due to lack of on-site verification and comprehensive inspection. Indeed, on some occasions the issue is never seen due to the work being covered up. This all links back to the performance gap previously discussed. The construction industry was described as a battle, a contest between the contractor aiming to maximise profit and the designer aiming to maximise building quality and performance. The issue of mind set in relation to material specification and cost was raised, with the contractor cost driven and the designer performance driven. In terms of the performance gap, the issue with small scale projects not having someone acting in the capacity as a Clerk of Works was also highlighted.

4.2. USE OF TECHNOLOGY

In relation to the potential for digital technology or BIM processes to assist with closing the performance gap, the responses suggested that a greater knowledge and understanding of these areas was still required. However, one noteworthy response was as follows:

"When you spend the time to consider and think about what BIM is and the technical side to it, it can be seen as an intelligent model. And what is a passive [low energy] house? It's an intelligent house in ways, because you are actually trying to design it so that it can deal with all these issues. It stands to reason, that there would be a benefit form them working alongside each other, they do at the moment, but it is not fluent in any way."

Views were wide ranging in relation to verification procedures and on-site practice, perhaps reinforcing the need for independent third party verification. The move away from traditional construction methods results in a change in mind set. This was apparent in the interviews, with signs of many years of repetition in terms of the delivery of projects using tried and tested methods in many of the answers given. As stated by Pitts (2017), "*Some important elements in determining the potential to achieve energy efficiency in buildings are the attitudes and knowledge of those involved in delivering them*."

4.3. DATA ANALYSIS

For identification of recurring themes, NVivo software was used. A word cloud highlighting the most frequently occurring words from the interview responses can be seen in Figure 2. NVivo also created a summary of the number of times specific words were recorded. The most commonly occurring words from the interviews included site, construction, design, energy and details. This highlights the importance of the on-site aspects as well as the design details to ensure energy efficient design.

Figure 2. Frequently Occurring Words.

5. Discussion

Higher design standards in low energy projects may result in increased issues on-site, with new materials and construction methods being introduced. During the interviews, much focus was placed upon the cost of materials and their installation. As outlined by Nelson et al (2010, cited in Zalejska-Jonsson et al. 2012) “*Financial and insurance institutions seek strong evidence of profitability in green projects*”. Resultantly, Issa et al (2010 cited in Zalejska-Jonsson et al. 2012) outline that “*Investors and developers defend the reluctance by expressing the concerns about the extra cost of ‘green’ buildings and the highly speculative return on investment and payback period*.” A counter argument to this would be that low energy design should begin with a fabric first approach and a focus on the performance of key building details. Whilst this may incur some cost increase in relation to the materials used, workmanship and on-site practice are aspects which do not add cost, but are critical in terms of performance.

Technology may be the solution to discouraging the practice of details being altered or changed on site. Using technology to verify constructed details and materials used may not only improve communication between designers and construction teams, as both know there is no hiding place, but also reduce the likelihood of changes being made to the design without consultation and agreement beforehand. This study is not exhaustive in relation to the myriad of issues which can arise in low energy design projects, however, from the issues that have been identified, it would appear that the BIM process and use of digital technologies could deliver various benefits. BIM and graphical programming is already being used to assist with verification of Passive House requirements (McNamara, 2017). There is also the potential to use the model, assisted by other digital technologies and work processes, to record and verify design progression, especially in relation to important details.

