School of Simulation & Visualisation

Glasgow School of Art

VIRTUAL ENVIRONMENTS: RE-INTERPRETING THE BUILT HERITAGE

Dissertation submitted for the degree of Doctor of Philosophy at the Glasgow School of Art

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I, Robin Stubbs declare that the enclosed submission for the degree of *Doctor of Philosophy* meets the regulations stated in the handbook for the mode of submission selected and approved by the Research Degrees Sub-Committee.

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Signed

[redacted]

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Abstract

The Built Heritage acts as a constant reminder of shared histories across society. It is experienced subconsciously through our multiple daily interactions with the physical environment we inhabit through buildings and spaces. However, this physical relationship with historic entities only serves to reveal a portion of the tapestry of experience contained within a building. Buildings and places are '*imbued with a message from the past*' that reveal a myriad of experiences associated with a place. This is referred to as the *'intangible'* aspect of the Built Heritage. It is within this scope of exploring the *intangible* that we can truly understand the full depth of past generations endeavours and achievements. Contemporary research within this area is largely underpinned by the written word and, in some cases the re-casting of information without thorough evaluation. The practice of applying digital technologies and processes to the Built Heritage area is on-going and continues to evolve, however this has focused primarily on advanced technical solutions to visualisation, data acquisition, data collation and reproductions.

I contend that a gap exists in contemporary research of the Built Heritage that successfully exploits the opportunities that digital technologies offer, through the implementation of (Building) Information Modelling, to enable access to the *intangible* richness contained within the historical legacy of a building, or place. In addressing this gap in knowledge, this research investigates the following questions:

- How can the application of digital information modelling, through the platform of virtual environments, create a new approach to accessing the *intangible* fabric of the Built Heritage?
- How can this novel approach enhance engagement with historic buildings and places so that it affords the end-user a greater level of understanding?
- In what way is this novel approach of significance to the wider heritage community in contributing to the theoretical discourse regarding the Built Heritage?

This research considers each stage of this novel process and puts in place a framework that allows access to this information that has not been previously considered. Furthermore, by utilising a series of Test Studies that are designed to demonstrate the new digital workflow this approach is evaluated through demonstrations, workshops, observational analysis, and interviews conducted on a selected audience of University level students. It then concludes with a discussion regarding where this work may reside within the broader academic heritage community.

Relevant Publications

Comiskey, D, **Stubbs, R**., Luo, X., Hyde, T. and O'Kane, E. (2018) 'The devil is in the detail: The link between building regulatory processes, on-site inspection, verification and technology, *2nd International Symposium on Small-scale Intelligent Manufacturing Systems (SIMS)*, pp. 1-6.

Thomas, K., Chisholm, G., Dempsey, B., Graham, B., and **Stubbs, R**. (2016) 'Collaborative BIM Learning via an Academia-Industry Partnership', *International Journal of 3-D Information Modelling,* 3, pp. 40-48.

Stubbs, R., Bourke, C., and Murphy, D. (2015) Applying Intelligent Applying Intelligent Modelling methodologies, through virtual environments, to the Built Heritage. Historic Waterford as a Test Study. In: *CITA BIM Gathering Conference.* Dublin :The Construction IT Alliance, pp.189-196.

Stubbs, R., Chisholm, G., Dempsey, B., Thomas, K and Graham, B. (2014) BIM in Education, an AEC interdisciplinary based Academia-Industry Test Study. In: *Conference proceedings of the 5th International Congress of Architectural Technology.* Aberdeen: International Congress of Architectural Technology, pp. 253-265.

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Glossary of Terms

AECO – Architecture, Engineering, Construction & Operations

AIM – Architectural Information Modelling

BIM – Building Information Modelling

CAD – Computer Aided Design

CDE -Common Data Environment

CGI- Computer Graphics Industry

DH – Digital Humanities

HBIM – Historic Building Information Modelling

HMD – Head Mounted Display

ICOMOS - International Council on Monuments and Sites

ICCROM - International Centre for the Study of the Preservation and Restoration of Cultural Property

ICT – Information and Communication Technologies

IFC – Industry Foundation Classes

IHM – Integrated Heritage Modelling

IHMEP – Integrated Heritage Modelling Execution Plan

IM – Information Modelling

IoT - Internet of Things

IPD - Integrated Project Delivery

LoD - Level of Detail

LoI - Level of Information

NPR - Non-Photo Realistic

UI- User Interaction

UNESCO – United Nations Educational, Scientific and Cultural Organization

VE – Virtual Environments.

VR – Virtual Reality

'Places remember events, and in this we can recognise how deeply time has become embedded within place, and might be said to have become one of its dominant characteristics'

James Joyce

1.0 Introduction

The Built Heritage is ever present and a reminder of our shared histories as a diverse society. It cannot be categorically defined as the ubiquitous nature of the term lends itself to individual interpretation depending on its context. The internationally recognised heritage organisation, ICOMOS (International Council of Monuments and Sites), identify that the Built Heritage comprises of two key components; that being the tangible which relates to physical buildings and artefacts, and the *intangible* that refers to the facets associated with a building or place that are less tactile but equally as important such as the practices, representations and expressions associated with the physical space (ICOMOS 2014, 36). Therefore, it is not surprising that research in this area is extremely diverse and provides an opportunity to established fields of study such as architectural history, building conservation, archaeology, and humanities for interdisciplinary research under the term Built Heritage.

Simultaneous to this, society at large is currently experiencing what some have termed the fourth industrial revolution (Radziwill 2018, 108-109) that being the age of disruptive digital technologies and trends such as the Internet of Things (IoT), Virtual Reality (VR) and Artificial Intelligence (AI). This seismic shift has permeated not only academic research but has altered the way in which we communicate, interact and indeed conduct commerce within society.

I argue that a gap exists in contemporary research relating to the Built Heritage, such that it does not successfully harnesses the capabilities of digital technological advancements to take advantage of the richness of the Built Heritage through combining its *tangible* and *intangible* forms. I contend this is the case primarily in public realm works, such as historic civic buildings and places of worship but is applicable to projects of more modest scale also. Through a multidisciplinary approach, a framework consisting of theory building, followed by robust testing, this thesis addresses that gap and provides an innovative approach to facilitating access to the full breadth and depth of information contained within, and associated with, the Built Heritage. To determine the value of this new approach I focus on one particular audience of university level students to demonstrate its capabilities for the primary reason that this cohort are the practitioners of the near future.

In addition, this work details the importance of such an approach to the heritage community. By contributing to the theoretical discourse relating to the Built Heritage, and in particular the sub-discipline of building conservation, this research articulates *'why'* it is significant and discusses where this work may land within the wider Built Heritage sector and the implications this has for the future.

1.1 Background

This thesis builds on my experience of many years lecturing to undergraduate and postgraduate architectural students coupled with applied research in the general areas of the Built Heritage and the implementation of novel technologies and processes to the mainstream AECO (Architecture Engineering, Construction & Operations) sector. Within the AECO sector, the advancements of digital and disruptive technologies have manifested in the creation of what is referred to as Building Information Modelling (BIM). In short, BIM is a multi-dimensioned model-based process for creating and managing information for the lifespan of a building and is explained in greater depth in chapter two. Interestingly, as BIM has begun to transform the AECO sector this has been reflected within institutes of higher learning. For instance, many Universities throughout Ireland and the UK now deliver programmes at both undergraduate and postgraduate level that have a BIM ethos to the core that provide graduates for the construction industry most notably, Waterford IT (WIT), Technical University Dublin (TUD), University of Salford, University of Strathclyde, University Ulster, University of Wolverhampton. Throughout my research experience to date it has been observed that, whilst attempts are made to integrate the Built Heritage and BIM, that a gap exists in aligning both practices to enable access to the *intangible* richness contained within the historical legacy of a building, or place.

Building upon research previously undertaken at master's level that focused on building conservation theory and empowered by real world experience of witnessing the advantages that digital technologies are having on mainstream construction practices, this thesis explores and develops a symbiotic approach that would be of benefit to both disciplines. This work has endeavoured to progress the application of computer science to building conservation theory whilst highlighting the opportunities to enhanced engagement with both the *tangible* and *intangible* aspects of the Built Heritage.

1.2 The Research Problem

I suggest that current research, both scholarly and applied, regarding building conservation and the Built Heritage is largely underpinned by the re-casting of existing information and unsubstantiated assumptions that have not been thoroughly challenged. For example, general assumptions are often put forward that older buildings are damp and draughty and so on. This statement may be correct, but it is rarely tested and simulated and as a result ill-informed design considerations can be deployed when proposing design interventions that may not be appropriate. The notion that computer science has a significant role to play in this area has not fully gathered momentum in terms of its application to the Built Heritage. Much contemporary research regarding the application of computer science has primarily focused on the *tangible* aspect of the Built Heritage in the form of visualisation, data acquisition, data collation and reproductions. As alluded to above this is particularly evident in relation to public buildings as evidenced by recent works to the Four Courts (seat of the Supreme Court, Court of Appeal, High Court and Dublin Circuit Court) building in Dublin. Contemporary digital technologies were duly employed in terms of surveying and producing measured documentation and visualisations. The building is not only a testament to the legislator of the Irish State but also plays a prominent role in the birth of the Irish nation, having played a key role in the 1916 Rising and the War of Independence (1922) bestowing a wealth of intangible heritage that is duly recorded but has not been curated within a robust digital repository for dissemination. Whilst this refurbishment was being undertaken the emphasis was on the physical building, the tangible. The recognition of *intangible* aspects of the Built Heritage has largely been overlooked. In short, the *intangible* is defined as the non-physical, the unseen, the cultural and spiritual practices that are intrinsic in all artefacts be it buildings, objects, peoples, or place and has been defined in greater detail in chapter two.

1.2.1 Research Questions, Aims and Significance

The primary research question that this body of work addressed was how can digital modelling, through the medium of virtual environments, increase the level of interpretation and engagement, of both *tangible* and *intangible* aspects of the Built Heritage in combination?

There were several interwoven threads that needed to be addressed in order to fully answer this question. The first was the clarification of key terms which are defined to help explain the scope of this study (refer to section 2.1.5), secondly the relationship that currently exists between computer applications and building conservation, and finally, the processes and frameworks that enable interpretation and engagement to occur in the first instance. An aspiration of this research was to expand on the existing narrative regarding building conservation by conversing to a wider audience through a digitally facilitated immersive experience. As such, the ***research aim*** was;

- to critically assess how the Built Heritage is consumed by the implementation of integrated digital modelling and simulation through demonstration and implementation, that will engage the end-user.

In order to achieve this aim, the ***objectives*** were;

- to develop a novel workflow that utilises BIM processes to capture, store and distribute heritage datasets.
- to appraise and evaluate the robustness of such a novel approach.
- to articulate the significance and contribution to knowledge for the wider research community of digital heritage.

Finally, if research into the Built Heritage is to remain relevant within academia, and provide informed discourse, then the methods that are employed must also embrace contemporary technologies. Therefore, the significance in achieving this aim has been to provide a new methodology for digital modelling, in the context of the Built Heritage, that facilitates a rich immersive experience for the end-user, unavailable through other means, within a Virtual Environment (VE).

1.2.2 Thesis Chapter Outline

Chapter two commences by establishing the context for this research with pertinent definitions relating to the Built Heritage and Virtual Environments, and their application to the rest of this thesis. Having established foundational definitions for key terms the emphasis then turns towards a review of interpretative tools currently deployed within Built Heritage. This is purposely organised into two threads of traditional and digital interpretive methods. The ensuing discussion focuses on current published research in the wider area of digital Built Heritage. Following a summary of the research findings and identification of the gap in knowledge within the Built Heritage sector the chapter concludes with the introduction, and definition, of the new workflow.

Chapter three identifies the appropriate research tools and techniques that have been employed throughout the duration of this work. An overview of the research design illustrated how each facet of the hypothesis was tackled. In addition, all evaluation methodologies employed are appraised and discussed regarding the appropriateness for assessing the research outputs. This chapter concludes with a discussion of the relevant ethical, and data security issues, that were encountered with appropriate mitigation measures summarised.

Chapter four outlined an in-depth explanation of IHM (Integrated Heritage Modelling). Firstly, the theoretical framework on which the workflow was predicated on is explained through discussion of the three key stages of the process that are *Information*, *Interaction,* and *Immersion*. These are key terms that are constantly referred to throughout the text and are explained comprehensively within this section. Secondly, the technical workflow of IHM is clearly mapped through a step-by-step format with each segment of the process explained and illustrated where relevant.

Chapter five demonstrates the initial stage of the IHM workflow, *Information,* through the format of an applied Test Study. Test Study A focused on *Information* through an exploration of digital modelling applied to a domestic scale building that focuses on physical building metrics such as thermal performance and user comfort. These findings are then put forward to the selected participants and evaluated through a series of on-site workshops that took place at third level universities throughout Ireland and the UK.

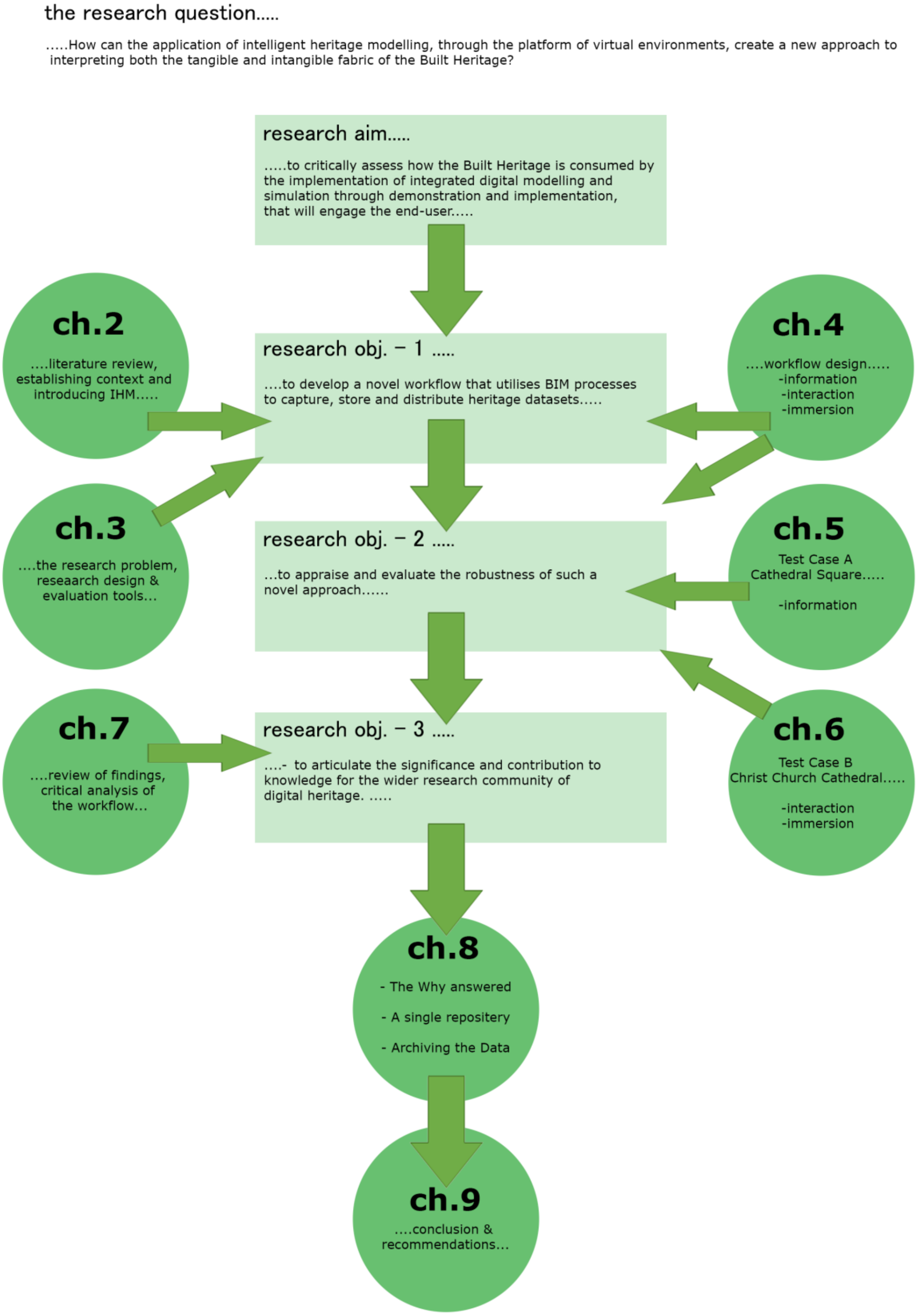
Learnings from Test Study A in chapter five are built upon in chapter six and a further Test Study is generated. Test Study B illustrates the more complex facets of the IHM workflow and demonstrates the *Interaction* and *Immersion* stages of the process on Christ Church Cathedral. In this instance, facets of historic data of a *tangible* and *intangible* nature are made accessible to the end-user. There then follows a process of evaluation through a series of participatory workshops.

Chapter seven is presented as the conclusion of the primary research where the novel IHM workflow of assembling data rich models is evaluated for robustness and rigour. The significance of the findings are appraised, interrogated, and evaluated accordingly through comparisons with similar workflows in cognate areas of research and interviews conducted with a selection of current knowledge providers in the general subject area of the Built Heritage.

Chapter eight consists of a focused discussion of the information unearthed in the work to date. To the fore of this discourse is the research question that was established in chapter two, structured in chapter four, outlined in chapter five, demonstrated in chapter six, and evaluated in chapter seven. Following this examination, the outcomes are further refined to envisage a way forward for this work and how it may be utilised in an effective manner within building conservation and possibly similar areas of research.

Finally, chapter nine is the conclusion of this project whereby the implications of the findings are discussed. The initial research aims of chapter one is revisited to establish if the body of work has successfully achieved its objectives. This chapter concludes with a full discussion regarding where the outputs may be explored further in any future research and suggests possible pathways for exploration.

Figure 1.2.2.1 - Diagram illustrating the thesis structure and relationship of content to aims & objectives*.*



2.0 Research Context

In order to clearly define the context of my research it is important to note that the origins of this work are broadly rooted in the fusion of digital technologies and building conservation. This amalgamation of what may appear diverse areas of research presented an opportunity to further develop the digitisation of the Built Heritage. Cognate areas of study in digital humanities have coined the phrases virtual heritage or digital heritage (Champion 2011, 25) whilst practitioners in the building conservation field refer to such fusions as heritage BIM (H-BIM) or digital reconstruction. Regardless of the specific research area, the over-arching contention is that these developing digital technologies of the past decade have altered methodologies in both how primary research is undertaken and how the findings are disseminated and interpreted. Academia is not alone in this regard. In many areas of society, the age of disruptive technologies has dramatically altered our behaviour in many aspects of how we live our daily lives. (Thomas 2019). Digital disruption is a constant and will continue to influence the work practices and processes as the technology becomes more accessible and pervasive (Radziwill 2018).

At this point it must also be stated that the advent of information modelling, and the current wave of new digital technologies, should not be perceived as the death knell of existing practices with the result that all traditional approaches are to be swept aside. On the contrary, this research demonstrated that both worlds can co-exist in a symbiotic manner and can be greatly enhanced by each other's existence. The concern of practitioners in the heritage community is that amalgamation of digital processes to historic projects has not been carefully managed at present and the worst-case scenario of creating a '*Shavian Monster,* (Papert 1998, 88) could become a reality if not conducted correctly. The *'Shavian Monster'* is an expression borrowed from George Bernard Shaw and adapted by Papert. It refers to Shaws response when once propositioned by a famous beauty who speculated how marvellous a child they could produce with *'her looks and his brains'*, however Shaw retorted *'what if the child had his looks and her brains'*. The inference being that instead of having the best of both worlds the situation could arise where they have the opposite. That is to say, if the application of digital technologies is *ad-hoc* and not correctly thought through that this would in actual effect have a negative impact as opposed to the desired positive outcome, such as inaccurately reproducing past historic states in a sense of completeness and assumed accuracy based on the recasting of information that has not been authenticated. Fundamentally, key principles must be defined and understood regardless of medium, be it pen & pencil, trowel, or indeed digital tablet.