Technological advancements such as the use of Quick Response (QR) codes for commissioning, Radio Frequency Identification (RFID) tags for tracking, Unmanned Aerial Vehicles (UAVs), Laser Scanning and Photogrammetry are already being used on projects. Indeed the potential for UAV or Drone usage for visual survey inspections has been highlighted in advice notes (DCLG, 2017) following the Grenfell tragedy, with their usage already approved for asset survey data capture by Transport for London (CIAT, 2018). In addition, a number of research projects are also investigating the general area of energy and performance related issues on-site (Built2Spec; INSITER; ACCEPT). Companies specialising in robotics linked to construction and some of the above processes have also been formed (Scaled Robotics, 2018) along with those utilising Artificial Intelligence (Doxel, 2018). It is forecast that the potential for use of robotics on construction sites is soon to be realised in Japan (For Construction Pros, 2018). Such an approach, the collaboration between humans and robots, is referred as a cobot. As outlined by Colgate et al. (1996) "A 'cobot' is a robotic device which manipulates objects in collaboration with a human operator." This a logical technological step forward for the construction industry, and simply follows other industries such as manufacturing. Focusing on verification of important on-site details, rather than selecting a single technology as a possible solution, the answer may lie in the use of such a collaborative technological or 'COLT' approach. At the cornerstone of BIM is collaboration, hence the combination of a number of above technologies working in unity, linked to the BIM process and combined with the knowledge and skillset of an individual to orchestrate and act as the link between the design and construction team may be a possible solution.

A combination of technologies which could not only flag that a detail is incorrect, but have an ability to identify a material change, impacting on performance, would be significant. However, it is important that a balance is struck between technological and human intervention. The knowledge and input of an individual's creativity and design influence is equally as important for a design to succeed. Technology should be used as an assistive authentication and verification tool in addition to the professional's background knowledge.

6. Conclusion

The need for improved verification standards is vitally important in future construction processes to close the performance gap. Findings would suggest that although some developments have been made in relation to collaboration and communication thanks to BIM workflows, especially on larger projects, more needs to be done in terms of verification. The emerging technologies within the construction sector can conceivably provide viable solutions to associated problems.

In terms of proposing a technology enabled workflow (Figure 3), this would begin (Step 1) by following the BIM Level 2 methodology, with a collaborative approach adopted and all team members engaged from the outset. This in itself would begin to solve many of the issues identified in this study. Moving forward (Step 2), the model could potentially be used for part automated compliance checking (see Ding et al, 2006; Eastman et al, 2009; Malsane et al, 2015) supported by human intervention and verification. This would be stage one of the COLT approach, with stage two being the use of a combination of smart technologies to flag any materials used or details constructed on-site which have not been specified and approved during the design and modelling stage (Step 3). This would conceivably allow for an accurate as-built model for the purposes of managing the building (Step 4). Figure 3 represents a scaffold approach which could be adopted, requiring the full completion of one step to move onto the next.

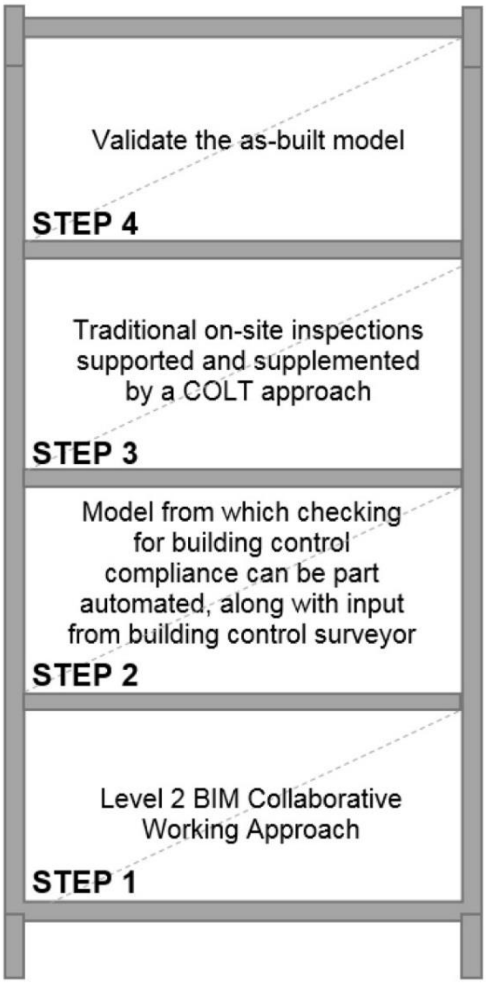

Figure 3. Proposed Scaffold Workflow.

Having analysed the available technologies to assist in achieving Step 3, it would appear that rather than selecting one to assist in the on-site verification perhaps a 'COLT' approach would be more beneficial, combining drone usage, high level cameras and laser scanning linked to a BIM model for the purposes of verification with human intervention.

Godden (2016) outlines the notion of a digital master builder role. This is an interesting concept, bringing back this historic role and reinventing it for the twenty-first century to help close the gap between design and construction. Such a role would complement the proposed scaffold approach by enhancing communication and ensuring on-site performance. What has been proposed is an optimum solution, but it has to be acknowledged that the industry in Northern Ireland and the traditional way of working means that it is not a realistic possibility in the near future. The greater use of prefabricated methods may be a more immediate way of ensuring better constructed details, but an approach that suits all construction types is required.

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THE CONTEMPORARY ARCHITECTURAL APPROACHES FOR FACADE DESIGN AND TECHNOLOGY OF INDUSTRIAL BUILDINGS IN TURKEY

Professional Practice

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Abstract. Turkey is a developing country located between Asia and Europe. This location has made Turkey a transition point which has hosted ancient transportation routes like Silk Road, and modern transportation roads like Baku–Tbilisi–Ceyhan pipeline. This geographical location still keeps the commercial and industrial activity levels high which is promoting industrialization of the country. The industrialization is increasing the demand for all kinds of buildings. As a result of evolving industrial enterprises and increasing incomes, a lot of industrial buildings are being designed and constructed. With the help of governmental incentives, some companies decide to renovate their old factory buildings and some decide to build completely new buildings. On the other hand the construction industry is the largest sector in Turkey. The contractors of Turkey are major players especially in the Middle East, former Soviet Countries, and North Africa. These contractors are also making the architectural, civil and mechanical engineering offices, and building materials, and components sectors evolve. Hence, Turkey is a fruitful area to make architectural design and technology related research. In this context, architectural design processes, which include both the conceptual and detail design sub-processes, of five industrial buildings in Turkey are evaluated in this study. Especially, design approaches for the facades of the selected buildings are focused upon. The roles and cooperation of different specialists and professional practices, and the integration methods of the facades with the other sub-systems are investigated within the

design and construction period. As a consequence, determination of the current status of professional practice on the subject of industrial buildings in Turkey is aimed to be photographed.

1. Introduction

Turkey is a developing country placed at the transition point between two continents; Asia and Europe. This strategical point has significant impact on economy and foreign relations. Connecting west and east since the ancient times Turkey has hosted the transportation routes from Silk Road to today's modern Baku–Tbilisi–Ceyhan pipeline. These transportation roads contribute to industrialization of the country which leads to economic growth. As a consequence, building construction sector evolved due to the increasing demand for all kinds of buildings. As the industrial enterprises increasing and incomes getting higher, number of industrial buildings are started to multiply. Also governmental incentives encouraged investors to renew old factory building, to build additional structures to expand the business or to build a whole new facility.

On the other hand construction industry is the largest sector in Turkey. With almost 2 million employees and approximately 8-9% contribution to the GDP, construction sector has a significant impact on development of Turkey's economy. Construction sector constitutes 30% of the economy of Turkey considered direct and indirect effects on the other sectors. (Turkish Contractors Association, 2017). One of the significant reasons behind the construction activities in Turkey is urban regeneration. Since the established law on conversion of areas under disaster risk in 2012, a notable number of buildings are reconstructed to increase earthquake resistance of buildings and preclude illegal housing.

Figure 1. Urban regeneration in Turkey.