To address these issues, I have undertaken a review of the current state of the art of research in this area divided into four distinct threads: theory, definitions, interpretation and current best practice. A truncated review of historical discourse regarding the Built Heritage was briefly discussed to illustrate how this continues to inform current thinking. Following this, it was necessary to define key terms within the scope of my research area before reviewing the myriad of interpretive instruments and process that are utilised at present. This chapter concludes with a discussion on the contemporary landscape and the fusion and evolution of practices at present before introducing the new workflow.

2.1 Defining the Built Heritage

It has not been the focus of this thesis to detail a complete history of building conservation theory, however it was necessary to identify aspects of a long tradition from which this research arises. There are many works that deal with this subject area in far greater detail, for a good overview and historical account of building conservation refer to Bernard M Fields's (1982) Conservation of Historic Buildings. Discourse in this area is on-going and largely focused on technical issues pertaining to how buildings/artefacts are conserved and managed in an appropriate manner. For this research, a key element of the debate centres around the notion of *interpretation* (defined in 2.2) and how this is presented to and consumed by the specified end-users. Defining *interpretation* was a challenge, commencing with Tilden's 1957 definition and eventually stating if indeed interpretation can be definitively articulated into a single definition. This in turn sparked the question whether *interpretation* was enhanced by the adoption of the novel workflow at the centre of this work and discussed throughout.

2.1.1 Theoretical Overview

The concept of conservation for buildings and monuments has existed for many years, monuments were sacred in conditions of cultural continuity, the sacred, the ritual since at least classical antiquity. Historians of Building Conservation suggest that it commenced in antiquities, Pliny the Roman writer and historian, described measures for the conservation of monuments (Duffy 1998, 22). Pausanias, a 2nd century Greek geographer described a contemporary rebuilding of the temple at Olympia where all but one of the older wooden columns were replaced by stone; this was left as a memory of its past state (Hunt 2006). As Dewidar (2017, 45) outlined, the Romans had laws to prevent towns being spoiled by ruins and to regulate the maintenance of buildings and monuments as they replaced but did not restore; a proof for this is that there is no Latin word corresponding with our term *restoration*. *Instaurare*, *reficere*, *renovare* do not mean to restore, but to reinstate or to make new (Dewidar 2017, 47). These early pieces of literature were broadly developed and enhanced upon through the proceeding years however it was not until the mid-18th century and the first academic chairs in the new discipline of history were established in European universities and the *science* of Archaeology began. At this point, many European countries had legislation for the upkeep of monuments (Diaz-Andreu & Champion T 1996, 314). This continued apace through the 19th century and led to a growing awareness of stylistic nuance based on informed study. Classical (and neo-classical) influences started to give way to Gothic and Medievalism under the influence of the picturesque. Medieval monuments which had been despised by the Renaissance as irrational become admired for this very quality (Duffy 1998, 15). By the mid to late 1800`s the debate shifted towards Conservation versus Restoration, in particular *stylistic* restoration and *unity of style* restoration were the conflicting themes of this period. On the one hand was the *destructive restoration* approach as practised by the *ecclesiologicalists* and assorted church *improvers*. The roots of their philosophy are to be found in the works and writings of E.-E. Viollet-le-Duc and George Gilbert Scott. This group called for measured interventions that facilitated the prolonging of the artefact, '*regarding ancient monuments, it is better to consolidate than to repair, better to repair than to restore, better to restore than rebuild, better to rebuild than to embellish; in no case must anything be added, and above all nothing should be removed'*-A.N. Didron (1839). Didron's view was best articulated by his claim that nobody ever considers correcting or completing say, the *Aeneid*, or other famous masterpieces from the past, so why would this be appropriate in the context of buildings?

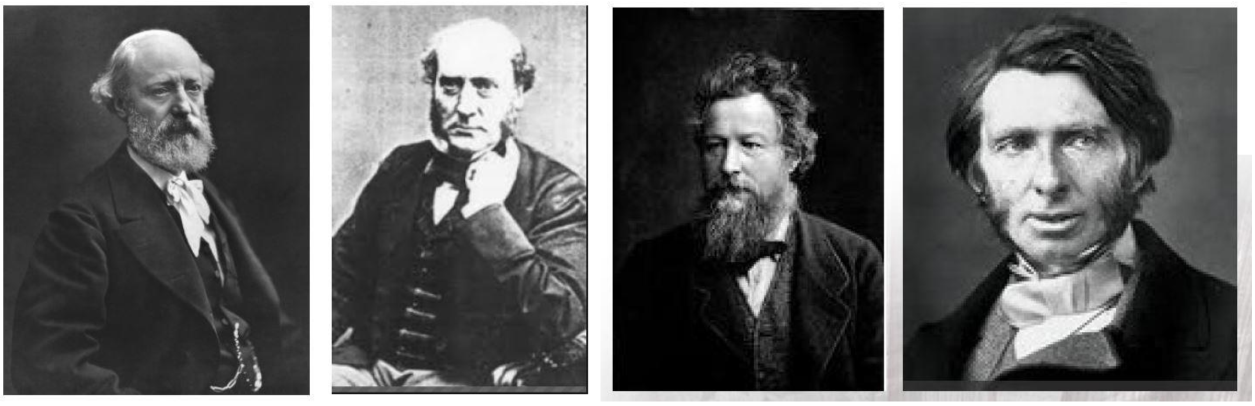


Figure 2.1.1 *– Conservation Theorists Le-Duc, Scott, Morris and Ruskin - Image Source – Feilden (1982)*

On the opposing side of the conservation movement where John Ruskin and William Morris. Morris was a textile designer by profession but also a renowned poet, novelist, translator and socialist activist associated with British Arts and Crafts (MacCarthy 1995) whilst John Ruskin was a leading art critic of the Victorian era as well as art patron, draughtsman, philanthropist and prominent social commentator (Collingwood 1912). A seminal work of modern conservation philosophy was Ruskin's book (first published in 1849) *The Seven Lamps of Architecture* (sacrifice, truth, power, beauty, life, memory, and obedience). Ruskin's writings led the shift towards a new taste for the Gothic, based mainly on its perceived spirituality. For example, he believed in the importance of Gothic over classical architecture because the Gothic or mediaeval craftsman was free to invent and by so doing express *his* individual spirituality. For this reason, Ruskin regarded all attempts at reconstruction as futile and a sham. It is within this spirituality that Ruskin referenced that the *intangible* resides which is the very essence of the building, the aura of past experiences embedded within the building. A viewpoint that is at the heart of this research.

These writings culminated in the founding of the Society for the Protection of Ancient Buildings (SPAB) in 1877, also known as the Anti-scrape Society. They felt it (building) should be honoured and left to decay, *'that restoration so-called is the worst manner of destruction…'* and *…'the spirit of the dead workman cannot be summed* (i.e. summoned*) up (Ruskin 1850)'*. Anatole France (1880) who shared many of Ruskin's beliefs, compared old buildings to ancient manuscripts where each page is written in a different hand (palimpsest). Their views were extreme, reflected in their manifesto, to the degree that buildings should be abandoned and allowed to become ruins and eventually disappear naturally.

'… or what is left we plead before our architects themselves, before the official guardians of buildings, and before the public generally, and we pray them to remember how much is gone of the religion, thought and manners of time past, never by almost universal consent, to be Restored; and to consider whether it be possible to Restore those buildings, the living spirit of which, it cannot be too often repeated, was an inseparable part of that religion and thought, and those past manners. For our part we assure them fearlessly, that of all the Restorations yet undertaken the worst have meant the reckless stripping a building of some of its most interesting material features; whilst the best have their exact analogy in the Restoration of an old picture, where the partly-perished work of the ancient craftsmaster has been neat and smooth by the tricky hand of some unoriginal and thoughtless hack of today. If, for the rest, it be asked us to specify what kind of amount of art, style, or other interest in a building, makes it worth protecting, we answer, anything which can be looked on as artistic, picturesque, historical, antique, or substantial: any work, in short, over which educated, artistic people would think it worthwhile to argue at all. …"
Extract from 'Manifesto' of the Society for the Protection of Ancient Buildings (Morris 1877, 2)

The writings of Ruskin, Morris, Boito, Viollet-le-Duc, and many others in the field at this time defined an early framework that continues to inform current guidelines and directives such as the

ICOMOS Charters (refer 2.1.2) formulated by agencies who have responsibility for the Built Heritage, be they State bodies or heritage interest groups. These guidelines provide solid foundations when approaching and managing the physical elements of the Built Heritage. However, the discussion continues to evolve and reflect current issues within the building conservation community, particularly for the purpose of this thesis in the two key areas of energy consumption versus conservation and, the application of digital technologies and processes to the Built Heritage. In later sections, this research refers to the energy efficiency aspect of building conservation for the purpose of demonstration, but the primary focus is on digital technologies managing historic buildings. In order to enrich the digitisation debate further the question of *how* and *why* the building is digitised in the first instance was discussed. This reflection on *how* and *why* is not a novel argument and has been revisited many times within the building conservation community such as when discussing design interventions with refurbishment works of historic buildings.

In the context of this work the key debates on *how* and *why* commenced during the Renaissance period when what became the modern profession of architecture was developed largely through the thoughts and opinions of Leon Battista Alberti and his influential book *De Re Aedificatoria* (Scheer 2014, 2). Its core premise is that before *we* build, *we* must appreciate why *we* build. The point being that the *how* of construction was relatively straight forward due to a limited palette of materials and structural capabilities, however, the *why* was more reflective and required a greater level of meaning and interpretation of form and space. It is advocated that a comparable situation now exists relating to the theoretical digitisation of the Built Heritage. The *how,* has to all extents and purposes been satisfied in terms of creating computer models given the development of digital data capturing instruments and supporting software and processes. The *why,* required further examination. Similar to Didion's view that no one considers completing the *Aeneid*, why therefore, in contemporary research is it commonplace to photo realistically re-create buildings and artefacts in a condition of completeness which might never have existed at any given time? *Why* are buildings and artefacts being digitally reconstructed in the first instance? What is the desired function for a digital reconstruction? Is it not to inform, or reflect, on the fabric associated with the building or artefact? Is there merit in obtaining a level of authenticity of the artefact as in identifying and relating to its true value of significance? As this research developed it has contributed to this debate further by attempting to answer these questions, and in so doing, expanded the conceptual framework in which the future digitisation of the Built Heritage operates.

2.1.2 Historical Definitions

The practice of categorising buildings and building features is quite prevalent in building conservation literature with the unintended consequence that a definitive wording cannot be suitably referenced as a *de facto* definition for the Built Heritage. The issue is that the Built Heritage can mean very different things to different people and professions. For some it is the mere fact that something is *old* that means it should be considered heritage, for others the *built* refers only to buildings and nothing else. A myriad of plausible definitions exists, and their use is normally determined by the researcher's specific bias and field of study.

Consequently, development of building conservation terminology and principles in the second half of the 20th century has resulted in a substantial volume of material disseminated in multiple publications. These principles or guidelines, promulgated either as charters, recommendations, resolutions, declarations or statements, were drafted and adopted mainly by international organisations, such as UNESCO (United Nations Educational, Scientific and Cultural Organization's) and ICOMOS with the main objective of protecting cultural property, which includes historical monuments, buildings, groups of buildings, sites and towns. The most significant guideline was produced by ICOMOS and is commonly known as the Venice Charter (1964), which set a benchmark for principles governing architectural conservation and restoration. The Charter has helped to broaden the concept of historic buildings, the application of modern technology in conservation works, international co-operation and, most important of all, has provided a set of principles for the protection of architectural heritage and sites. The term *historic monument* used in the Venice Charter was reinterpreted by ICOMOS in 1965 as *monument* and *site*; and by UNESCO in 1968 as *cultural property* to include both movable and immovable. The different terminology between the UNESCO and ICOMOS was reconciled at the World Heritage Convention (Ahmad 2006, 292-300)

UNESCO and ICOMOS have been to the forefront in defining common terminology and scope of heritage since 1965. The term *historic monument* in Article 1 of the Venice Charter 1964, *not only the single architectural work but also the urban or rural setting,* was not defined clearly enough to provide clarity. The Charter did not address the question of what constitutes an historic monument and did not allude to the characteristics of urban and rural settings and the definition of sites. Therefore, in 1965 during the Constitutive Assembly of ICOMOS, the scope of heritage was redefined. Heritage was then defined as monuments and sites:

Article 3:1 (states);

The term monument shall include all real property, …whether they contain buildings or not, having archaeological, architectural, historic, or ethnographical interest and may include besides the furnishing preserved within them….

The term site shall be defined as a group of elements, either natural or man-made, or combinations of the two, which it is in the public interest to conserve….

In 1968, at the 15th session of the General Assembly in Paris, UNESCO adopted the Recommendation Concerning the Preservation of Cultural Property Endangered by Public or Private Works, of which, among other things, sought to define the scope of heritage. The definition of heritage as *monuments* and *sites* established earlier by ICOMOS in 1965 was not taken by the General Assembly as a whole; instead, it redefined the term cultural property introduced at The Hague Convention 1954. Cultural property was redefined in 1968 as movable and immovable. Movable cultural property was referred to as *museum collections* and immovable cultural property was referred to as *architectural heritage*. Immovable cultural property was defined to include not only historic sites and features but, more importantly, it recognised the need to include groups of traditional structures and historic quarters in urban and rural areas: (Ahmad 2006, 292-300)

Article 1a(states);
…archaeological and historic or scientific sites, structures or other features of historic, scientific, artistic or architectural value, whether religious or secular, including groups of traditional structures, historic quarters in urban or rural built-up areas and the ethnological structures of previous cultures still extant in valid form. It applies to such immovable constituting ruins existing above the earth as well as to archaeological or historical remains found within the earth. The term cultural property also includes the setting of such property…

Thus, by the end of the 1960s and particularly after the Venice Charter, what actually constitutes an historic monument was defined somewhat differently by UNESCO and ICOMOS. Even though both organisations agreed in principle that heritage was no longer confined to historic monuments and buildings and should be extended to include groups of buildings and historic quarters, the terminology used was different; while UNESCO defined heritage as *cultural property*, ICOMOS defined heritage as *monuments and sites.* In 1972, this differing terminology, and the scope of architectural heritage, was reconciled at the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage, otherwise known as the World Heritage Convention 1972. The UNESCO Convention regarded heritage as both cultural heritage as well as natural heritage, and UNESCO's earlier definition of movable and immovable cultural property was dropped (Ahmad 2006, 292-300). The definition of monuments and sites as mentioned in the ICOMOS statutes adopted in 1965 was rephrased and a third category *groups of building* was introduced. Cultural heritage was now defined to include monuments, groups of buildings and sites. This was a clear move to ensure that groups of buildings and urban settings were being protected. Cultural heritage was defined by UNESCO in 1972 as:

Article 1:1

- *monuments: architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science.*

- *groups of buildings: groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science.*

- *sites: works of man or the combined works of nature and of man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological points of view.*

Later, in its revised statute in 1978, ICOMOS maintained the two broad categories of cultural property—monument and site—but added the 'group of buildings' as the third to clearly spell out urban and rural context and to be the same as those defined by UNESCO:

Article 3b

- *group of buildings: shall include all groups of separate or connected buildings and their surroundings, whether urban or rural, which, because of their architecture, their homogeneity or their place in the landscape, are of value from the historical, artistic, scientific, social or ethnological point of view.*

UNESCO terminology has remained unaltered to the present day. Jokilehto (2005), identified in a report created as part of the ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property) Heritage and Society working group a comprehensive inventory of definitions for cultural heritage. The scope was vast and included many diverse areas of cultural heritage. In this report Jokilehto (2005) identified in excess of sixty reference documents beginning with the earliest on record, that of Theoderic the Great in the 6th century AD. In specific reference to the Built Heritage, guidance was sought in more modern times beginning in 1975, and the Council of Europe Amsterdam Declaration. The Congress of Amsterdam recognised that Europe's *unique architecture is the common heritage of all her peoples, and which declared the intention of the Member States to work with one another and with other European governments for its protection.* The Congress likewise affirmed that, *Europe's architectural heritage is an integral part of the cultural heritage of the whole world and noted with great satisfaction the mutual undertaking to promote co-operation and exchanges in the field of culture contained in the Final Act of the Congress on Security and Co-operation in Europe adopted at Helsinki in July of this year (1975).*

In so doing, the Congress emphasised the following basic considerations in relation to the Built Heritage:

Apart from its priceless cultural value, Europe's architectural heritage gives to her peoples the consciousness of their common history and common future. Its preservation is, therefore, a matter of vital importance and that the *architectural heritage includes not only individual buildings of exceptional quality and their surroundings, but also all areas of towns or villages of historic or cultural interest.*

This was further elaborated upon at the 1985 Granada Convention for the protection of architectural heritage. The theme of the conference was the *handing down to future generations a system of cultural references, improving the urban and rural environment and thereby fostering the economic, social, and cultural development of States and regions.* The scope of architectural heritage and the Built Heritage was further expanded to include;

the expression 'architectural heritage shall be considered to comprise the following properties:

- *Monuments: all buildings and structures of conspicuous historical, archaeological, artistic, scientific, social, or technical interest, including their fixtures and fittings;*

- Groups of buildings: homogeneous groups of urban or rural buildings conspicuous for their historical, archaeological, artistic, scientific, social, or technical interest which are sufficiently coherent to form topographically definable units;

- Sites: the combined works of man and nature, being areas, which are partially built upon and sufficiently distinctive and homogeneous to be topographically definable and are of conspicuous historical, archaeological, artistic, scientific, social or technical interest."

Furthermore, in this body of research a distinction was made between an historic *artefact* and *building* where an historic *building* can be identified as a product of human activity, realised with artisan technologies and stratified during its life as its aesthetical and material consistency takes on a specific testimonial value of the cultures and transformations that have generated and modified it over time (Brusaporci 2017, 124). This was important to clarify as to avoid unnecessary confusion with similar areas of research, such as archaeology where the term artefact has particular resonance amongst its community of scholars.

Having outlined the journey and evolution of how specific key definitions have evolved through the past 50 years to shape the current vocabulary deployed when discussing the Built Heritage, the following section focused on more nuanced terms that are relevant to this research, in particular, *tangible* and *intangible*.

2.1.3 Tangible and Intangible Heritage

The primary purpose of the guidelines and publications referred to above was to define and establish the scope of heritage and attribute definitions. Since the Venice Charter (1964), the scope of heritage has broadened from an appreciation for physical heritage to acknowledge the *intangible*. This *intangible* heritage, transmitted from generation to generation is constantly recreated by communities and provides them with a sense of identity (Scovazzi 2012, 180). The Burra Charter (1979) was later amended in 1981, 1988,1999 and 2013 to reflect the current concern of heritage and conservation in Australia, including conservation of *intangible* values. It recognises social and aesthetic values as part of cultural significance, as well as *intangible* values or *intangible* cultural heritage referred to by UNESCO as an integral aspect of heritage significance. The importance of *intangible* values as part of heritage was emphasised by UNESCO when it adopted a convention in 2003 that helped to protect *intangible* cultural heritage, which was defined as;

Article 2

- *practices, representations, expressions, knowledge, skills, instruments, objects, artefacts and cultural spaces associated with communities, groups and individuals.*

By the end of the 20th century, the scope of heritage, in general, was agreed internationally to include *tangible* and *intangible* heritage as well as environments. To better inform the international communities, in 1999 UNESCO clarified the scope of *tangible* values as cultural properties to include monuments, groups of buildings and site (Article 23:5) and the scope of environments as natural properties (Article 43:10); and adopted the Convention for the Safeguarding of the Intangible Cultural Heritage (UNESCO 2003), which defines *intangible* cultural heritage as;

Article 2:2

- *The practices, representations, expressions, knowledge, skills—as well as the instruments, objects, artefacts and cultural spaces associated therewith—that communities, groups and, in some cases, individuals recognise as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environments, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity. This includes oral traditions and expressions, language, performing arts, social practices, rituals, festive events and traditional craftsmanship.*

If further emphasised that;

- *The intangible cultural heritage, as defined in paragraph 1 above, is manifested inter alia in the following domains: (a) oral traditions and expressions, including language as a vehicle of the intangible cultural heritage; (b) performing arts; (c) social practices, rituals and festive events; (d) knowledge and practices concerning nature and the universe; (e) traditional craftsmanship.*

It is within this framework that the most relevant and accurate description of *Built Heritage*, *intangible heritage* and *tangible heritage* was derived for this research and best encapsulated in the UNESCO Plan 1990-1995;

"…the aim is not only to preserve increasingly numerous items of cultural property but also to safeguard complexes which go far beyond single large monuments or individual buildings. The idea of the heritage has now been broadened to include both the human and the natural environment, both architectural complexes and archaeological sites, not only the rural heritage and the countryside but also the urban, technical or industrial heritage, industrial design and street furniture…"

2.1.4 Virtual (Heritage) Environments

Similar to defining key terms associated within the Built Heritage community, there is not an agreed definition to what constitutes a Virtual Environment, or VE. The term is often interwoven with the term Virtual Reality, or VR. The 3D stereoscope viewers of the Victorian age are acknowledged as the earliest examples of virtual reality (Jacobson 1993, 27) whilst the Virtual Reality aficionados maintain that VR had its beginnings before the concept was ever coined. This viewpoint is based on the notion that virtual reality is a means of creating the illusion that we are present somewhere we are not (www.vrs.org.uk) and considers the 360 deg. murals from the 19th century as the original virtual reality experience. The purpose of these artworks where to fill the field of vision of the viewer and thus make them feel present in the scene.