Turkish contractors are involved in a wide variety of projects not only in Turkey but also in many other countries. "In the period between 1972-2017 March, Turkish contractors have undertaken 9000 projects in 115 countries, with a total value of 350 billion USD.... In the 1972–2017 March period, according to the country distribution of international works undertaken by Turkish contractors, the Russian Federation has been the leading market with a share of 19.6%, followed by Turkmenistan (13.8%) and Libya (8.4%)." (Turkish Contractors Association, 2017). The driving power of the construction sector forcing other construction related sectors like architectural, civil and mechanical engineering offices, building materials and components sectors to improve.

In this context, the contemporary status of building construction in Turkey is aimed to be determined. The building life cycle and role of the professional actors in these life cycle steps is going to be evaluated. Architectural design methods and construction methods are going to be stated. Then architectural design processes, which includes both the conceptual and detail design sub-processes, of five industrial buildings in Turkey is going to be evaluated. Design approaches, the roles and cooperation of different specialists and professional practices, and the integration methods of the facades with the other subsystems are going to be investigated within the design and construction period. As a consequence, current status of professional practice on the subject of industrial buildings in Turkey is aimed to be determined.

2. Method

Architects in Turkey are grouped under the umbrella of TMMOB, Chamber of Architects which is a constitutional professional organization established in 1954 for public and community benefit. 37.30% of 52.264 architects who are members of the chamber practise their profession in İstanbul (TMMOB Chamber of Architects 2017). These architects became specialized on designing and constructing specific buildings. Selected office is a family corporation with 12 industrial building projects and numerous architectural competition prizes with over 50 years of experience. One of the partners of the company is an active member of İstanbul Associates of Architects in Private Practise which is an independent association with 75 active members. It is thought that choosing an office which is taking part in the sector for many years and experienced in the field of industrial building designs will be beneficial for making an observation about the current status of design process of buildings, factors and professional practices involved in the design process in Turkey. It is also chosen not only for the experience on the subject but also for ease of following and analysing the design processes, methods, and reaching people for interviews. Statistically it is not possible to make a general assumption based on the evaluation of only one architectural office. However the office selected to investigate is chosen because it is a good singular example for the area designated as the research space of this study with its professional experience on the industrial buildings. Design researchers like Jones (1992, p.46) defines the design process of an architect as "a black box" which cannot be easily observed by a third party. Yet still there are several methods for data collection that can be used. Data can be collected either from primary sources using observation, interviewing and questionnaire or from secondary sources such as government's publications, an organization's records, articles, journals, magazines, books, etc. (Kumar, 2011). Effective results cannot be produced using a single method, but instead several methods can be integrated and used together. First method used in this study is structured interview. Questions of the interview are defined beforehand and shared with the architects. Then previous industrial building projects of the office are collected and examined. Five of these projects are selected to be analysed as case studies in terms of different aspects in detail. Case studies are selected and evaluated according to four criteria; conceptual facade design approaches, detail design process of facade, interaction of professional practises in the detail design process of facade, and relationship between employer, designer and contractor. Later on, questions are directly asked to the architects working on the selected 5 case studies for additional information about the design and construction process. Conceptual and detailed architectural drawings examined and discussed with the designers. Data derived from the interview cross checked with observations and questions directly asked to architects involved in the design process of the case studies to understand the design methods and processes. In the light of the collected data, case studies and their evaluations are presented with self-reflection in this study that aims to grasp the architectural design process of industrial buildings in Turkey.

3. Architectural Design and Construction

Contrary to general acceptance, life of a building starts at the planning phase instead of operational phase. Building life cycle covers all the steps of the building in its entire life. Building life cycle has four phases; new built which contains strategy, construction decisions, design, project management planning, construction steps, use, refurbishment and deconstruction (König, Kohler, Kreißig & Lützkendorf, 2010). A building can be more effective if the design, construction methods and material choices are made thinking building life cycle through. According to ISO 15686-1:2011, phases of building life cycle contains "initiation, project definition, design, construction, commissioning, operation, maintenance, refurbishment, replacement, deconstruction and ultimate disposal" (2011, para 2).The success of an efficient building lies within its design process. The depth level of detailing in the design process affects the construction of the building and resemblance of the designed project and constructed building. In the design process architect makes the significant contribution to the project with a creative approach using different design methods. Different design methods can be used by architect according to the project or architect's way of designing. In the categorization of design methods, craftwork which is a primitive design method and design-by-drawing which is a method improved with the scaled drawings and division of labour can be assumed as traditional methods whereas designer as a black box, designer as a glass box and designer as a self-organising system are categorised as new methods (Jones,1992). Jones (1992, p.46) defines new design methods as:

From the creative viewpoint the designer is a black box out of which comes the mysterious creative leap; from the rational viewpoint the designer is a glass box inside which can be discerned a completely explicable rational process; from the control viewpoint the designer is a self-organising system capable of finding short cuts across unknown territory.

Many different professionals, like engineers, material producers, design managers, etc. take a role in the design process of a building. However, architects have the most important and active role in this process. Hasol (2012) states that the aim of an architect is creating buildings which are economical, ecological, aesthetical, respecting the geographical and local data, and responding to functions with the most appropriate material and technology choice. Hasol (2012) also claims that, as the buildings get complicated day by day, architect is forced to cooperate with other disciplines. Architect manages the coordination and collaboration of the technical team in terms of aesthetic, technical, and functional planning in the design and construction phase of a building.

According to Lovell (2010, p.12) "a building's envelope addresses the threshold between inside and out, between performance and form". Building envelope separates the interior environment of the building from exterior effects. It has the largest surface area amongst other building elements and therefore it is expected to show effective performance. Besides building envelope is important in terms of conceptual design as it constitutes the visible part of the building and attracts the attention. All things considered, building envelope is one of the most complex elements of a building.

Construction methods can be divided in two main categories: cast-in-place and precast construction. Cast-in-place construction refers to a production made in the place of the final product. This means the raw materials are put together in the construction site where the constructed element is needed to be. This type of the building construction method requires more labour and long production time but the work is adaptable. On the other hand the method of producing building elements other than the place the element will be installed is called precast construction. In this case precast building elements are assembled in the site which leads a fast construction. Use of precast materials may lower the labour costs but factory produced materials can be expensive. When using prefabricated materials all the details must be designed in advance since the material is not flexible. In Turkey, generally reinforced concrete structure is used in the dwellings and offices while steel structure is used in industrial buildings due to building form, functionality and long span distance. 58% of steel structures in Turkey are industrial buildings, 20% are towers, 13% are power plants, 5% are commercial buildings, 3% are bridges, and 1% are dwellings (Structural Steel Association of Turkey, 2005). In the roofing system of the dwellings timber structure and clay tiles, which are widely produced and used in Turkey, are mostly preferred. Whereas, in the industrial buildings steel structure and metal roofing materials are more popular. For the facade of dwellings and offices massive brick blocks are used whereas sandwich panels which are light and constructed fast are largely chosen for the industrial buildings.

In this paper, facade design and technology of the industrial buildings in Turkey will be evaluated in four topics. At first, architectural conceptual facade design of the selected case study projects will be investigated. After that design process of facade details and interdisciplinary relation with the designer and other professionals that take part in this process will be examined. Finally relationship between employer, designer and contractor will be analysed.

4. Case Studies

Industrial buildings are a specialized typology in terms of function and design. “Industrial building is a space where industrial production and storage tasks are performed. The term factory as alternative for industrial building includes generic aspects of industrial production.” (San-José, Losada, Cuadrado & Garrucho, 2007, p.3917). Parameters that are considered in design process of all kinds of buildings like facade pattern, material selection, structural system and integration of service systems constitute the key points of the design in industrial buildings. The need for a specialized and experienced architect emerges to clarify these key points and generate architectural solutions for them.