The modern definition of VR was based upon the work by the pioneers of the 1950`s and 1960s. In 1962, the filmmaker Mort Heilig designed and produced Sensorama, the *cinema of the future.* It was an arcade style device with a visual display, vibrating seat and had the ability to produce scents as well as wind for the user (Turi 2014). Following on from Heilig, Ivan Sutherland, who was already known as the creator of the innovative computer interface Sketchpad, conceived of what he termed *The Ultimate Display* , which he described as *a room within which the computer can control the existence of matter* (Dixon 2016, 38). In 1965, Sutherland the renowned pioneer and the reputed grandfather of modern VE`s, set out a roadmap for research in the areas that would encompass the next 25 years (Jerald 2015, 15) He stated that the primary challenge would be for the user to perceive the display device as a portal into a realistic virtual world. He demonstrated an extremely preliminary iteration of such a device, a periscope-like video headset called the *Sword of Damocles* in 1968.

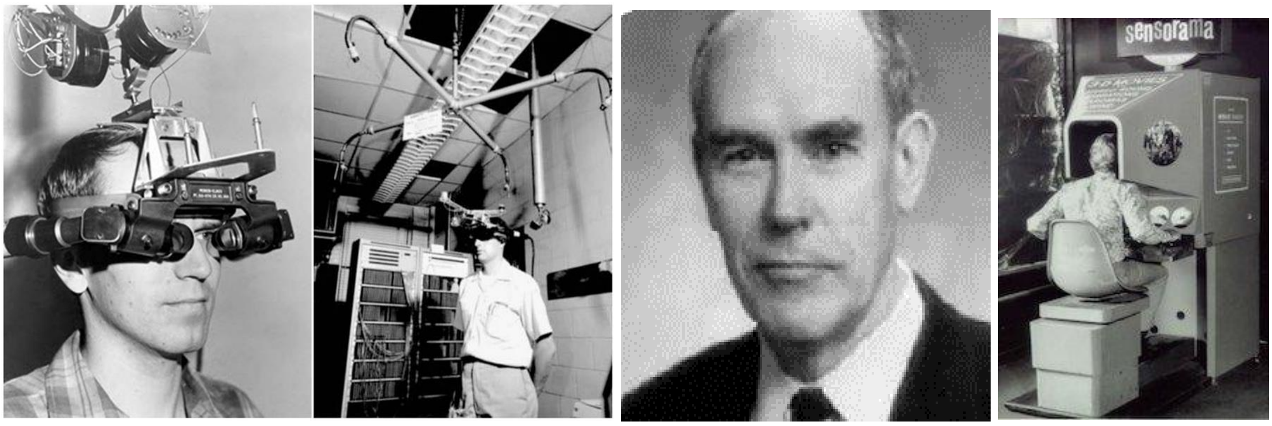


Figure 2.1.4.1 *–Early VR Pioneers. Image source: mortonheilig.com*

In terms of development, VR has experienced a somewhat turbulent history, often falling in and out of favour (Armstrong 2016, 42). As such, the technical development of platforms has evolved in a sporadic fashion. At present, it is enjoying a revival of sorts and this current manifestation has been deployed primarily in the entertainment and gaming industry. These companies have the capacity to invest heavily in creating reliable robust platforms for general consumption. This injection of commercial funding into the technology has enabled less resourced areas of research access to low-cost hardware which in turn has permitted scholars to explore the possibilities (Harris 2019, 27). The Built Heritage sector is one such research domain.

This current iteration of VE development for the Built Heritage resurfaced in the early 2000`s. March et.al (2001) attempted to define four general types of virtual environments that could be applicable to the Built Heritage including work-related: informative, entertainments, education and training. Champion (2011, 108) further extrapolates from this classification system and suggests seven reasons why VE`s may prove useful, in the context of cultural heritage, the supposition that VEs can '*present ideas, objects, or techniques that are difficult to perceive or conceive of in real-world form, or conventional media'* and the ability '*to develop the technology to preserve cultural artefacts through a three or even four-dimensional record of history.'* This adoption of VE`s to contemporary research has not gone unnoticed by the wider virtual heritage academic community. In order to safeguard and legitimise research in this area of virtual heritage, the London Charter (Deanard et al, 2009) was devised and generally supported by the various active research communities within this broader sector. The charter was quiet far reaching and endeavoured to encapsulate a wide spectrum of digital technologies and processes and more importantly how they are applied to historic cultural research. Its preamble states;

The Charter defines principles for the use of computer-based visualisation methods in relation to intellectual integrity, reliability, documentation, sustainability and access.

Original definitions (Pape, D. et al. 2001, Roehl, D. B. 1997, Roussou, M. 2002) by experts in the field had established that the reconstruction of physical elements as the principal aim of virtual heritage. Virtual heritage is considered by many as a fusion of virtual reality technology with cultural heritage content (Addison, 2000; Addison et al., 2006; Roussou, 2002). One broad early definition of Virtual Heritage by Stone and Ojika (2000,73) is *'the use of computer-based interactive technologies to record, preserve, or recreate artefacts, sites and actors of historic, artistic, religious, of cultural significance and to deliver the results openly to a global audience in such a way as to provide formative educational experiences through electronic manipulations of time and space'* These early definitions omitted any reference to the more expressive and informative potential of Virtual Environments as a form of an interactive digital platform. This definition evolved as digital heritage experts (Champion, E. & Sekiguchi, S. 2004, Jacobsen, J. and Holden, L. 2007) took into consideration the meanings, purposes or processes behind physical elements, along with symbolic elements, human activity and dynamic interaction as integrated components of the virtual environment. At this juncture there is a realisation that *intangible* heritage requires recognition when defining virtual heritage. Jeffrey (2015, 144-152) suggests, that virtual heritage either of existing or re-imagined, is not simply a technical exercise, more '*an act of a powerful expression of our present world view'*. He argues that the initial responses to this challenge (of virtual heritage) employ co-production of the digital object and at the same time wholeheartedly acknowledge and '*embrace the creative and craft elements of digital visualisation production'*. He continues that these approaches if successful could have a profound effect on the '*relationship between heritage professionals, the broader community and our engagement with the past'*. This challenge is on-going and to the fore of this research.

Hence, what makes a successful VE? Pujol & Champion (2011, 83-102) suggest that what separates a successful virtual heritage environment from a failed one is not readily apparent. If we do not know what virtual heritage is, it is difficult to determine how successful individual projects are, and perhaps impossible to create evaluations that can be used as a standard methodology across different projects. Therefore, it is paramount to clearly express a definition within the realm of this research. The definition referenced in this work is an adapted version of that offered by Champion (2015, xiii);

Virtual heritage is the attempt to convey the significance of cultural artefacts and the associated social endeavour through the use of immersive digital platforms.

On reflection, the creation of the London Charter, and the subsequent development of the Seville Principles (2011) have legitimised and structured research that entails the utilisation of virtual environments. Going forward within this research, the terms Virtual Environment and Virtual Reality have been interspersed as appropriate but are essentially defined as follows;

The application of real-time multi-faceted datasets, combined with direct manipulation and display technology to permit the illusion of immersion in the virtual world.

2.1.5 Summary of key definitions

To clarify key terms within this research the following definitions have been applied;

The **Built Heritage** shall be defined forthwith as *all buildings and structures of conspicuous historical, archaeological, artistic, scientific, social, or technical interest, including their fixtures and fittings.*

Intangible (Built) heritage shall be defined forthwith as *practices, representations, expressions, knowledge, skills, instruments, objects, artefacts, and cultural spaces associated with communities, groups, and individuals.*

A **Virtual Environment** shall be defined forthwith as *the application of real-time multi-faceted datasets, combined with direct manipulation and display technology to permit the illusion of immersion in the virtual world.*

Virtual (Built) Heritage shall be defined forthwith as *the attempt to convey the significance of cultural buildings, and the associated social endeavour through the use of immersive digital platforms.*

2.2 Interpreting the Built Heritage

The Built Heritage consists of many facets and encompasses a range of scholarly endeavour. As explained above, in this research, the Built Heritage refers specifically to historic buildings and the qualities they possess be it *tangible* or *intangible*. To allow meaningful engagement with historic buildings, these features must be conveyed in a manner that is comprehensible and compelling to the end user. This process can be facilitated through interpretation and, by extension, interpretative tools that provide a narrative which enables engagement with the building.

Designing, or selecting, an appropriate method that has the capacity to engage with the end-user was a critical challenge within this study. High end visualisation projects such as Rome Reborn (www.romereborn.org) or The Acropolis (www.acropolisvirtualtour.gr) are two examples of successful approaches used to interpret a day in the *life* experience of Ancient Rome or Ancient Greece. One of the successes of Rome Reborn is the design pipeline that consisted broadly of three successive phases of development and refinement: firstly, historical research and content providing (gathering the available information about Rome's urban configuration); secondly, modelling (creation of the architectural model of Rome, which later was populated with dynamic characters to increase realism; and thirdly ,the technical implementation (optimization of the model for online visualization (Moltenbrey 2008, 17). Both projects tended to focus on capturing the *tangibl*e characteristics of the buildings, places and people whilst possibly not engaging with the *intangible* nuances of both ancient Greece and Rome which posed the question of what exactly is the purpose of experiences such as Rome Reborn and The Acropolis? How is the success, or otherwise, of such experiences gauged or evaluated? Is it not that what is primarily being challenged is the notion that the virtual experience of Rome Reborn, by an end user can enhance interpretation and actually be evaluated? In answering this dilemma, the first necessary step is to accurately define interpretation in the context of virtual (built) heritage.

As alluded to previously, Tilden (1957) defined interpretation as *'an educational activity which aims to reveal meanings and relationships through the use of original objects by first-hand experience and by illustrative media, rather than to communicate factual information',* therefore, *'the chief aim of interpretation is not instruction but provocation'.* According to ICOMOS, interpretation refers to the full ranges of potential activities intended to heighten public awareness and enhance understanding of cultural heritage sites (ICOMOS 2007). Digital humanities contain many plausible definitions, Rahaman and Tan (2010, 96), researched and compiled a table consisting of twelve viable definitions of interpretation from various sources of academic heritage scholars to recognised international heritage associations.

	Affiliation	Definition of Interpretation
Heritage Scholars	Uzzell (1994)	Interpretation is that it opens a window on the past.
	Harrison (1994)	The art of presenting the story of a site to an identified audience in a stimulating, *informative* and *entertaining* way to highlight the importance and *provoke* a sense of place
	Beck and Cable (1998)	Interpretation is an educational activity that aims to *reveal meanings* about our cultural and natural resources.
	Moscardo (1999)	Interpretation is a special kind of communication
	Howard (2003)	Interpretation is deciding what to say about heritage and how and to whom.
	Goodchild (2007)	Interpretation is, in fact, only one aspect of the broader topics of '*Presentation*', 'Supplementary *Education*' and 'Visitor *Satisfaction*'.
Interpretation Associations/Authorities	Interpretation Association Australia	Interpretation is a means of communicating ideas and feelings which help people enrich their *understanding* and *appreciation* of their world, and their role within it. (source: http://www.interpretationaustralia.asn.au)
	The National Association for Interpretation, USA	Interpretation is a mission-based *communication process* that forges emotional and intellectual connections between the interests of the audience and the meanings inherent in the resource. (source: http://www.interpnet.com/)
	The Association for Heritage Interpretation, UK	Interpretation is the process of communicating messages and stories about our cultural and natural heritage, providing the audience with *inspiration* and a wider *understanding* of our environment. Or quite simply, interpretation is about telling stories. (source: http://www.ahi.org.uk/www/)
	ICOMOS Ename Charter (2007)	Interpretation refers to the full range of potential activities intended to heighten *public awareness* and enhance understanding of cultural heritage site.
	ICOMOS Charleston declaration (2005)	Interpretation denotes the totality of activity, reflection, research and creativity stimulated by a cultural heritage site.

Figure 2.2.1 *–List of Definitions of Interpretation (Source: Rahman & Tan, 2010)*

This list has been added to in more recent times with the previously discussed Burra Charter (2013) to encompass aspects of *intangible* and an acceptance of a more diverse understanding of what the Built Heritage encompasses be it a building or artefact. On reflection, The ICOMOS Ename Charter (2007) definition of *interpretation refers to the full range of potential activities intended to heighten public awareness and enhance understanding of cultural heritage site* best reflects the research objectives explored throughout this work and has been utilised as the underpinning definition to develop upon as the work progressed.

2.2.1 Traditional methods of Interpretation.

Illustration, drawing, markings are all forms of expression that chronicled man`s endeavour from the earliest times. The ability and desire to represent seminal events are evident amongst many civilisations. Illustrations allow for visual communication of deeds, conquests and events without the burden and restriction of the spoken word. In its earliest form, illustrations comprised of hand markings depicting spiritual beliefs and an understanding of natural elements such as sun, sea, air, and water. Many civilisations have bequeathed a legacy of illustrations, drawings and forms of art that enable contemporary society to interpret the environment in which they inhabited and date back to pre-history such as existed at the complex of caves at Lascaux, France.

In terms of interpreting the Built Heritage the practice of creating drawings/illustrations dates to antiquity and was intrinsically linked with the development of painting as an art form. The Roman philosopher Pliny wrote in his *Natural History (c.77-79AD)* that *'we have no certain knowledge as to the commencement of the art of painting, nor does this enquiry fall under our consideration. The Egyptians assert that it was invented among themselves, six thousand years before it passed into Greece; a vain boast, it is very evident. As to the Greeks, some say that it was invented at Sicyon, others at Corinth; but they all agree that it originated in tracing lines round the human shadow' (Ch.5, Book XXXV).* Pliny told many stories of this nature to help explain the origin of painting. These tales later informed a mildly popular sub-genre of art in mid to late 18th and early 19th centuries, depicted by artists, under titles such as *The Origin of Painting, The Invention of Drawing* and *The Art of Painting.* One such work is Schinkel's piece *Die Errfindung der Zeichenkunst* (1830)

Fig: 2.2.1.1 *- Karl Friedrich Schinkel, "Die Errfindung der Zeichenkunst", (1830)* Here, Schinkel depicts the story that many refer to as the *Origin of Draughtsmanship* as in the context of architectural draughting being employed as an interpretive tool to explain a building. The painting depicts the story of a girl named Diaboutades who is attempting to recreate an image of her departing lover and requires a memento of her likeness. As Evans (1995, 24) points out in, the *Projective Cast: Architecture and Its Three Geometries* there are key elements to this illustration that are noteworthy. Firstly, the use of parallel light in the scene that allows for parallel projection, previous interpretations alluded to the scene been lit internally by a lamp or candle thus providing centric projection. Secondly, there are no buildings in the scene which identifies the drawing must precede the building. Thirdly and most interestingly, the artist is operating under instruction from Diaboutades which enforces the distinction between the vision of the architect and its translation into a drawing. Hence, the drawing became the interpretive tool of the architect.

The fundamentals of architectural illustration have not changed over time. Scheer (2014, 3) states that '*drawing/illustration in architecture has two essential aspects, as medium and as craft'* both of which are necessary for an effective interpretive process. Architecture is not alone in this regard with identifying the drawing as the interpretative tool. Banning (2002, 277) points out *'that Archaeological illustration is a form of technical drawing which aims to provide an accurate and detailed record of a subject in a consistent way and that these images are drawn to specific conventions which often highlight information (such as soil texture or material) in an abstracted style, emphasising select information and embedding meaning into graphic form in a way which a photograph cannot*'. Watterson (2015, 23) further develops the importance of technical illustration in the context of archaeology by considering it as a product of the interpretative process; '*Artefacts are singled out to be drawn for publication and plans believed to be of particular significance are drawn for publication. In this sense, illustration focusses and distils the fieldwork process into conclusive accompanying material. This process may seem routinely linear and, on some level, transparent but as any seasoned illustrator will know these images are often the result of drafting, reflexive discussion, and revisions to make particular details more apparent and obscure others. These predominantly silent choices shape what we make and how this material is received'.* Indeed, the importance of sketching, or manual illustration as part of the interpretative the process was perhaps best described by Finish architect Pallasmaa (2009) who writes; '*Sketching and drawing are spatial and haptic exercises that fuses external reality of space and matter and the internal reality of perception'.*

It is important to highlight at this juncture that the role of traditional methods within the interpretative process should not be construed as being under threat, such methods continue to have a prominent role to play in the subsequent move towards digitisation. For instance, there are exceptions where the adoption of such approaches is still disputed. Design and in particular the architectural design process, is still very much divided. It sits quite comfortably in one stable as Oxman & Oxman (2016) articulate in a series of essays by scholars titled the *Theories of Digital in Architecture*. It charts the evolution and adoption of innovative technologies and provides a theoretical framework that is both robust and convincing. Scheer (2014) in *The Death of Drawing, Architecture in the Age of Simulation* develops the process a step further and suggests a time when the architectural design process may be fully digitised. An opposing viewpoint is somewhat more traditional in approach. Polanyi's (2006) *The Tacit Dimension*, a development on the writings of Gilbert Ryle, the celebrated 20th Century British philosopher, in which he (re)establishes the ever-present distinction between *'knowing-that'* and '*knowing-how'.* Where '*knowing that'* refers to the fact that a person knows *'what'* happens or has happened. *'Knowing how'* implies that the person understands the mechanism that makes something happen. When applied to the architectural design process it involves the integration of both kinds of knowing, an intellectual process that can cannot be automated.

2.2.2 Digitising the Built Heritage

People are increasingly encountering sites and monuments and learning about the past through digital media, in the form of virtual reconstructions, digital representation of artefacts, online videos and so on. This is particularly the case for the younger generations, for which the first experience of cultural heritage is often through a digital surrogate that shapes their understanding and perception (Economou 2015, 215). The digitisation of the Built Heritage has been on-going for some time and the technologies involved are continually evolving. Many countries and jurisdictions have created, or are in the process of creating, electronic archives and have made attempts in digitising their Cultural Heritage (UNESCO 2015) such as the Digital Repository of Ireland (www.dri.ie) or the RAE Project by Historic Environment Scotland (www.historicenvironment.scot). The early adopters experienced issues such as data preservation due to the creation of an additional repository to be curated and data security. Whilst issues persist in some areas most organisations have concluded that the advantages far outweigh the initial shortcomings due mostly to the ability to reach a far wider and more diverse audience (National Research Council 2015, 5) The focus of this thesis was not so much regarding the process of digitisation itself, but on the possibilities of digital content as a tool for engagement.

The digitising processes and technologies associated with interpreting the Built Heritage has been spearheaded mainly by commercial companies and software vendors. Mainstream industry has delivered increasingly robust and concise platforms for data acquisition and streamlined workflows for data management. Equally, the development of digital interpretive platforms has also continued to progress.

For the purpose of framing the discussion regarding the digitisation of the Built Heritage a timeline is provided below. This is not intended as an exhaustive and definitive account but rather an indicator of key milestones that relate directly to this body of work and should be viewed in that context.

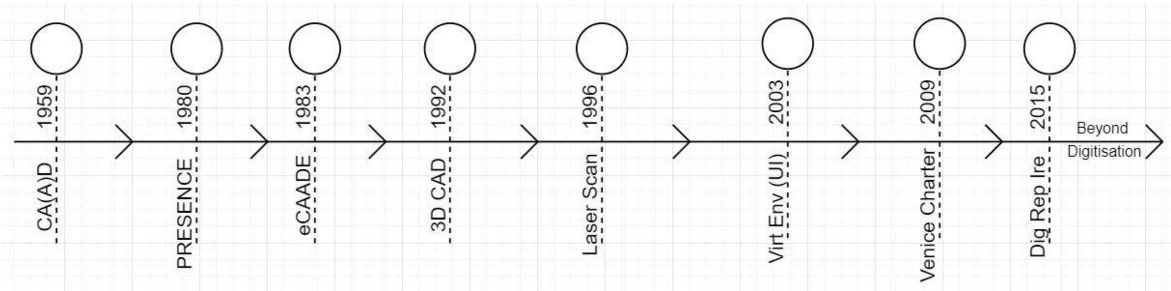


Fig 2.2.2.1 *– Key milestones in digitising the Built Heritage.*

This process, I have contended, originated with the development of Computer Aided Design, or CAD. CAD was first mooted by Ross in 1959 and later developed by Sutherland in 1963. Schmitt (1999, 7) identifies that Sutherlands principles of CA(A)D is based on three key themes, that being; interactivity, modular design and object-orientated modelling, themes that were ideally suited to architecture and engineering and CAD was initially marked by the early digitisation of manual illustration. It was not until the mid-1980`s that a CAD software platform became commercially viable and not until the 1990`s that 3D capabilities where fully implemented (Carlson 2003). There are now dedicated organisations such as eCAADe (Education and research in Computer Aided Architectural Design in Europe) with accompanying repositories (e.g. CUMNICAD) and quarterly journals (IJAC, International Journal of Architectural Computing). On occasion these specialise in the application of digital technologies to the Built Heritage.

The improvement in processing power computer memory and graphics display systems have been such that CAD systems are now widely utilised by a diverse cohort of practitioners within the AECO sector who have availed of the versatility the software provides in adapting it for their own intended use. Contemporary research within CAD has largely focused on parametric modelling (refer to section 2.3.2) and design but there are instances where the focus has been on developing techniques for recording historic buildings and analysing physical building details with supporting guidelines like those published by Historic England (historicengland.org.uk).

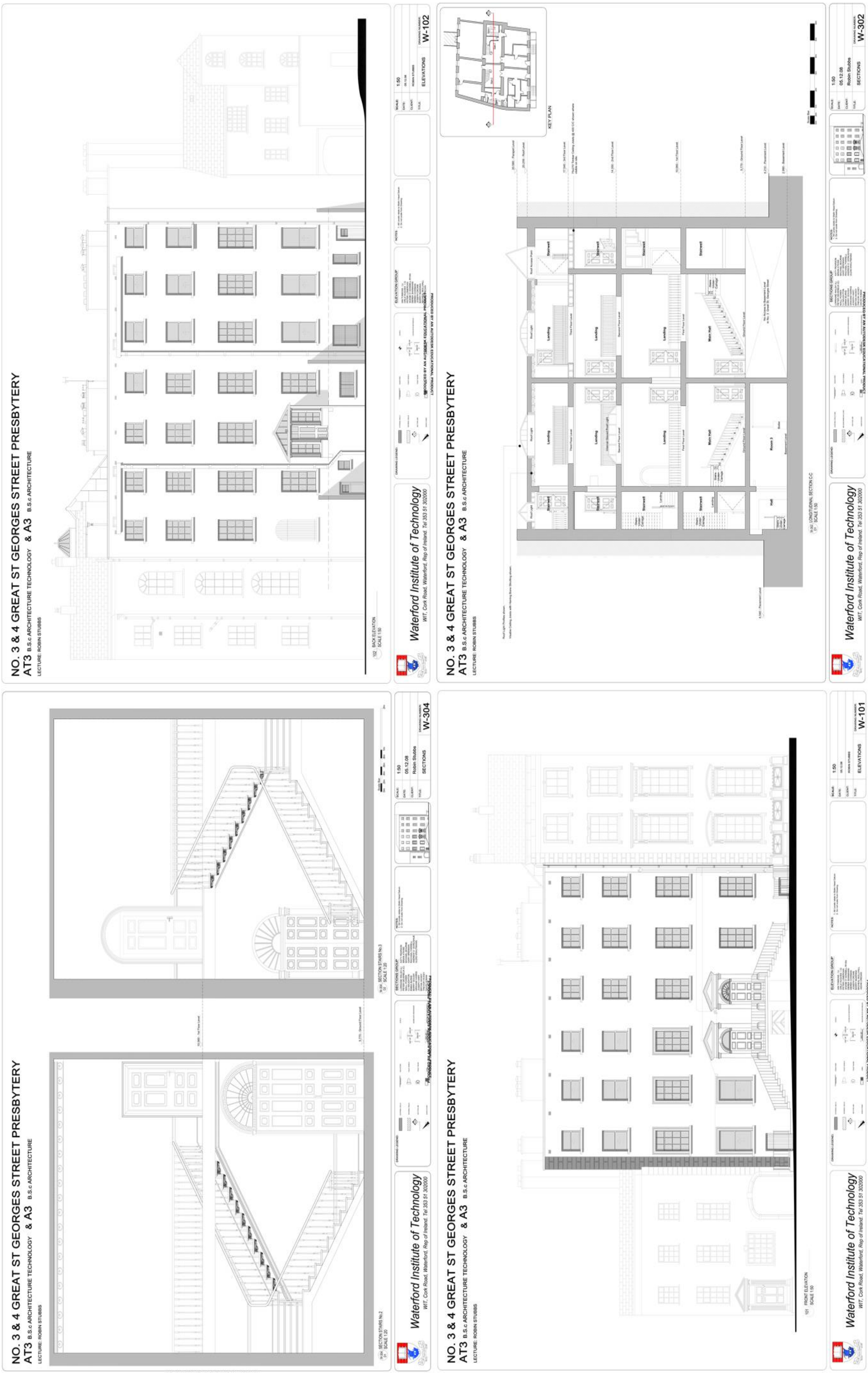


Fig 2.2.2.2 *– AutoCAD survey drawings (Courtesy of Dept. Architecture, WIT)*

However, can CAD truly be described as an interpretive tool? There is a school of thought that suggests the *cold hand* of CAD, or the homogeneous digitisation of the recording process has somehow standardised the representation of a building or an artefact. Champion (2015, 52) argues that '*CAD systems are designed to get buildings built, to quantify rather than qualify the architectural experience'* when in fact, '*real world experiencing of architecture is always mediated through a dynamic and imperfect sensory interface: our minds and our bodies'.* What was being argued was that CAD is no more than a vehicle for transcribing the illustration into a digital format and is somewhat limited as an interpretative tool, in that, it can be utilised as an analytical tool as it produces scaled dimensioned representations of the artefact that can enable interpretation, albeit in a restricted manner as a 2D/3D tool (Di Mascio 2015).

Traditionally, the construction of digital models for visualisation created in CAD applications can result in excessively complex models once translated into real-time 3D software that can result in underwhelming results (Pelosi 2010). Such visualisations often required significant hardware to facilitate the processing that was required. With improved hardware and greater interoperability of software platforms this process has improved to a situation where hyper-realistic depictions of past buildings and artefacts are now achievable. This prompts several questions. The *how* to create such detailed visualisations has been advanced, but the question of *why* the need to create such images has yet to be made clear. The sentiment that pictures can convey a thousand words is a familiar one to most, but the reality is that this is not quite true. A good visualisation often requires a thousand words to describe it. The reasons being many, ranging from a preconceived bias, ambiguity, or misconception by the viewer (Turner 2012, 139).

Digitisation of the interpretive process has developed to such a degree where historic and ancient environments can be replicated in a realistic manner and Jessop (2008) contends that digital visualisation is more than just illustration; it is also a scholarly methodology. Not all agree, many have argued that realistic render presentations offer nothing more than a flexible form of reconstruction drawings (Bracelo 2000 & Gillings 2005) while others raise concerns that photorealism attempts to reproduce the image as realistically as possible falsely increases the authority of a particular visualisation (Franklin 2012) This is an on-going debate amongst scholars (Eiteljorg 2000, Earl 2006 and Frankland 2012), the assertion being that realistic representations serve only to compound already assumed knowledge relating to interpretation in the guise of a re-casting of information. Such representations pose further questions regarding authenticity of the artefact. Kullman (2014, 20-31) refers to this as *'loose realism, incomplete but not false*'. In other words to communicate visually with suggestions rather than trying to describe everything in precise detail. Is the visualisation technically correct? has conjecture been applied at any stage due to a lack of background information? or simply the restraints of the software? The expectation of the viewer is that if it is realistic than it must be real, whilst that may not always be correct. Pujol-Tost (2011) argues that hyper-realism, in the sense that the depiction is more realistic than the original may ever have been and echoes the trends in hyper-reality, in visualisations is actually counterproductive in some instances and unnecessary, in that it can prove a distraction more than an aid to the participant in term of interpreting what they are engaging with. The perceived *realism* removes a level of enquiry by the spectator as they do not question what they are engaging with. Regardless of the position scholars take on the structure of digital visualisations, be it *'realistic', 'hyper-realism'* (Jeffrey 2004) or otherwise, the reality is that they are a central interpretive tool that now exists and are being utilised.

This research is developing an approach that will harness and apply digitisation in a manner that maximises its interpretive capabilities whilst ensuring the *'authenticity of the artefact'* (Jones & Yarrow 2013; Jeffrey 2018).

In the AECO sector there has been research conducted into exploring the link between construction modelling and the entertainment/gaming industry to create suitable virtual environments to allow for client investigation. This approach has been developed to facilitate user interaction (UI) with the building design and construction process. Hone & Kehoe (2003) began to explore this area of virtual environments in architectural visualisation due to the advanced graphics and sound specifications of gaming engines. This work has been built upon by the research of Boekyens (20012) and Pauwels, et al (2013) through engaging with collaborative technologies and thus simplifying the process of creating virtual environments and developed again by Edwards et al.(2015) who looked at a collaborative approach geared towards end-users. This *gaming* approach has further been developed by embracing digital simulation as a tool within design processes. It has sparked a deeper debate, within architecture, regarding the role that digital technologies are having on the profession. Traditional drawing, with its influences on the thought process of the architect is in question for the first time since it was established during the renaissance period. The divorce of design from construction, suggested by Alberti and manifested in modern architecture is being overthrown by the replacement of drawing by simulation whereas architectural drawings exist to represent construction, architectural simulations exist to anticipate building performance (Luce 2009). As Scheer (2014, 11) states;

'Simulation collapses the distance between representation and reference, establishing instead a functional near-equivalence. The representational aspect of building stands to be lost as architects lose the ability to think in representational terms. As a medium, simulation is immaterial. If a notion of craft exist is in simulation, it can only mean ensuring the accuracy of predictions based on the model'

Simulation, within the context of the Built Heritage, has experienced a steady growth due in no large part to developments in cognate areas of research, such as virtual archaeology, the concept of *Presence* and developments within the serious gaming industry. Serious gaming is predicated on user interaction with a simulated virtual environment. The user normally has first person control and the ability to interact and engage with the environment. Interactive projects such as *Joycestick* (www.joycestick.com) fuse historic information with immersive gaming platforms to create an experience for the end-user. Presence on the other hand is an established research field with multiple avenues for discourse and dissemination. It originates from the term *'telepresence'*, made famous by the computer scientist Marvin Minksy in a 1980 paper of the same name (Minsky 1980). Presence has been typically defined as the capacity of the technology to make the user feel transported into a remote place and be able to efficiently interact with it (Pujol & Champion 2012), whilst others would describe it as a *'flawed pseudo-phenomenology'* (Huggett 2015) as this is something that can never really be achieved given the level of conjecture that is required to be applied and that in reality all it is creating is a version of a past state that cannot be validated due to the emotional response of immersion cannot be accounted for.

To date and regardless of the advances in hardware and associated software platforms the issue is that archaeological and architectural digital simulations have traditionally been concerned with exact replication rather than with understanding, for the latter raises the conundrum of how to present scientific uncertainty, for a computer model almost invariably implies certitude and replication of the facts. For some time, heritage institutions have been experimenting with such digital tools and platforms to open up to diverse communities and encourage alternative viewpoints and interpretations. Irrespective of the discipline, this move to digitation is not without scrutiny. As Economou (2016, 216) poses; '*What is gained and what is lost when heritage is experienced via digital surrogates? What are the main characteristics of this new way of communication?'*

These questions raised above have contributed to the narrative as this work progressed. The current academic environment illustrates that digitisation is commonplace throughout the multiple areas of research relating to the Built Heritage. This situation continues to evolve and encompass new approaches as they emerge. One such area that I perceive to be advancing at present, is the concept of digital collaboration interwoven through information modelling.

2.3 Beyond Digitalisation – Information Modelling

Traditionally, the architectural conservation community has been slow to adopt and implement the use of digital technologies, particularly in relation data capture and production of drawings. The argument put forward was that the technology did not lend itself to the specific requirements to the often irregular and non-uniform geometry of the buildings (Pocobelli et al. 2018). On-going developments in computer applications has improved the functionality of hardware and the performance issues, previously experienced by software developers and users, have been addressed. In contrast to the architectural Built Heritage community, the mainstream AECO sector has embraced the opportunities afforded by such technologies largely due to the fact of perceived financial benefits afforded to the correct implementation of streamlined digital processes.

In the AECO sector, this adoption of digital technologies has manifested in the embracing of BIM, which is fundamentally a collaboration process for the design and delivery of buildings via the creation of a multi-dimensional digital model that contains vast amounts of information.

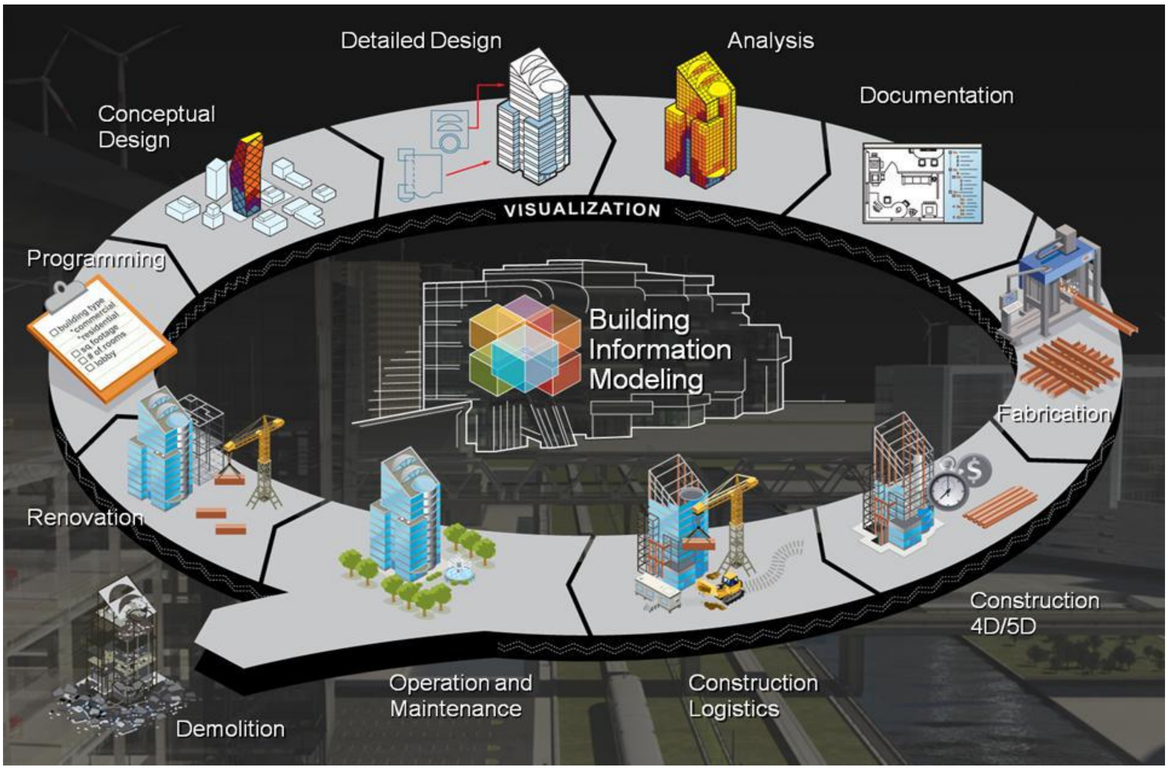


Fig 2.3.1 *BIM Infographic (source bim4efm.com)*

Building Information Modelling (BIM) is a data-rich, object-orientated, intelligent digital representation of a building. It is both a process and a technology. (Ernstrom 2006). BIM theory and practice has been advanced by the construction sector to revolutionise the process in which buildings are procured, produced, and maintained. The traditional procedures regarding construction project delivery had proven to be inefficient and where in need of refinement. The BIM approach is designed to streamline the existing process through sophisticated collaboration that allows for a reduction in consumption, be it energy, finance, or time. It is an innovative and collaborative way of working that is underpinned by digital technologies which support more efficient methods of designing, creating, and maintaining the built environment (Saxon 2013)

Although BIM adoption is on the rise now, it has actually been in existence for quite some time, originating in the United States in the 1970`s with the research of parametric modelling (Khemlani, Eastman, et al. 2011). In more recent times, BIM has started to become an achievable goal as software has advanced to facilitate the level of virtual cloud collaboration required. BIM represents a new paradigm within AECO, one that encourages integration of the roles of all stakeholders on a project. It has the potential to promote greater efficiency and harmony among players who, in the past, saw themselves as adversaries (Azhar et al. 2008). BIM also supports the concept of Integrated Project Delivery (IPD) which is a novel project delivery approach to integrate people, systems, business structures and practices into a collaborative process to reduce waste and optimize efficiency through all phases of the project life cycle (Glick & Guggemos 2009).

There are clear advantages to the BIM process as the digital model is capable of producing traditional 2D plans, sections, elevations, construction details, product information, schedules, and analysis. This facilitates the entire project information to be retrieved from one single source, the federated model. The process utilises dynamic integrated technologies to analyse and quantify all of a building's constituent parts prior to any onsite, or off-site, production. Furthermore, Foxe (2010) defines BIM as a process in which software is used to create a single virtual model of the geometry of a building that is a visual representation of an intrinsic database containing information about construction materials and assemblies, as well as spaces and areas within the building. This single central file, generally referred to as *the model,* can be worked on simultaneously by multiple users, and the geometry of the model is constantly updated within all plans, sections, elevations, and 3-D vignettes. The information, or metadata, contained within the model is central to the entire concept as the model contains data of an object which is a replication of an actual object. This information refers to properties such as the physical size, appearance, thermal performance, basically whatever data is encoded as part of that component.

A door for example contains the physical information of an actual door, therefore it comprehends it must be placed in a wall within the model. As a wall-based object, it also knows how many of this door type is within the model making it easier to quantify. Each object in the 3D model will have parametric functionality embedded within. By embedding this information into the model, it becomes a straightforward process to retrieve this data when it is required by project stakeholders. Companies and manufacturers are now producing 3D components of their product with their manufacturing details and information embedded which can be used in any model considering the file format is correct (Kymmell 2008).

It is noteworthy that there is a distinction to be made at this juncture regarding BIM in differentiating between the *concept* of BIM and the specific *applications* of BIM. The concept of BIM can be summarised in short as *better collaboration*, all parties engaged and working efficiently in a shared digital environment. Whereas the *applications* of BIM refer to the technical processes and is heavily reliant on computer software. This research focuses on both the *concept* of BIM and utilises the existing *applications* of technical practices and processes that are deployed within the AECO industry to establish a novel approach that is applied to the Built Heritage.