Production process is the main factor affecting the design process in industrial buildings. A professional consultant may take part in the design process to inform the architect about the production phases and procedures as layout of spaces will be set accordingly. Moreover it is important that the materials and systems used in these structures are economical because they are built with great investments from the producers. Thus, material producers may contribute the material choosing and detail design process to provide technical support and information about innovations in material sector. Material and system choices of facade affect both the exterior appearance and interior conditions of the building. Facade of industrial buildings can be designed to reflect the prestige of the company. On the other hand, facade design plays significant role to ensure a visual contact with exterior environment for workers in long operating hours to create a positive psychology.

According to interviews with the architects from the selected office, at the first phase of a project land area, topography, orientation, vehicle circulation, personnel and goods entrances, possible future extension area, production or storage type and capacity, number of employees are main factors affecting the conceptual design. The office spaces in the industrial buildings generally stands out to emphasize an attractive entrance to the facility as they diverge from the production or warehouse spaces in terms of facade aspect. Facade design may also be based upon the policies of the company to create a prestigious influence. Apart from these, some technical requirements may affect the facade configuration. For instance facade openings for the ventilation of the technical spaces, goods entrance, loading area and eaves for the protection of loading areas from weather conditions may be arranged to give an effect to the facade.

Different professionals take role in both conceptual or detail design phases of a project. Civil engineers, mechanical engineers, electrical engineers constitute the core technical team with coordination of the architect. In some cases other professional consultants may involve the process in terms of fire protection, hygiene, production process and requirements of the production spaces.

In the detail design phase, architect makes a proposal to the employer about the facade materials and system to realise the designed image. In this step building material producing companies involve the process to provide technical information, give counselling and propose materials and systems. The company may be chosen according to the suggestion of the architect or employer. Also, the type and thickness of the facade materials in terms of isolation are selected according to the heating calculations made by mechanical engineers. In compliance with the company's technical knowledge and architect’s design, detail drawings are developed.

In all cases evaluated below, the relationship with the employer and architect is the similar. For the project delivery method, design-bid-build method is used for all case study projects. In this method also known as traditional method, owner/employer makes contract with an architect for the construction drawings. Then bids are made with contractors according to construction drawings. Generally a deal is made with the lowest response amongst all the constructors.

4.1. CASE STUDY 1

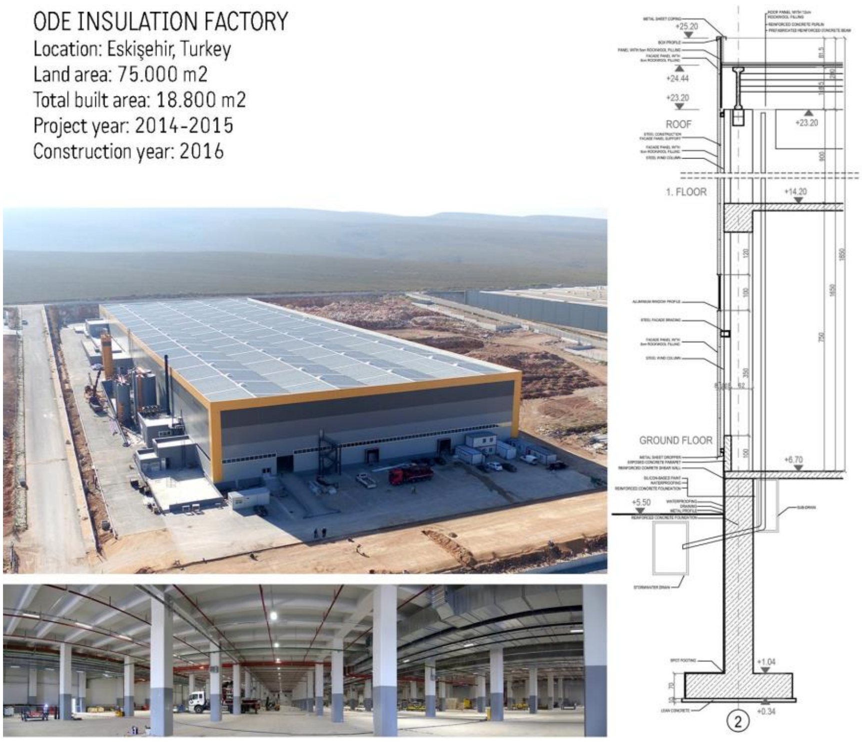

Figure 2. ODE Insulation Factory.