In mainstream BIM for this concept to be implemented there are necessary guidelines and procedures to be adhered to. The BIM process has many advantages for the construction industry, but it is not altogether flawless as it requires a substantial investment of time for the model authors to create a fully federated model i.e. all the supporting files combined in a cohesive manner without conflicts.. It also requires each member of the design team that directly contributes to the model i.e. structural engineers and mechanical, electrical, plumbing (MEP) to have a certain level of skill in the chosen software programme used to create the model. To date, several countries have adopted legislation to promote the process. In the UK, the government mandated that BIM be integral to all Government contracts in excess of £1 million since April 2016. Scotland (2018), France (2019), Italy (2019) and Ireland (scheduled for 2022) have all followed suit and are aligning with the Scandinavian countries who pursued this route much earlier. This has prompted the publication of various standards and guidelines to enable stakeholders the opportunity to acquire the necessary skills for BIM implementation in the guise of a series of documents referred to as PAS (Public Access Specification) 1192 and since superseded by ISO 19650 in 2019.

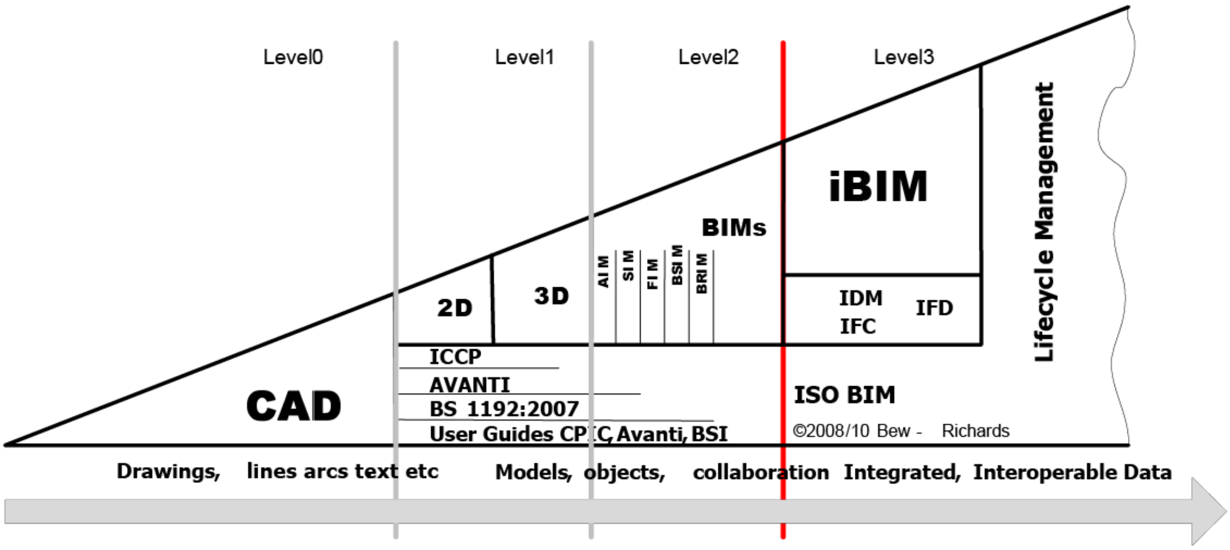


Fig 2.3.2 – The BIM Wedge, Source Bew and Richards, 2008

The application of BIM processes is defined by the UK model (Fig 2.3.2), developed by Mark Bew and Mervyn Richards (2008). Instantly recognisable by its wedge shape, it has been a useful diagram in defining levels of maturity and identifies benchmarks within the process. The levels can be defined as follows;

- Level 0 is defined as unmanaged CAD. This is likely to be 2D, with information being shared by traditional paper drawings or in some instances, digitally via PDF, essentially separate sources of information covering basic asset information.

- Level 1 is a mix of 2D and 3D information using ISO 19650 with a collaboration tool providing a Common Data Environment.

- Level 2, which was mandated in April 2016, is described as collaborative BIM. Federated model information is shared within a Common Data Environment. The UK government website (www.bim-level2.org) provides a one-stop-shop access to the Level 2 standards including PAS 1192 and ISO 19650

The common misconception regarding BIM is that it is solely seen as an efficient process to create a verified model and nothing else. Critics argue that the creation of the BIM stifles creativity and is unnecessarily cumbersome in the design process of buildings. However, as stated above, the 3D element of BIM is merely one aspect. Above all other things, BIM is essentially a structured collaboration of the design & build team to ensure efficiencies and the harmonisation of data. The

"I" of BIM means Information, whereas if the process is applied correctly it is argued should be redefined to mean Intelligent.

2.3.1 Information Modelling - Data Acquisition?

Data acquisition as a process and how it is applied to this research is referred to earlier in this chapter 1.2. This section of the thesis refers specifically to the process of acquiring information and data directly related to the development of the digital model.

In common practice a digital model would have been created from heterogeneous datasets, organised, and filtered by the surveyor and then digitised by a CAD operator. Digital surveying has almost entirely replaced this practice in the field. The use of 3D technologies has been seen as a mechanism for recording cultural heritage for some considerable time. As the re-emergence of Virtual Reality was popularised in 1980`s, there have been examples of projects seeking to recreate heritage-based artefacts (Addison, 2000). Furthermore, Geographical Information Systems (GIS), that is primarily a data management tool but has also been applied as a significant tool to support the recording of cultural heritage. Since the publication of the UNESCO *'GIS and Cultural Resource Management: A Manual for Heritage Managers' (*Box 1999) there has been increased interest in GIS developments among heritage conservation groups (He et al. 2015) Saygi et al. (2013) highlight the benefits of GIS with respect to cultural heritage, in particular the ability to integrate multiple datasets such as photographs, textual descriptions, and 2D thematic drawings to help us to understand heritage data beyond geometric features (Baik & Boehm 2015). This allows for fast, effective, and flexible exploratory analysis of data, both at spatial and temporal levels, Meyer et al (2007). However, a limitation of GIS focuses around the representation of the 3D geometry of the physical artefacts (Saygi et al. 2013). Tobias (2016) investigated a range of software technologies currently available within the domain of cultural heritage and concluded that GIS has significant advantages with respect to managing spatial data, however prevailing Building Information Modelling (BIM) software tools present the ability to develop more detailed 3D digital models for integration with GIS (San et al. 2009).

In terms of obtaining measured information, laser scanning is widely accepted as been the most commonplace technique in capturing as-built buildings and artefacts. The terrestrial laser scanner is a device that automatically measures the three-dimensional co-ordinates of a given region of an object's surface, in a systematic pattern at a high capture rate in near real time. The laser ranger is directed towards an object by reflective surfaces that are encoded so that their angular orientation can be determined for each range measurement. The entire instrument and/or the recorded object are rotated to achieve, where possible, complete 3D point coverage (Mills and Barber 2004). In the UK, 3D laser scanning was identified by Historic England as an important aspect of the cultural heritage process and as such a guidance document *3D Laser Scanning for Heritage* was published in 2007 and then subsequently revised in 2018 (Historic England 2018). The guidance covers issues surrounding available technologies, resolution, and the procurement process. Whilst it is incredible to record such a high level of information relating to a historic building or asset, one of the key issues to understand is what should be modelled geometrically in three dimensions and the scope of any modelling to ensure cost effectiveness of the project (Morrical 2017). There are three types of scanners suitable for metric surveys for cultural heritage: triangulation, phase comparison and time of flight scanners. Triangulation scanners calculate 3D co-ordinate measurements by triangulation of the spot or stripe of a laser beam on an object's surface that is recorded by one or more CCD (charge-coupled device) cameras. Phase comparison systems calculate range based on the difference in phase between emitted and returning wavelengths. Time of flight scanners calculate range, or distance, from the time taken for a laser pulse to travel from its source to an object and be reflected back to a receiving detector (Boehler et al. 2001).

Whilst Terrestrial Laser scanning is considered extremely precise it is an expensive process for the general user. There are alternative techniques that are employed that can produce usable data, photogrammetry being one. Photogrammetry is the science of making measurements from photographs. The output of photogrammetry is typically a map, drawing, measurement, or a 3D model of some real-world object or scene. Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena (Slama 1980). It can be classified into distinct techniques of aerial photogrammetry, and close-range photogrammetry. In aerial photogrammetry the camera is mounted to an aircraft/drone and is usually pointed vertically towards the ground. Multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. These photos are then processed and eventually create a Digital Elevation Model (DEM) file which is essentially a 3D topographical representation of the capture area.

In Close-range Photogrammetry the camera is close to the subject and is typically hand-held or on a mounting device. Everyday cameras/smartphones are used to model and measure buildings, structures, for archaeological artefacts and essentially a myriad of small to medium sized object. This type of photogrammetry (CRP for short) is also sometimes referred to as Image-Based Modelling (Historic England 2017)

There are several other techniques, but laser scanning and photogrammetry are the most common methods employed in current practice. The net result of each process is to produce a point cloud. A point cloud is a set of vertices in a three-dimensional coordinate system. A dust-like representation of the surveyed area, normally with imagery applied to illustrate the object in a realistic manner. This point cloud can then be utilised in a multiple of authoring platforms to be developed further dependent on the intended end-use. There are issues to be considered however such as the partial lack of interoperability between the survey tools and model software (Tommasi et al. 2016). Each of the above methods are employed for capturing tangible dimensioned data and is employed for the development of a 3D digital dataset. This process is referred to as *Scan2BIM*. Tang et al. (2010) summarise the Scan2BIM process in three distinct stages, including the capture of data in the form of a point cloud, pre-processing of data such as merging multiple scans together and finally the geometric modelling using a BIM authoring tool.

This approach of essentially, scanning, and traditional digital modelling, continues to be the accepted approach as detailed in the study by Lopez et al. (2018). Whilst this can yield accurate results, it is noted by Xoing et al. (2013) that this is still a manual process and can be subject to mistakes and requires experienced operators. Also, the accuracy of the point cloud depends on the instrumentation employed to acquire the data and the skillset of the surveyor. Furthermore, as Watterson (2014, 27) '*highlights that the use of systematic and automated digital survey techniques can have a negative effect on the interpretive process as it mediates and mute's practitioner engagement with the site or artefact'*. Finally, it is also worth considering that in terms of utilising the information garnered from such methodologies Watterson (2014, 29) also indicates a possible flaw in *'the matter that digital acquisition techniques may be presented as an objective means of data capture and representation, but this is due to a false sense of neutrality and transparency. In reality, much like photography…. it involves a series of technical decisions and choices which single out sites, structures, and objects for display'.*

2.3.2 Information Modelling - Data Authoring

As data is collected and appraised it requires to be harnessed and manipulated into an entity that is readily useable. This applied process is referred to as Data Authoring. The term encompasses the design and assembly of the IM. A digital model must be assembled in such a way as it is required to possess certain characteristics that allow for increased functionality ranging from an organisational framework for the collated data to an assembly structure with appropriate naming conventions. Direct 3D modelling by whatever means, be it geometry based, vector based, or coding is not deemed sufficient in this regard. Critical to the process of information modelling in

BIM is parametric modelling. As Tedeschi (2001) wrote, *'The parametric software – protagonist of a wide and transversal spread thanks to an initiative use that doesn't require programming knowledge- let to organise the projects in associative systems based on the relationships between parts, offering the possibility to alter the overall configuration of a system, by working on the parameters at the base of the design process, according to a logic of propagation of changes'.*

Parametric modelling is constructing components and applying real world behaviours and attributes. Mapping parametric objects, as opposed to vectors, on to the point cloud can overcome the slow task of plotting and locating every vector onto the cloud surface. The use of parametric objects can also introduce the opportunity to develop detail behind the object's surface concerning its methods of construction and material make-up. The process of mapping parametric objects onto a 3D point cloud can be achieved by placing 2D or 3D shapes onto the point cloud by locating/defining shapes on the point cloud as primitives. For example, a primitive shape of a cylinder can be mapped onto the point cloud to represent a column, which is then textured from the associated image data (Abmayr et al. 2005). Underpinning the rationale for parametric modelling is defined by BIM's Level of Detail (LOD). This defines how the 3D geometry of the building model can achieve different levels of refinement and is used as a measure of the level of information required. There are five LOD options ranging from 100 to 500. Throughout the geometric modelling of the building, the LOD is required to be specified to ensure that the model meets the requirement and the time/cost constraints are balanced with the required outputs. LOD for design-based BIM projects is specified through a range of toolkits such as the USA LOD Specification (BIMForum 2017) or the NBS Toolkit in the UK (NBS 2017)

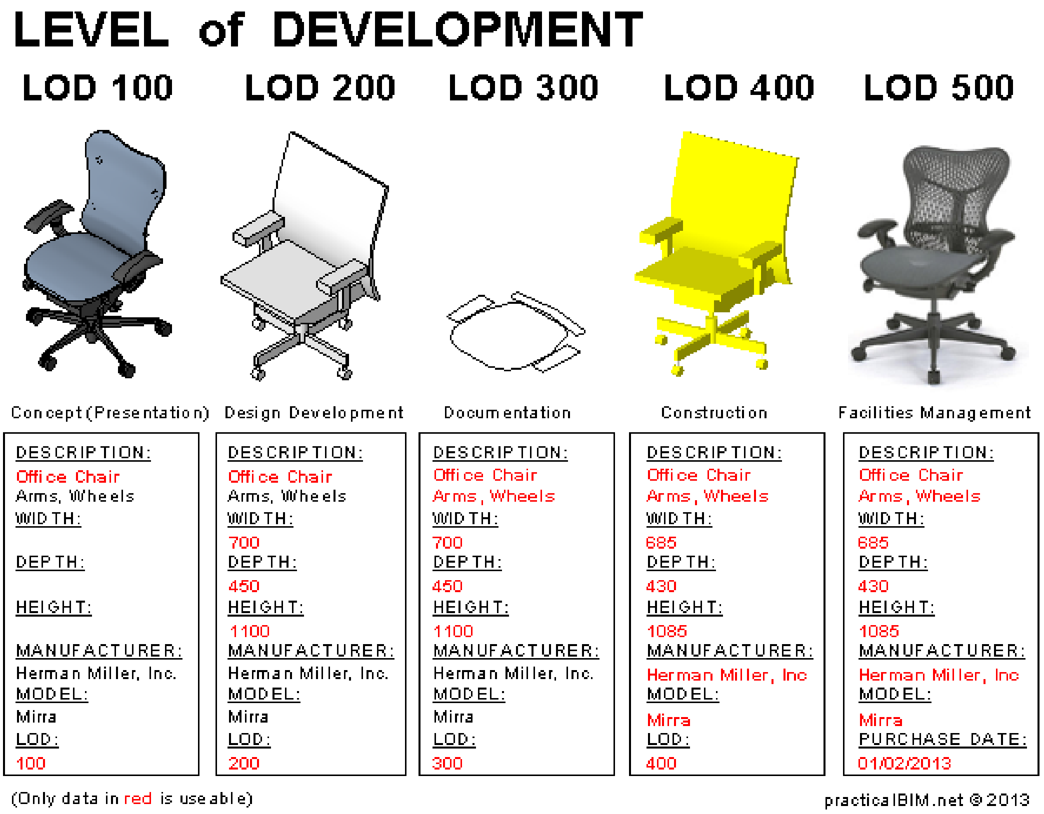


Fig 2.3.2.1 – Source : *practicalBIM.net@2013*

LOD 100 - Concept Design

The building 3D model is developed to represent the information on a basic level. Thereby, only conceptual model creation is possible in this stage. Parameters like area, height, volume, location and orientation are defined

LOD 200 - Schematic Design

General modelling where elements are assembled with approximate quantities, size, shape, location and orientation and also attach non- geometric information to the model elements

LOD 300 - Detailed Design

Accurate modelling and shop drawings where elements are defined with specific assemblies, precise quantity, size, shape, location, and orientation. At this stage non- geometric information to the model elements can be embedded.

LOD 400 - Fabrication & Assembly

Model elements are modelled as specific assemblies, with complete fabrication, assembly, and detailing information in addition to precise quantity, size, shape, location, and orientation. Non-geometric information to the model elements can also be encoded.

LOD 500 - As-Built

Elements are modelled as constructed assemblies for maintenance and operations. In addition to actual and accurate in size, shape, location, quantity, and orientation, non-geometric information is attached to the modelled element

To further support the issue of LOD for heritage-based projects, Historic England has defined four levels of graphical detail when generating 3D geometry in BIM projects (Antonopoulou & Bryan 2017). Whilst these provide a level of guidance during the development stage, there is yet to be a full global standard established for heritage projects (or indeed for BIM projects). This has often led to individual projects developing their own bespoke standard (Folwell 2015).

In addition, parametric modelling must have the capacity to acknowledge metadata (Pocobelli et al. 2018). Without metadata, the IM`s ability to be meaningfully interrogated by end-users is diminished. Metadata is data that describes other data. Meta is a prefix that in most information technology usages means *'an underlying definition or description'.* Metadata can be created manually, or by automated information processing. Manual creation tends to be more accurate, allowing the user to input any information they feel is relevant or needed to help describe the file. However, for the IM to be of greater value in the interpretive process of the Built Heritage the ability to embed paradata is also required. Paradata, as described by the London Charter (Denard et al. 2012) is;

'Information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset of how evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in emphasis, to contextual metadata, which tend to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted'.

Essentially, the authored IM must not only contain the dimensioned and empirical information required for the purposes of recording but would also encapsulate the ability to contain both para and meta data associated with that building or artefact within a parametric digital model.

2.3.3 Information Modelling (IM) - Data Management

BIM as a paradigm is focused on the philosophy of creating a database containing connected 3D geometric and informational data about the objects (Eastman et al. 2011). The process of managing the data contained within the IM is to the forefront of contemporary thinking. The argument presented in this research is that there is scope for a new dynamic approach that will harness these rich datasets in a way that relates to the Built Heritage. Potentially the management of the data offers boundless possibilities for a myriad of end-user's, dependant on their requirement.

Intangible Built Heritage data and cultural documentation, in many cases are still preserved in a 2D format holding only geometric drawings without semantic attributes or definitions (Tommasi et al. 2016). The ability to incorporate *intangible* Built Heritage data provides a greater challenge possibly due to the more fluid and dynamic nature of the information involved. Dore & Murphy (2012) did propose that a 3D digital geometric model could contain historical information about the creation, origin, and chronology of heritage objects. These could then be linked to historical documents in different formats i.e. manuscripts, 2D floor plans and sections, photos, or voice recordings. Fai et al. (2011) also suggested that BIMs could contain non-graphical *intangible* data such as photographs and oral histories. These suggestions were never acted upon and one of the potential reasons for this limited uptake is the lack of a comprehensive solutions specifically designed to model and manage semantically enhanced 3D models of historic buildings (Tobias 2016). Fassi et al. (2016) suggested that more interactive functions within 3D models would be required to enhance the uptake and thus could support the inclusion of *intangible* heritage data within the context of a model. The authors suggested a *read and write* mode where the model could be asked questions and VR could be used to compare present and past, and to assess and quantify the changes caused by time.

In the mainstream AECO sector this process of asset management is commonplace in post occupancy of buildings in the form of facilities management. This would entail a heterogenous data set of material that is often cumbersome to manage and interrogate such as paper-based folders and drawings. The development of BIM has helped to mitigate this by digitising the process. Applying a similar approach to BIM-based documentation in the field of heritage and conservation is not without precedent. Arayici (2008), for example, advocated the adoption of BIM for existing buildings in order to move beyond 3D visualisation through the incorporation of multifunctional, intelligent and multi representational data (Fai, et al. 2011).

In the Built Heritage sector an opportunity exists to apply a similar approach in cultivating data within a complimentary framework. Beginning with Pauwels, et al (2008) who proposed an expanded approach to BIM through the development of Architectural Information Modelling that facilitates the inclusion of *'theoretical and historical'* in conjunction with construction orientated information there has been an acknowledgement that the capabilities of BIM have not been fully utilised. Within the Built Heritage sector Arayici (2008) Penttila et al. (2005:2007) have identified the requirement to refine International Foundation Classes (IFC), the dialect of BIM, to foster relationships between qualitative and quantitative data. This approach was further developed by Fai (2011), who discussed integrating aspects of *intangible* heritage with physical geometry whilst Tommasi et al. (2016) further noted that in order to expand this approach the geometric model should contain multiple threads of information. Building upon the works of earlier scholars and adopting the more advanced BIM technologies regarding both data harnessing and management a novel approach and workflow where a digital model containing multiple datasets is now possible.

2.3.4 Information Modelling – Best Practice

Given the multidisciplinary nature of this work, in that it encompasses branches of research ranging from building conservation theory to virtual archaeology to cultural *presence* to BIM, identifying current best practice requires a structured response. The primary research goal, as expressed in chapter 1.2.1, is to enable a greater level of interpretation of the Built Heritage through utilising both information modelling and virtual environments. On review, the term *information modelling* is not readily identifiable within Built Heritage research at present. The closest parallel is found within related disciplines and, as highlighted above, the mainstream AECO industry has begun to adopt the virtues of BIM. To date, it has primarily focused on large scale, new build projects. Applied research relating to BIM implementation for heritage projects in this area is beginning to gather momentum.

Contemporary research in BIM processes and their application to the Built Heritage began to evolve in the mid 2000`s with an emphasis on procedural semantic modelling. Boulaassal et al. (2008) devised a system to retrieve lines of façades in laser point clouds that allowed for the dimension of openings within the walls. The Test Studieswere quite simple façades where this method was successful, however the lack of parametric architectural libraries at the time meant it was quite limited. De Luca, L. (2007) investigated a technique of modelling from architectural rules and pattern books such as old treaties for ancient and classic styles. The Test Study proved quite successful however it was limited to internal architectural mouldings. In contrast to this research, Chevrier & Perrin (2008) took an alternative approach of devising the parametric model of the building component and in turn create libraries based on historical data and then alter the parameters of these components in relation to the actual survey of the building in an effort to create an efficient workflow. A plugin for Autodesk Maya (3D modelling software) was created, which allowed for this information to be inserted into a parametric CAD model of a building. This approach was further developed with the improvement in data acquisition techniques such as laser scanning and photogrammetric surveys by Chevrier, et al. (2010). Building on this early research, De Luca (2012) developed parametric CAD objects which can be mapped directly onto the primary survey. The parametric primitives or objects can be modified to fit a range of geometry and texture requirements for virtual illustration of historic structures. This eventually evolved into what is now termed HBIM.

The term historic building information modelling (HBIM) was first coined by researchers in Dublin Institute of Technology and Trinity College Dublin. Murphy, et al. (2009) looked at a methodology for constructing a library of interactive parametric objects based on how historic architectural data is presented using geometric descriptive language (GDL). As a multi-disciplinary and evolving approach, HBIM has been developed to encapsulate the survey of existing structures using remote sensing followed by the mapping of parametric and information rich objects onto a geometric framework based on the remote survey data. The resultant HBIM can then be used for automatically producing limited conservation documentation and analysis of historic structures in addition to visualisation (Dore et al. 2015). Garagnani (2015) and Marzouk et al. (2016) both emphasise the on-going need for HBIM and the ability to capture history and culture in a single repository, where all model elements, data and entities are integrated. Pauwels et al. (2013) noted that in order to fully depict a heritage asset, disparate information should be integrated with existing BIM tools that will document and combine all heritage information with accurate visualisations providing a holistic dataset that can be easily understood. Tommasi et al. (2016) concurs with this philosophy suggesting that a benefit of integrating a range of data sets aids the management and conservation of archaeological areas, monuments, and artefacts. These rich data sets provide the ability to undertake a more enhanced analysis of cultural heritage sites (Baik et al. 2015) and as such the 3D models created can be used for more than just visualization (Dore et al., 2015)

A significant body of research in the paradigm of HBIM focuses on the recording and use of BIM based technologies for the development of models depicting solely the remaining *tangible* aspects of buildings and sites. However, as discussed by Tommasi et al. (2016) there is a need to extend this, noting that in order to represent cultural heritage the geometric model should contain additional information. As far back as 2007, Penttila et al. (2007) defined approaches whereby BIM tools were implemented to provide additional historic data to be accessed semantically. There is an international community emerging in this area of research. HBIM projects by the CIMS laboratory at Carleton University (Fai, S. et al. 2011; 2013; 2014), are exploring advances in not just creating digital models but identify workflows for efficient data and document management. Fai et al. (2018) discussed the integration of some aspects of *intangible* cultural heritage with the physical geometric elements of the BIM through a Test Study project in Canada. They included *intangible* data such as photographs and also a timeline within the model to highlight the change in the environment during the nominated period. Using proprietary BIM software, they advanced the potential to use the technology abilities to link other types of data such as music and storytelling. Likewise, researchers in Milan applied a similar approach to the Cathedral belfry with varying degrees of success (Oreni et al. 2014).

Building on the work of the EU funded Valhalla Project in 2003, Counsell and Taylor (2017) proposed framework for HBIM and cultural heritage that included integrating additional *tangible* heritage data through use of sensors and recording of materials. However, they also advocate the development of *intangible* aspects through inclusion of location-specific *intangible* cultural heritage and using the HBIM for community engagement and community-based bottom-up readings. One of the key challenges focused on how to bring about a HBIM which, hitherto is arguably a very technical / specialist process to non-specialist users, of containing both *tangible* and *intangible* data (Kurin 2007). Guarnieri et al. (2010) discussed the potential benefits of interactive media as an interface and Osello et al. (2018) highlighted the potential of emerging Virtual Reality based technologies to support the visualisation of BIM data developed through proprietary BIM authoring tools. This approach still required a level of manual intervention with data exchange between software tools and reprogramming to ensure all graphical and non-graphical data was viewable in the final simulation. The use of VR tools can significantly aid the interpretation and understanding of HBIM particularly for members of the public (Garcia et al. 2018) and this could then be used to generate a greater level of impact and subsequently help to achieve a richer database of *intangible* heritage data.

As highlighted, there are different approaches in achieving the HBIM with primarily two areas of research which have focused on developing the knowledge base, Computers Sciences and the AECO professions. A review of literature to date highlights a recurring insight that is based on how each of these strands of research predominantly view the *'I'* in BIM. For some, the *'I'* refers more to *intelligence* rather than *information,* whilst others perceive the 'I' merely as *interoperability* between software platforms. I suggest that HBIM, as it is now perceived in current research, does not align with the developments and philosophies in mainstream BIM, in that it is more of a data acquisition/collation method (BIM Level 1) as opposed to a robust approach that can generate a model that has the ability to be cross-interrogated (BIM Level 2) by the end-user. What is apparent, regardless of the adopted methodology, to the exploration and advancement of HBIM is that the research undertaken to date has mainly focused on the physical Built Heritage, whilst not necessarily engaging with the *intangible* facets of the built fabric and the very essence of what is deemed *significan*t, in the context of the Burra Charter(refer section 2.1.), regarding the artefact or building. The physical, or *tangible* qualities of a building/place are only a part of the legacy, the embedded *intangible* fabric is considered of equal value.

The Built Heritage community is not alone in tackling this issue. Cognate areas of research, and in particular, scholars exploring the notion of Cultural Presence, the notion of *being then and there* (Steuer, 1995) are to the fore. The LEAP Project (www.upf.edu/web/leap) being a case in point, an EU-funded project (LEarning of Archaeology through Presence), devised by Dr Laia Pujol-Tost, with the aim to, *develop this crossroad area by researching, implementing and evaluating a new interdisciplinary theoretical and methodological framework for Archaeology. The idea behind the project was that Cultural Presence (the feeling of being then and there) was the key to design and evaluate experiences that would enhance understanding, social relevance and enjoyment of Cultural Heritage'.* The project the experience consists of a one-day trip to Çatalhöyük (Turkey) 9000 years ago. There are two display modes, immersive and screen-based while model has six different versions (architecture only, objects, hotspots, still characters, scenes, and storytelling) permit the users to explore five pre-defined points of interest displaying the most representative cultural aspects of Çatalhöyük. There are many interesting aspects of this project to consider such as the decision to restrict the realism of the environment and the ability to allow for a self-directed interpretive experience. Lessiter et al. (2001) list four criteria that determine presence and immersion in virtual environments. The four criteria are physical space, engagement, naturalism or realism, and negative feelings (such as phobia, motion sickness etc.). Champion (2012) contributes further that the concept of cultural presence is a sense that a cultural viewpoint inhabited the site. The premise of Cultural Presence is signposting a methodology for inclusion, of what this research defines as *intangible* heritage, but with regard to the digital formation of such an environment the challenge still exists as to how this *intangible* cultural knowledge be constructed digitally? (Alivizatou-Barakou et al. 2017, 6).

On reflection, and having conducted a thorough review of both historic and contemporary research in this diverse area relating to the Built Heritage that has reviewed not only current best practice but also the theoretical opinions that underpin processes and methodologies relating to the digitisation of historic buildings, I contend that an opportunity had presented itself for a combined approach that encapsulates the positive attributes of several areas discussed previously and propose a novel workflow going forward.

2.4 Introducing Integrated Heritage Modelling (IHM)

In summary, this chapter establishes a context for the research within the heritage domain. Although the overview presented above has identified that this area of research is quite diverse and incorporates scholars from various backgrounds it is important to identify that the underpinning subject area for this work is based within building conservation and its relationship with digital technology. Key definitions were defined and are referred to throughout the remainder of this text. Multiple approaches have been reviewed and assessed with many questions still left unresolved from both a theoretical standpoint regarding the *how* and *why* to more technical aspects regarding the fusion of the two subject areas. The theoretical debate is a constant theme, revisited throughout the forthcoming text with an informed opinion offered for discussion in a later chapter. In dealing with the technical issues raised regarding the fusion of building conservation and digital processes I contend that a gap exists in the current research environment that successfully tackles this issue. To further contribute to the discourse and in an attempt to narrow that gap of knowledge, a new approach is introduced called **Integrated Heritage Modelling**. In short, Integrated Heritage Modelling encapsulates the processes of BIM, underpinned with a knowledge of building conservation, and fused with advanced digital technologies in order to interrogate the subject matter for the enhancement of the interpretive experience to the end user. Integrated Heritage Modelling (IHM) is defined here as;

A process of creating a multi-dimensional digital repository that allows for the capacity to host rich data-sets that has the ability to be interrogated by the end-user.

The forthcoming chapters comprehensively outline the structure and framework of this novel approach and demonstrate its application via case studies. Furthermore, the IHM method is robustly evaluated through a multi-faceted approach with a select cohort of participants to ascertain its effectiveness in achieving its stated goals of incorporating both *tangible* and *intangible* heritage within a digital repository for consumption and enhanced engagement. Through demonstration, via the case studies, not only is the technical workflow outlined in a clear workflow but the theoretical argument of *why* is further built upon through the qualitative findings provided from the input of the participants who engaged with the case studies. These outputs provide further insight regarding the success, or otherwise, of *why* the digitisation of the Built Heritage is of significance.

2.4.1 The Research Question

In order to formalise this process of investigation in a structured academic fashion and to ensure the necessary rigour is applied, the research question that this work has endeavoured to answer is;

How can the application of intelligent heritage modelling, through the platform of virtual environments, create a new approach to interpreting both the *tangible* and *intangible* fabric of the Built Heritage?

3.0 Methodology

The previous chapters have identified that the primary aim of this research is to identify how the application of Integrated Heritage Modelling (IHM), through the platform of virtual environments, can create a novel approach that improves the level of interpretation for both the *tangible* and *intangible* fabric of the Built Heritage. Chapter two examined contemporary debates in the domain and identified a gap in the existing knowledge that successfully exploits the opportunities that digital technologies offer, through the implementation of (Building) Information Modelling, to enable access to the *intangible* richness contained within the historical legacy of a building, or place.

This thesis adopts a mixed methodological approach as it was determined that this was the most appropriate. Such an approach using mixed methods is suitable for this study as it not only assists in evaluating specific elements of *intangible* heritage for inclusion but also appraising the interactions of the workshop participants through observation and the subsequent semi-structured interviews with knowledge providers and is based on a multi-nodal approach that was both quantitative and qualitative utilised within the LEAP and is explained in greater detail in section 3.3.

This chapter fully describes the overall research design of the thesis, incorporating the techniques, methods and instrumentation employed for each stage of the workflow and a rationale for the selected evaluation processes.

3.1 The Research Problem

Chapter two identified the current thinking as regards the position of digital technology and processes within the scope of study. Whilst this research straddles several areas of research such as, building conservation and virtual heritage, and explores more nuanced areas such as *Presence*, the challenge that exists is the adoption of contemporary digital technologies such as virtual, augmented, and mixed reality to disseminating knowledge within the realm of building conservation.

As discussed previously in chapter one, the selected audience for the purpose of this thesis has been identified as a cohort of university level students. Given the specific nature of the participant, that being a perceived *digital native* the solution should be readily identifiable. In that, the selection of this sub-group would suggest that the knowledge transfer would be requested and expected in this digital format. On reflection, is it accurate to describe the end-user as a '*digital native'*? The designation of Digital Natives/Immigrants has been argued and questioned within higher education. Prensky (2001, 1) who devised the definition originally declared that *'Our students have changed radically. Today`s students are no longer the people our educational system was designed to teach'.* If this statement where in fact accurate we would have expected the educational system to have reacted accordingly in the time since this statement was first mooted. There is a lack of empirical data across multiple geographical regions to support the notion of digital natives and digital immigrants and moreover the evidence suggests that today's students are a diverse group from various backgrounds with a myriad of interests, motives and behaviours and that they never cohere into a solitary group or generation with common traits (Jones & Shao 2011). Furthermore, many educational technology advocates identify that *digital immigrants* were, to all intents and purposes, the original creators of these devices and digital environments (Stoerger 2009) and thus challenging the perception that the current student body is any more, or less, advanced than previous cohorts. Perhaps the JISC report authored by Lanclos (2016) that argued the '*The 'digital native' is a generational metaphor. It is a linguistic metaphor. It is a ridiculous metaphor. It is the notion that there is a particular generation of people who are fundamentally unknowable and incomprehensible'* has definitively pronounced the '*death of the digital native'* term. The term *digital native* may be debunked and considered a *'ridiculous metaphor'* but what cannot be disputed is the access and influence digital technologies now exert within many strata of society, education and research being front and centre.

Complimentary fields of research are further forward in answering this problem then building conservation. As alluded to in Chapter two, the building conservation community is still somewhat entrenched in the written word and is just beginning to adopt contemporary technologies in a meaningful way. What development there has been is due to the loose adoption of the BIM acronym in the guise of HBIM. The pervious chapter challenged the notion that HBIM was an inaccurate title for the work currently being declared as such. It is of undoubted value, but primarily directed towards empirical data acquisition as opposed to the collaborative process of which BIM is predicated on. It is also suggested that the current HBIM approach is dedicated more to improving technical workflows of data capture. To date, research in this area has focused on the capturing of *tangible* information pertaining to the building and not fully explored, or exploited, the possibilities associated with BIM in capturing the *intangible.*

A core issue that this work addresses is that applying digital technologies to the Built Heritage overlaps multiple fields of enquiry, but its genesis is within the area of building conservation. This is not a new problem and has been discussed for some time by notable scholars in their relevant field of research. As referenced in chapter two, the propositions put forward by Sutherland in the 1960`s regarding digital advancements and their impacts and possibilities are still evolving today by a range of scholars such as Champion et al. (2015), Pujol-Tost (2016), Huggett (2014) and Fai (2015). It is not possible to prescribe a definitive all-encompassing collective approach, or solution, is not readily available given the multi-disciplined nature of the task to hand. The continued development of technology and the subsequent digitisation of society is providing an impetus for evolving approaches to be applied. The goal for the conclusion of this process is an informed end-user who has been exposed to enhanced datasets and information both *tangible* and *intangible*. Therefore, as stated in chapter 2.4.1, the research question that this work is endeavouring to answer is, *how to develop data rich integrated models that provide a repository for both tangible and intangible heritage?* In attempting to solve this issue, a new approach to assist in disseminating this information will also be created.

3.2 Research design for workflow and case studies.

The following section outlines the design that underpins the research methodology. To begin with, a novel workflow is described that provides an infrastructure for the adoption and application of Integrated Heritage Modelling, which was introduced at the end of chapter two. A brief synopsis of the technical tools employed and the appropriate justification for selection is then outlined. A discussion follows identifying the scope of the study and an explanation of the selection of test subjects for the subsequent Test Studies and demonstration workshops. The chapter then continues with an outline of the evaluation criteria utilised to monitor the success, or otherwise, of the research is discussed. Given the digital nature of this work with live participants, issues relating to matters such as data collection, data legacy, data security (GDPR) and ethics are identified, and mitigating measures are discussed in detail. Finally, there is an outline of the accompanying appendices that support the main body of this research.

It is noteworthy at this juncture to highlight that due to the subject matter of this research that an accompanying digital deposition is included with this research. Due to the large file sizes associated with the primary research a decision was taken to include this information in digital format and to act in support of the written submission. An overview of the content and layout of this segment is outlined in detail to ensure ease of navigation and access.

3.2.1 Scope of Study

In order to explore and evaluate the proposed new approach Test Studies were developed with accompanying workshops formulated to evaluate the level of enhanced understanding to the prescribed end-user. Buildings selected for inclusion had to ensure that a thorough examination of the proposed new approach was possible. IHM, as a workflow, seeks to create data-rich repositories that are accessible and engaging. Therefore, two varying buildings were decided upon from different historical periods that varied in terms of construction, scale and typology but were of not only historic, but also social significance. In addition, certain practical considerations had to be assessed such as access and availability of information relating to both buildings.

Key decisions were made at an early stage in terms of visualisation of the subject matter. The utility of photo-realistic representations has been debated in earlier chapters, in light of this, and in order for the 3D models to be consumable, it was decided to employ an NPR (non-photo-real) graphic. The rationale is that the aim of the study is to explore how the *intangible* can be engaged and not to replicate an assumed realistic representation of a past state. The emphasis of this approach is on self-directed engagement and allow the users to develop a level of subjective autonomy to interpret their own experience.

Several possible buildings where reviewed and evaluated including Poolbeg Power Station, Dublin and Curraghmore Estate in Portlaw along with a selection of ecclesiastical buildings including Holy Cross Church in Tramore and the Cathedral of the Most Holy Trinity in Waterford City. These were rejected mostly due to scale but more crucially due to other practical issues, such as restricted access or data not being readily available. Two buildings were deemed sufficient to accurately demonstrate the IHM approach and both chosen buildings had an element of continuity in terms of a shared history, varied in construction, scale and typology and in addition where readily accessible.

The building chosen for Test Study A is no. 1 & 2 Cathedral Square, located in Waterford City in the heart of the Viking quarter. A small/medium scale building that contains multiple iterations of design input, albeit on a modest scale. The majority of the construction dates to the 18^{th} century with one section of timber structure having been dendrochronology dated to the late 15^{th} century. Given the multi-phase development of the building, with its various construction methods, it was chosen to be a worthwhile endeavour to demonstrate how scientific data associated with an historic building can be embedded into the IHM process.

For Test Study B, Christ Church Cathedral was selected. Also located in medieval Waterford, Christ Church Cathedral possessed a more complex challenge in that it contained multiple threads of *intangible* heritage ingrained within its fabric having played a prominent role in the history of Waterford City. It was also of a much larger scale than the previous Test Study and from a different historic period.

The Test Studies were developed sequentially in order to align with the three-stage workflow of IHM, of *Information, Interaction & Immersion*. These stages are outlined in detail in chapter four. In short, Test Study A focused on demonstrating step one of the process *Information* and the ability to embed *tangible* datasets. Lessons garnered from Test Study A where applied, where applicable, in developing Test Study B. Test Study B then focused on steps two and three of the IHM workflow, *Interaction* and *Immersion* and the ability to embed *intangible* datasets for enhanced engagement.

3.2.2 Instrumentation

The adoption of digital technologies within the historic built environment is continuously developing primarily in the area of labour-intensive practices that are being streamlined through digitisation to great benefit, such as manually surveying a large building for dimensional data compared to laser scanning the same building for the same information. A task that would have traditionally taken many hours, days even, has now been reduced to a fraction of the time in terms of acquiring the information. This is not to say that traditional tools and techniques do not still have a role to play in the process and the physical experience of visiting and engaging in a tactile manner with the physical building is still an important part of building surveying as it allows the surveyor to engage and experience the building. Applying contemporary technology does not prevent this from occurring rather than it allows for greater opportunity to concentrate on the more intriguing and engaging aspects of fieldwork by reducing the repetitive tasks of data acquisition and collation.