A factory is designed in 75.000m2 area with investment of a building material producing company named ODE. Project is planned to build in two phases. First phase is built which constitutes production space and service buildings with a total of 18.800m2. 22.200m2 future extension area for production and administration offices are going to be built in second phase.

Structural system is designed with a combination of prefabricated and cast-in place reinforced concrete elements. Columns are designed with maximum of 10m span and built with cast-in place construction method. Each column has a reinforced concrete footing with a maximum 4.1m width and 0.8m height which forms spot footing type of foundation. Roof is constructed with prefabricated reinforced concrete beams and purlins.

Although the company produces isolation materials for buildings, the thickness of their panels were not enough to ensure required thermal comfort conditions for the designed project. As a result of meetings between contractor and employer, a facade company that contractor suggested is chosen. Sandwich panels with 12 cm rock wool filling are used as roofing material. 93,36% of the 8.230m2 facade area are covered with panels, 1,32% are windows and 5,32% are doors. Sandwich panels with 8cm rock wool filling are used as facade cladding material. Facade panels are supported with steel wind columns and steel bracings. On the west side of the building, where the future expansion is planned, same facade panels are fixed to the pumice concrete wall with box profiles. Centrifugal fan gas unit heaters are used for heating in the production space.

4.2. CASE STUDY 2

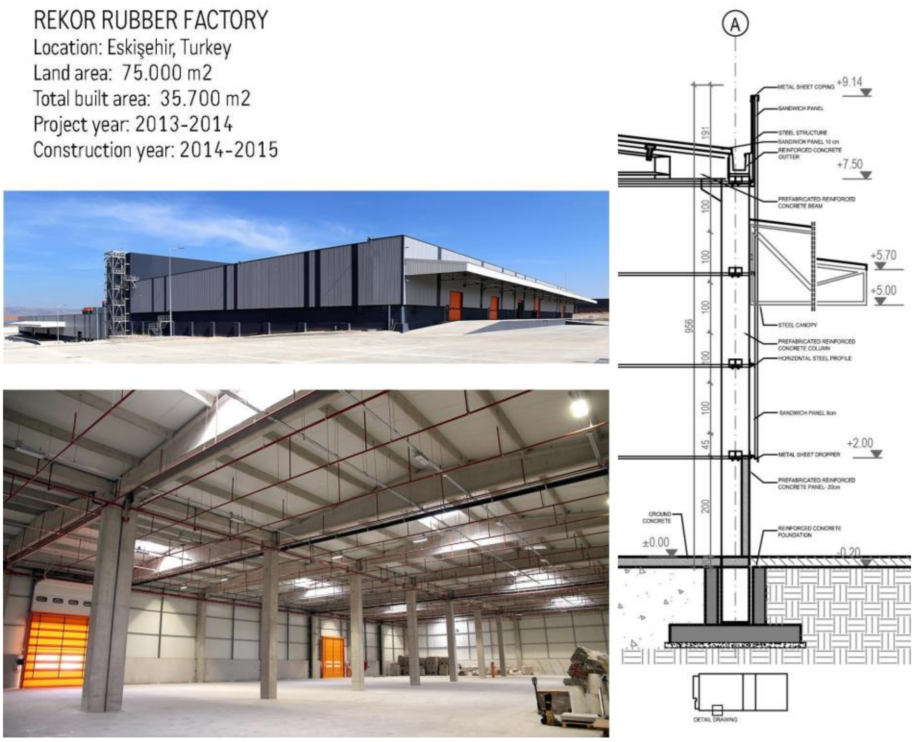

Figure 3. Rekor Rubber Factory.