The instrumentation applied in this research in order to demonstrate the theoretical framework of Integrated Heritage Modelling is both traditional and contemporary. Software, it is argued, is considered a contemporary digital instrument as opposed to a tool and necessary in the IHM process. For clarity, the instrumentation required for this process is segregated into three specific areas of *acquisition*, *authoring* and *engagement.* These three stages represent the process pathway and requires specific instruments to be implemented at each juncture. *Acquisition*, whilst fundamental is not necessarily essential, as the information may already be available via third party means, whilst *authoring* refers to the task of collating and preparing the information into a robust digital repository. The final stage of *engagement* requires specific platforms to successfully interact with the end-user. It should also be noted that in tandem, traditional techniques, such as physical site visits, interviews, hand sketching, and photography were utilised when necessary and deemed appropriate.

3.2.3 Data Acquisition

As alluded to in the previous section and elsewhere, whilst data acquisition as a practice is not a necessity it is fundamental to the IHM workflow. Acquiring the data from existing third-party sources who have already completed the task may also be considered. In this scenario, having selected the buildings for both case studies, due consideration was given to which form of approach would be employed in order to acquire the necessary datasets. A multi-faceted method was formulated which involved both traditional and more contemporary techniques given the context of the information that was required. In collating the physical information, a conventional approach was deployed in the form of site surveys, reviews of local government drawing repositories, condition reports and a thorough evaluation of all previous works conducted on both buildings by scholars and practitioners. Laser scanning was considered but deemed unviable in this instance. Whilst the accuracy of the laser scan would provide greater measured data, early testing illustrated that the resulting point cloud would have proven overly cumbersome in creating the IHM given the extremely large data files created from such a process, e.g. up to 6TB. For Test Study B aerial photogrammetry was conducted retrospectively for model validation through the deployment of an UAV (Phantom 4).

This is not to say that a successful IHM could not be created utilising laser surveying techniques, but that it is not fundamental to achieving the desired aims of this research. No doubt within a short period the issue of large raw data files will be overcome and successful scan-to-bim applications will be developed for the heritage sector.

Information relating to and representative of the intangible heritage of the Test Study buildings was collated from multiple sources. Given the nature of the heterogenous data sets available ranging from existing drawings, past surveys, ancillary historical records and Local Authority reports a thorough process of evaluation of the available material occurred. This entailed visiting both local and national libraries, interviewing the relevant stakeholders and reviewing texts/works from cognates areas of research relating to both buildings.

3.2.4 *Participant Selection*

The digitisation of society and the dichotomy regarding digital natives/immigrants has been elaborated upon previously (refer 3.1). Within educational circles the merits of bespoke blended approaches continue to be discussed and evaluated as the technology continues to encroach on traditional practices. This is not unique to any particular subject area as many sectors struggle to implement new pedagogical approaches that acknowledge the development of ICT. User-centred design (UCD) and participatory design (PD) are nowadays considered different philosophies in Human–Computer Interaction. The term UCD was coined by the American Donald Norman in the late 80s (Norman, 1990) and refers to the need to take the end user into account from the first stages and throughout the whole process of design. The typical UCD design process is iterative and comprises the following steps: (1) ethnographic research (to understand the needs and expectations of target end users); (2) creation of scenarios of use; (3) specification of user requirements; (4) prototyping; (5) evaluation with end users; and (6) refinement. In comparison with previous design practices, the goal in UCD was to adapt the product to users (rather than the other way round); yet, these had an external, reactive role, and their input was *'translated'* by the designers (Scaife et al., 1997)

The digitisation of the commercial built environment sector and its related teaching programmes with pathways to qualification have struggled with this integration of ICT technologies. BIM implementation is perceived as the current driver in this capacity. AECO professionals have been educated in isolation from one another. In terms of the broader scope of IT in AEC education, Thomas (2004) discussed the educational challenges of integrating a variety of people, processes and technologies, concluding that students in different disciplines should be encouraged to mix, undertake group assignments, share digital information and generally appreciate the potential contribution of other disciplines to the AECO industry whilst Stubbs, et al. (2014) states that the significant advancement of BIM technologies in recent years has brought a much greater focus upon the enhanced collaboration for better building and facilities. Indeed, Barison & Santos (2010) cite integration of different programs as the single biggest challenge facing educational institutes wishing to implement BIM. Kymmel (2008) reinforces this view, stating that the BIM education of the different professionals at all levels should be carried out in a more pro-active and integrated manner. However, enhanced collaboration in industry is *'code'* for changing existing processes in addition to the adoption of new ICT. In higher education it requires changing how and what we teach. Lockley (2013) refers to the complexity of this *'dramatic change"* and the reality that it will take some time to be fully achieved.

Building conservation, whilst intertwined in many architectural and heritage-based programmes normally acquires an individual status. A review of a selection of programmes offered within higher education at a selection of University level Institutes (via prospectus and websites), within three jurisdictions, highlighted various novel approaches to how heritage related modules are delivered. They are predominantly traditional but little evidence could be sourced regarding the application of a similar hybrid approach that encapsulated the collaborative ethos of BIM with the technical know-how developed within digital humanities, whilst still respecting and acknowledging the traditional values underpinning the subject area of building conservation. It is advocated that the IHM approach developed within this research will work to fill this gap that is currently not been addressed.

Therefore, the selected participant groups for evaluation are sourced from where the perceived gap exists i.e., University Level students from selected HEI`s that contain a module(s) that are currently being delivered on the programme they are enrolled upon relating to the historic built environment.

The chosen colleges were Waterford Institute of Technology, Glasgow School of Art, Ulster University and Cork Institute of Technology based on key criteria, namely;

- Stated learning outcomes of existing module content and delivery.
- Access to the student body.
- Diverse student cohorts in each HEI (Higher Education Institute).
- Geographical diversity.
- Safeguard against unintentional bias towards researcher, i.e. non-WIT students.

In total, 147 participants undertook the study whilst additional interviews were conducted with knowledge providers, in this scenario the module lecturers.

3.3 Evaluation

Evaluating interpretation, or understanding, is not a new concept and has been approached by scholars from a variety of research areas. A framework is required that accurately identifies that an increased level of engagement and understanding has been experienced by the end-user. It is critical to avoid testing only a process that records their technical proficiency, and not necessarily their cultural understanding (Champion 2011). To evaluate if the level of interpretation of the end-user has been enhanced, an approach is put forward based largely on the work previously undertaken within the wider digital humanities community. Present day scholars of digital heritage have been adopting varying approaches ranging from; hermeneutic environments through game style interaction (Champion 2003; Champion & Dave 2002) to Embodied Interaction through semantic impulse (Flynn 2008) or haptic devices (Roussou 2008) to MUVEs (multiple user virtual environments) with dynamic content to greater immersion through augmented stereographic panoramas (Kenerdine 2008) or immersive displays (Tan, 2007). This is not an exhaustive list as there are innovative approaches to evaluating interpretation being developed on a continuous basis.

The previously referenced LEAP (Learning of Archaeology through Presence) project has become a reference both for the expert community as well as non-expert audiences within the digital humanities community. Its framework put in place for evaluation, which was informed by the earlier works of Economou & Tost (2009) employed a multi-nodal approach that was both quantitative and qualitative in that it addressed the common issue of asking users to express something that is visual and experiential with words, which is not an easy task. The approach developed within LEAP widened the scope of evaluation to include observational with pre and post testing in order to measure cognitive gain.

3.3.1 Workshop Series

A workshop/demonstration was considered to be appropriate in this context and developed with a view to create an environment favourable to the meaningful involvement of stakeholders within the research. Whilst there is a minor element *participatory design* to this approach in that users should be involved in *designs* they will be using, and that all stakeholders, including and especially users, have equal input into interaction *design* (Muller & Kuhn, 1993), the primary framework that informs this project and for each set of workshops is a hybrid of adopted elements and different methodologies, similar to that outlined within the LEAP & 3D-CoD frameworks (Pujol-Tost 2015). Both these published frameworks have proved most beneficial in designing, structuring and constructing the questionnaires for Workshop series of this nature in relation to the digital Built Heritage.

Interactive workshops are considered most beneficial in this regard and are classed in three possible formats, blended workshops, stretched workshops and frontal and interactive workshops (NMARK, EMF, 2010). As can be seen from the average memory pyramid below that Practising and Teaching accounts for 75% to 90% of memory capacity, the more interactions exist, the more active the participants become, and the more knowledge is retained. These methods can be adopted and integrated according to the objective being pursued.

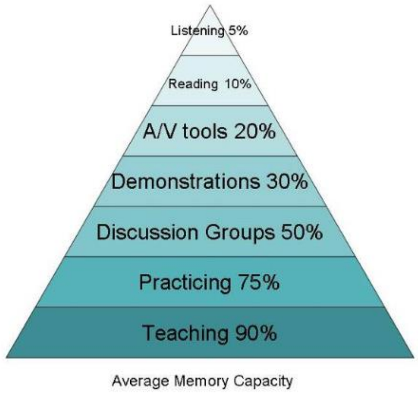


Fig 3.3.1.1 *– Learning Pyramid Source – National training Laboratory, Uni of Maine, USA*

The workshop series served as a vehicle to address two key aims of the research, firstly to demonstrate the process to a large cohort and secondly as a mechanism that best demonstrated the capabilities of IHM and gauge its effectiveness in increasing engagement with the Built Heritage amongst the participants. As alluded to above, workshop series one focused on Test Study A and examined the process of extracting *Information (refer to 4.1)* from the IHM process and evaluated how this was communicated to the end-users. In total, the first tranche of demonstrations was delivered to 47 participants located in WIT and GSoA. Learnings from the initial Workshop series were than appraised and contributed to shaping the second series. Workshop series two focused on the *Interaction* and *Immersion(refer to 4.1)* capabilities of the IHM process and was delivered to 100 participants in WIT, Cork IT, Ulster University and the GSoA.

The Workshops were designed as follows;

Workshop One was structured to illustrate the benefits and functionality of Integrated Heritage Modelling (IHM) in delivering *tangible* Information associated with a historic building. In this scenario it was an 18th Century dwelling, and the emphasis was placed upon building performance and exploring occupancy comfort levels for that time period. The rationale for selecting such an approach is to highlight that by encoding factual scientific data regarding the construction and assembly of the building, this permits accurate *Information* to be extrapolated from the model in the form of quantifiable statistics and hence challenge, or reinforce, assumptions that may be made regarding historic buildings.

The initial step was a pre-Workshop questionnaire to establish the participants current level of understanding. Then followed a Prezi style presentation focusing predominantly on the *tangible* historic data associated with the building. Prezi was chosen given to the fluid navigation of its presentation style and was deemed more akin to the style of this research than say a more rigid slide deck type platform such as Powerpoint. The presentation commenced with a brief historical account of the building to provide context with a hypothesis then put forward in relation to living standards at the time. The process of constructing and developing an IHM was set-out and the findings were discussed in order to address the hypothesis. To conclude the workshop a second questionnaire was circulated to evaluate had their impression or original thoughts progressed after the presentation via a selection of open-ended questions.

Workshop Two was designed and informed by the outcomes of workshop one. Its objective was to illustrate that by incorporating stages two and three (Interaction & Immersion) of the IHM workflow that the level of understanding was enhanced. As before a pre-workshop questionnaire was supplied to each candidate and a similar audio visual presentation was performed for the group. In this instance, following the presentation all participants were invited to a dedicated station where they were encouraged to interact with the IHM in order to explore elements of *intangible* knowledge that where located within the model. On completion of this they were then asked to another dedicated workspace. Utilising a head mounted display (HMD), each participant was immersed in a virtual environment containing the historic building model and expressions of *intangible* heritage associated with it. Finally, the participant was asked to complete a post-workshop questionnaire. Elements of workshop two were recorded for observational analysis purposes.

3.3.2 Questionnaires

Questionnaires are one of the most widely used social research techniques and normally fall into one of three categories of structured, semi-structured and unstructured (Blaxter, et al, 2010). A structured approach was chosen for this research with the intention of obtaining key information from the participants and based upon previously published approaches by Pujol-Tost (2015).

- What demographic they belonged to?
- What was their level of prior knowledge regarding the built heritage?
- A specific question about their experience of the workshop.
- Provide an opportunity to the participant to discuss if their level of engagement had increased as a result of their experience.

In order to garner this information, the questionnaires were separated into pre-workshop and post-post workshop documents and contained a variety of question styles allowing the participant the opportunity to divulge a more insightful response. A Likert-scale system was employed for certain questions which enabled quantifiable analysis of the subsequent results. In this instance it was considered to deploy an NVivo type platform for analysis, however given the number of participants who engaged it was not deemed appropriate. It is accepted that not all avenues of enquiry are covered within the questionnaires as the main focus for evaluation in this sense was for statistical analysis. The questions are available for review in Appendix C & B where they are recorded as part of the ancillary information illustrating both series of workshops. In addition, the rationale and structure of each question is outlined in chapter five (5.7.1) and chapter six (6.6.1) and resides in close proximity to the resultant answers obtained from the participants.

3.3.3 Observational analysis

Whilst observational analysis is normally associated with ethnographical research there is an opportunity in this body of work to engage, albeit in a limited capacity, in observing the participants as they navigate their experience within the virtual environments. By considering their gestures, expressions, comments, etc, it is possible that there is learning that other methods may not reveal. The sentiment here is that asking participants to express something visual and experiential with words is not that straight forward. Therefore, by conducting observational analysis, further insight may be garnered to evaluate interpretation that may be otherwise disregarded. Creswell (2007) discusses four types of observational research you can employ, ranging from detached observation with no participation on your part (complete observer) to immersing yourself completely in the environment (complete participant). For evaluating the IHM process the *'observer as participant'* technique was chosen. In this situation the researcher may be known and recognized by the participants and in many cases, the participants are aware of the research aims and objectives, and there will be limited interaction with the intention to maintain a neutral role as much as possible. This approach is generally deployed to understand how participants uses software products to accomplish goals.

In order to collate the data for evaluation an informal data sheet was compiled on each participant in order to record systematically the proceedings for further appraisal. The information sheet had two sections, one for the *Interaction* element of the workshop and a corresponding section for the *Immersion* element. (refer to Appendices B&C) The data sheet was set out as follows;

Observation Notes – Interaction

Q.1 - Level of engagement with user interface – Laptop/Tablet

Note one was somewhat subjective in that the Observer had to place a value on the assumed level of interaction by the participant. In an effort to quantify this a Likert scale grading mechanism was implemented.

Q.2 - Comments from observing subject relating to reaction, navigations difficulties, visual evidence of understanding, etc, etc

Note two was more reflective with the rationale of trying to textualize the participants subconscious reactions in interacting with the IHM , such as which path did they navigate, what first attracted their attention, how aware of their surrounds were they, did they stop and engage, if so, with which elements of the model and so on.

Observation Notes – Immersion

Q.1 - Level of engagement with the Virtual Environment

Similar to above, the initial observation note was an attempt to quantify in a subjective manner the assumed level of engagement with the virtual environment. In this phase of the workshop demonstration the participants are wearing HMD`s which makes the task more challenging. To assist in evaluating their experience remotely a second screen was employed to bear witness to the experience of the participant in the VE.

Q.2 - Comments from observing subject relating to initial reaction, receptiveness, exploration of space, etc

Observational note two specifically focused on the participants behavior within the virtual environment and attempted to measure the level of engagement with the space. Within the VE, the participant was deliberately fixed in position as to force the user to listen and observe as oppose to navigate. In this instance particular emphasis was placed on eye and head movement of the subject and their reaction to the information that was narrated within the VE.

To facilitate the observational aspect of the research a selection of equipment was utilised in the form of a Samsung Gear 360 camera, GoPro Hero Black 4 and multiple visual display units, HMD`s and audio devices. The resultant video footage is available for review on the digital deposition that supports this work.

3.3.4 Semi-Structured interviews

The final part of the evaluation process involved interviewing the lecturers/professors involved who are currently engaged in delivering the relevant heritage modules to gauge their opinions for such an approach as IHM. The rationale was that evaluating the student's response was not offering a complete picture and for a more informed and balanced overview it was deemed necessary to engage with the knowledge providers in a meaningful manner.

There are three primary categories of research interviews: structured, semi-structured and unstructured. Given the backgrounds and stature of the interviewees, and in order to gain maximum insight from the process, it was decided that semi-structured interviews were the most appropriate option in this instance. Semi-structured interviews consist of a small number of key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge to pursue an idea or response in more detail (Britten,1999)

A Rapid Ethnographic Assessment (Bentley et al. 1988) was adopted, this involves intensive excursions into the interviewee's roles, which is an interventional as well as an observational method to create contexts through which to delve into questions that will reveal what matters to those people (Pink et al. 2013) In this context, opinions on heritage and digital technologies were sought and the role it plays within higher education at their University. In total there were four semi-structured interviews undertaken with knowledge providers from Ulster University, Glasgow School of Art, University of Wolverhampton and the Cork Institute of Technology, three of which had students who undertook the earlier testing. All interviewees had significant experience in delivering heritage-based modules on their programmes that ranged in discipline from Heritage Visualisation to BIM to Architectural, however, their adoption of digital technologies varied due to reasons that are discussed later.

The questions were assembled and intentionally set in a provocative tone to encourage opinions to be expressed. The process began with a rudimentary control question.

Q1 - Can you state your name, academic post, academic institute, and experience to date of teaching/lecturing in the area of BIM/Heritage based modules.

The purpose of this question was simply to allow the attendee to state their full credentials for the record and to put them at ease for the remainder of the interview.

Q2 – How would you describe your approach to lecturing this topic?

On reviewing the course content of each programme, it was evident that each HEI had a varying approach to heritage in terms of where it was placed within the curriculum, some had it to the core whilst given the nature of other programmes it was considered a support module. This question allowed the interviewee to put forward their own opinion on how they deliver the content.

Q3 – In your opinion, has the development of digital technology assisted your teaching in anyway?

Following on from question two which established their existing approach this question tried to establish if digital technologies played a meaningful role in how the subject material was delivered. For the interviewees with a traditional background the intention was to gain their insight as to why digital technologies are not being employed and for those who have adopted such approaches try to garner where they see the real benefits of such an approach.

Q4 – In your opinion, has the introduction of digital technologies enhanced, or hindered, the level of engagement of the end-user, i.e. the student?

At this juncture the interviewees are predominantly split between a traditional and more contemporary approach. The question is deliberately left open for the interviewee to discuss how levels of engagements have been hindered/supported by the adoption of technology.

Q5 – In your opinion, how do you see the future of heritage studies and digital technologies evolving.

To complete the interview the opportunity is presented to the interviewee to express an opinion on how they see this area developing in the future.

It should be noted that all interviews with the knowledge providers took place independently of the Workshop series and at a time when all workshops had been completed. Although the knowledge providers did not participate in the Workshops in a formal capacity, they were present at the time of the demonstrations. The rationale for this time delay was to avoid any form of *recent bias* from the interviewee. On completion of all Workshops at the stated Universities/HEI, and ancillary interviews, the data was collated (refer to Appendix), evaluated and appraised and viewed in conjunction with the results from the Workshops in order to inform the discussion in chapter seven.

3.4 Ethics and Access

'Ethics is the study of man's internalization of his understanding of terms such as value, dignity, integrity, fairness, justice and care among others' (Sibinga 2018, 46) Given the nature of this research it posed little in terms of ethical or moral dilemmas. The participants were made aware that the research was purely for the purpose of a PhD research project and that partaking in the survey they had agreed to the information being used for this study. In addition, they were notified that no personal information would be used, shared or published, Ethics clearance was sought for GSoA and where required; subsequent clearance was sought from the contributing Universities/HEI`s. In the case of WIT, additional clarification was sought in accordance with Waterford Institute of Technology General Data Protection Regulations (GDPR) policies that in part ensure the anonymisation of all participants taking part in the workshops. All instances where appropriately mitigated against and permissions were forthcoming. Refer to Appendix A for all necessary documentation.

3.5 Data Legacy & Ownership

In terms of scholarly understanding, there is surprisingly little written and debated about the 3D digital heritage model considered as a learning tool or experimental device rather than as a finished (if virtual) object. Simply put, 3D models are not yet fully integrated into scholarly discourse (Huggett 2012, 538–552). According to UNESCO's Charter on the Preservation of the Digital Heritage; *'Preservation of the digital heritage requires sustained efforts on the part of governments, creators, publishers, relevant industries and heritage institutions. In the face of the current digital divide, it is necessary to reinforce international cooperation and solidarity to enable all countries to ensure creation, dissemination, preservation, and continued accessibility of their digital heritage. The stimulation of education and training programs, resource-sharing arrangements, and dissemination of research results and best practices will democratize access to digital preservation techniques.'* (UNESCO 2003,74–76). Sustainable digital cultural heritage has been considered a serious national issue in many countries for some time (Zorich 2003), where Jeffrey (2012) also highlighted the emergence of a *'new digital dark-age'* in reference the long term preservation of digital archives. This has been further expanded upon by Richards, et al. (2013, 313-329) in referencing data management and preservation. This is an area that is discussed in greater detail in section 8.4 and the proposed technical solutions to this problem of the '*vanishing virtual'*—that is, the dilemma of technology superseding itself (Thwaites 2013, 327–348)

In relation to this research project, whilst not ICT specific, consideration has been afforded to the handling, archiving, and curating of the assembled datasets. In this instance, all information has been archived with the GSoA digital repository, RADAR. To enable navigation of this repository a structured file naming system for cross referencing internal ancillary data such as questionnaire feedback, observational notes and digital models has also been created and incorporated within the PhD deposition folder to reinforce the validity of the data collated. All models and digital content are readily available for review in support of this research.

In order to establish clarity, the internal referencing system that relates to the responses of the questionnaires and becomes evident in chapter five and six is set out as follows. Each participant was given a unique identifier code at the time of the workshop associated with their questionnaire. The workshop was organised in such a way that students attended the varying demonstration stations in sequence. Once the questionnaires were submitted, they were tagged and stored. The sequence was noted which enabled the observational analysis to be conducted remotely at a later date by correlating video footage with the number sequencing. Once all information was compiled on each participant, it was collated and stored as one document. In order to ensure anonymity, the individual files where reorganised randomly and set new reference numbers. The naming structure appears as, *Workshop Number_Participating University_Document number.* For example *(WS2_GSA_101)* would identify as WS2 (Workshop series two)_GSA (Glasgow School of Art)_101.

In conjunction with data archiving the issue of data ownership must be acknowledged, in the context of the data contained within the digital built model surrounding ownership and copyright. In the mainstream AECO sector where similarly aligned BIM processes are more commonplace, the issue of data security and ownership are ever present (Delgado et al. 2020, 24-27). These issues are less relevant in reference to this work given that being, a scholarly endeavour within academia, however there is a discussion is chapter 8.2 regarding this and the proposal of open source data and how this approach may be implement to a wider academic community.

3.6 Summary

Whilst IHM is a novel workflow that attempts to address the gap in aligning building conservation with contemporary digital technologies it is not to be construed as a definitive approach for the wider heritage community, more a bespoke workflow developed for the specific area of digital building conservation. This chapter has outlined the required constituent parts that enabled this research to be undertaken. Having identified and extrapolated the research question in chapter two regarding the alignment of digital technologies and building conservation practice, this section has identified a roadmap in how best to *answer* that question. The approach to conducting this research focuses on a straightforward process of *collection, creation, consumption, and evaluation*. The tools, and instruments, required to undertake each stage of that process have clearly been identified and a rationale for selection put forward. The proceeding chapters clearly demonstrate the IHM workflow and put in practice the research design as outlined above.

4.0 Integrated Heritage Modelling (IHM)- A novel workflow

Through the adoption and manipulation of mainstream BIM theory and processes this chapter presents a new approach, that will allow for richer data sets to be incorporated into a 3D model that provide for an enriched level of engagement by the end user. As identified previously, the end-users in this research were University level students with an academic interest in the Built Heritage. An outcome of providing a greater level of understanding was the technical workflow that enables access to both the *tangible* and *intangible* aspects of any given aspect of the heritage be it a building, object, or place. Several existing workflows were reviewed and evaluated to identify if a solution was readily available. Chapter 2 discussed how earlier research within the historic (AECO) sector tended to focus on developing more efficient techniques for data acquisition, based primarily on the use of laser scanning and advanced photogrammetry techniques. Chapter 2.3.4 identified that contemporary research has begun to tackle the challenge of embedding *intangible* data. For instance, Fai & Rafeiro (2014) commenced by linking heritage information to a BIM but also included documentation related to *tangible* and *intangible* heritage, albeit in a very limited capacity and without evaluation. Stubbs et al, (2015) developed this process further by incorporating immersive platforms into a similar workflow through the use of gaming environments to enhance the dissemination of information to the end-user, again in a limited fashion and without evaluation.

Two clear streams of research have emerged in this area commonly referred to as HBIM, which were discussed fully in chapter 2.3. Briefly, the early adopters who applied BIM for heritage have referenced the limitations and restrictions of BIM authoring software. This motivated the development of alternative modelling techniques based around the development of parametric libraries suitable for use in historic buildings. Various projects (Bail et al. 2014; Chervier et al. 2010; Murphy et al. 2013; DeLuca 2012) have developed parametric library objects that support more intricate architectural detail while decreasing modelling time through automated procedural modelling (Dore & Murphy 2017). The alternative approach is to engage a more theorical-based workflow that embraces the collaborative ethos of BIM in creating a viable digital asset repository. The novel workflow described in this chapter, Integrated Heritage Modelling Building (IHM), builds upon these earlier works of scholars in this area (Pauwels et al. 2008; Boeykens et al. 2012; Fai et al. 2018; Stubbs et al. 2015).

4.1 IHM Workflow Design

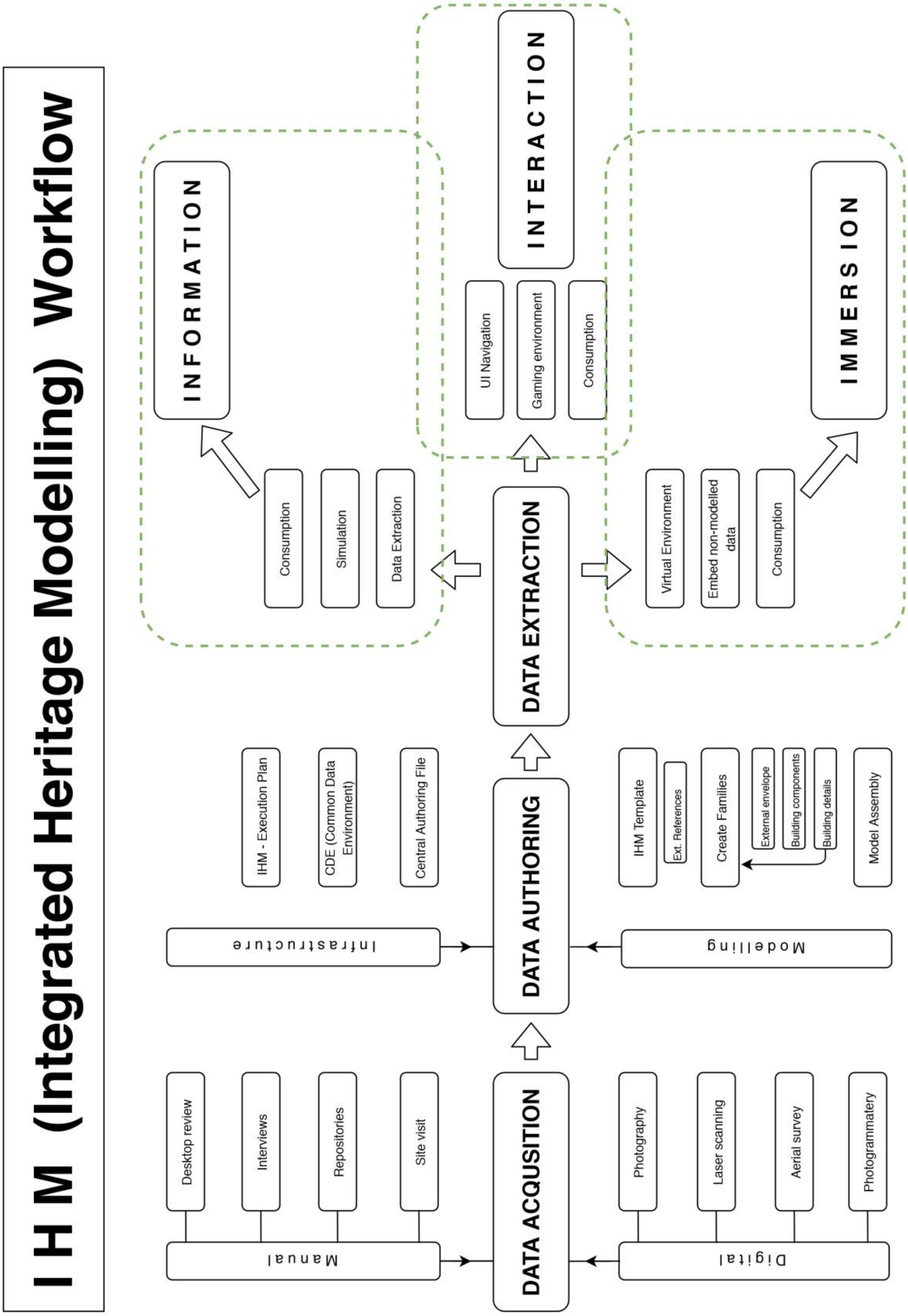


Fig 4.1.1 – IHM Workflow Diagram

The theoretical concept that underlines this new approach is a linear process that attempts to increase the level of engagement of the end user through a three-stage process. These stages are *Information*, *Interaction* and *Immersion*. Simultaneously, as the user progresses through this process their ability to interpret information evolves with the opportunity to interrogate more holistic datasets relating to *intangible* aspects of the Built Heritage through enhanced experiential engagement, similar to that expressed by Pujol-Tost (2017)

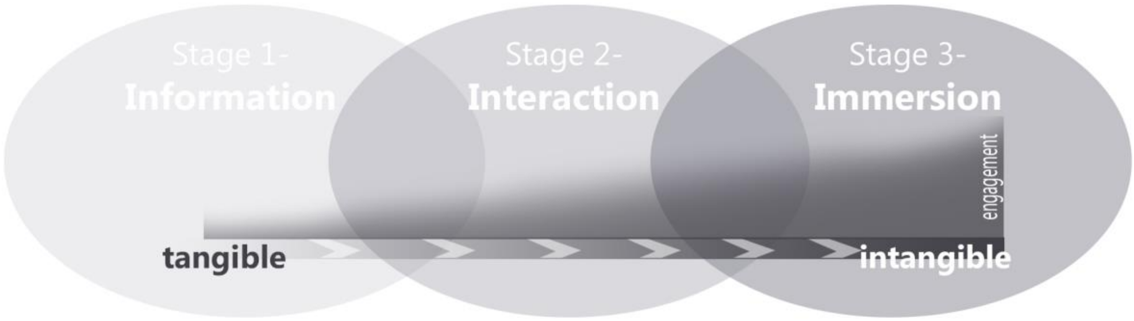


Fig 4.1.1 – *IHM Three stage process*

Stage One – Information. Information refers to the data that is acquired, collated, and embedded in the 3D model, be it metadata and/or paradata. This is the most vital element of the process and if done correctly would ensure the robustness required going forward through the workflow. The appropriate information must be acquired, evaluated, and prepared correctly for inclusion so that the IHM can be fully interrogated. The GIGO (Garbage In Garbage Out) principle applies in this scenario. The utility and authority of the IHM is contingent, at all stages, on the accuracy of the data supplied. If this data is correct than the consequent information, be it empirical in relation to building volumes/quantities, or performance based relating to building fabric can be evaluated and validated accordingly. Primarily, this initial step focuses on providing data relating to *tangible* heritage, i.e. the building fabric.

Stage Two – Interaction. The intention at this stage is for the user to interact with the data compiled and assembled from stage one, *Information*. If the user can *Interact* and self-direct their learning experiences, the premise was that it will facilitate a deeper understanding than through the Stage two role of a passive consumer of information. In interacting with the IHM via a variety of digital platforms, the three fundaments of HCI (Human Computer Interaction), that being the user, the computer and the ways they converse are employed to provide enhanced engagement. This stage of the process allows for access to both the *tangible*, and *intangible* datasets.

Stage Three – Immersion. The key step of the IHM workflow is identified as *Immersion*. In this stage the emphasis is specifically centred on engaging with facets of *intangible* heritage. Representing aspects of *intangible* heritage can be an arduous task and even more difficult to consume for the end-user. *Immersion* refers specifically to placing the user within a virtual world that has been produced by the IHM workflow. A scenario was created where the user is bearing witness to an element of the buildings history that is deemed somewhat abstract. An opportunity to experience, through immersion in a virtual environment, the feeling of being there (Steuer 1995). It is noteworthy at this juncture in stating that this research has focused on the historic built environment, however the suggested process provides a theoretical framework that could be applied to a multiplicity of historic artefacts as well as built structures. This is discussed in chapter 8.3 in greater depth.

4.2 Workflow- Data Authoring

Data authoring, as a process has been discussed in chapter 2.3.2. Briefly, it is the harnessing and manipulation of data into an entity that is readily useable. Authoring, in this context, essentially refers to the creation of data-rich 3D digital models. The level of authoring is determined by the level of information that is to be embedded within the digital repository. This part of the workflow requires a suitable authoring instrument that possess the ability to host both the *tangible* and *intangible* datasets. The process of selecting a suitable tool commenced with field testing of a variety of readily available industry software. The initial experimenting dismissed any product that did not facilitate the ability to programme or embed data. In addition, the software had to be established with a proven record for reliability and a dedicated user base. Through a process of elimination two software packages, Graphisoft ArchiCAD and Autodesk Revit were more fully tested further prior to a final selection. Whilst ArchiCAD has an excellent OGL scripting language and is the software of choice of many HBIM advocates, early deployment exposed its lack of interoperability and functionality with other software that would be required later in the process. The IHM pipeline requires additional software plugins and the ability for the file format to be exported in a *'live'* workflow through various platforms, i.e. a bi-directional *'linking'* mechanism.

AutoDesk Revit		Graphisoft ArchiCAD	
pros	***cons***	***pros***	***cons***
-parametric BIM modelling	-no scripting language	-parametric BIM modelling	-lack of experience (author)
-bi-directional workflow		-supports GDL scripting	-steep learning curve
-community of users	-restricted modelling tools	-community of hbim users	-reduced interoperability
-previous experience			
-variety of plugins			
-software interoperability			

Fig 4.2.1 *–Data Authoring selection table.*

The review concluded that the most favourable option was to proceed with Autodesk Revit mainly due to its compatibility within the wider Autodesk suite of software that enables the functionality that was required. Revit is considered the industry leader as a BIM authoring tool and as such there is an abundance of supporting plugins and an extensive user base. The Model Authoring phase of the workflow contains the following steps;

4.2.1 Applying Standards.

At present there is not a specific set of guidelines or regulations available that govern a process of such as IHM. However, a robust structure was required for such a workflow. Existing publications were consulted. PAS 1192 (refer to Ch. 2.3), a series of guidelines published by the UK government and the subsequent document ISO 19650 were referenced. In addition, more recent publications by Historic England (2017) *'BIM for Heritage'* and "*The Application of Building Information Modelling (BIM) within a Heritage Science Context*' and '*BIM for Heritage– Developing the Asset Information Model'(2020)* were also reviewed and evaluated in terms of contributing to this new workflow.

The key purpose of step one was to put in place an authoritative framework that identifies the criteria relating to, but not restricted to, achievable outcomes, aims, objectives, file structure, naming conventions, Level of Detail, versions of software and ancillary information necessary for the efficient administration of a project. This document is referred to as an IHM Execution Plan (IHMEP) which is essentially a reformatting of the previously discussed BIM Execution Plan(BEP), in section 2.3 . This is an essential element of the process, particularly if a project requires multiple parties and involves cloud collaboration.

4.2.2 *Infrastructure for Collaboration*

Collaboration, whilst not necessary, is to the heart of the BIM ethos as discussed in chapter 2.3.To ensure an infrastructure that can facilitate the IHM assembly of the historic building it requires implementing a collaborative platform that allows for various datasets to be federated from multiple sources to a dedicated location, preferably on a cloud-based server. There are many such platforms to choose from. Early trials explored the capabilities of Revit Drive, a standalone server located on a network, however issues relating to data protection and firewall restrictions made this option unworkable as the flow of data was constantly interrupted and became corrupted.. Other platforms that are available include generic cloud-based offerings such as *Dropbox*, *One Drive*, *Google Drive*, however they have all restrictions that soon became apparent when the process of federating the model begun on a multi-user project. The Revit Drive was superseded by A360, Autodesk's initial attempt at a cloud based common data environment (CDE). It had many shortcomings and consequently has been replaced by the next iteration which was BIM 360 and subsequently rebranded as BIM 360 Docs. This CDE was extremely stable and offers multiple variations depending on the professional application, which was intended for, i.e. Site Engineering, Project Management and so on.

The function of a CDE is to provide oversight and an ability to manage multiple datasets regardless of their source. In the IHM process the Central Authoring file acts as a Masterfile with multiple links to subservient placeholder files. The workflow in Revit commences by selecting a template at the beginning of each new Project. This template files contains information relating to the task at hand. For instance, there are pre-determined templates for Architecture, Construction, MEP and so on. Experienced Revit authors normally manipulate a template file based on their own user requirements and habits. The Central Authoring file for this research was created from a bespoke template file that contains ancillary data and libraries that are hardwired into the computer application.

4.2.3 *Modelling Environment setup*

Once the appropriate template has been opened and saved as the Central Authoring project file, the next step required the importing of the survey data, be it a hand sketch, ordinance survey data file or a point cloud. The key action was to *import* the file rather than *load* the file into the project. Loading the file increases the files size greatly and was unnecessary. By importing the file from its location within the CDE it is readily visible and useable. It is also worth noting that any revisions to the updated raw files such as edited laser scans can easily be accommodated and revisions readily identifiable by simply updating the link. If a member of the project updates the file, a warning system will be enacted that alerts the model author that changes have occurred and require attention, thus mitigating against uncommunicated revisions by team members. Revit is three-dimensional working environment and core information regarding building heights and levels are required from the outset. Therefore, the first act of modelling was to assign buildings levels based on survey information i.e. site level, ground level, eaves level and so on. These can be simply edited if required as the project develops, and revised information emerges.

4.2.4 Creating Families.

Modelling families is an essential part of the process as they provide the model with the distinctive characteristics and features of the actual building. Parametric families within Revit are ultimately separate projects linked to the main project, updating automatically as they are being created. By creating families for each building element, or component, it considerably helps to expedite the modelling process. Once a family was created it can be placed within the model so it can be utilised as many times as required.

As regards creating families there are two critical decisions to be made at the beginning and refer back to the IHMEP from step one. Firstly, what was the Level of Detail (LOD) required for the particular project. As discussed in chapter two, the LOD determines not only the appearance but also the level of information/data to be encoded. Secondly, the information that is encoded is not limited to *tangible* information. Revit permits the functionality to embed additional information that is not directly related to construction, per se, and presents an opportunity to embed alternative information relating to the building.

In the IHM process, families are created in the following sequence.

- *External Envelope (families)*

The information required to construct the external skin of the building is completed first. Information regarding materials, construction assembly and additional data such as scientific parameters relating to building performance are inputted at this point. This process is completed for all floors, walls, and roofs. For each project, specific building systems are created as they are unique to each project. For example, the wall build-up of an industrial building may have different configurations as the buildings rise. In this instance a bespoke wall family is created, this is referred to as a *stacked wall family* and is specific to that project.

- *Building Components (families)*

Once the information relating to the external skin has been compiled and coded in the correct manner the focus then switches to individual building components, such as windows, doors, plumbing and electrical. In mainstream practice the majority of these families are accessible through various online libraries with the information provided by the manufacture or online user-forums such as *Revit City(revitcity.com)* and *BimObject (bimobject.com)*. However, when dealing with a historic building this is not the case. In this instance window and door families are created as unique objects that reflect and resemble what is present in the building. This is time consuming but nevertheless necessary to ensure accuracy. Once created the families can re-used for buildings of a similar typology an era with minor adjustments required. As before all necessary data is coded into the family at this juncture.

- *Building Details (families)*

Every project will undoubtedly contain bespoke architectural details that are unique to that particular building be it in the form of ornate cornice detailing, external features, light fittings and so on. When commencing a project, it is important to conduct an inventory of which details are required to be modelled as parametric families. The process for modelling is the same as above and it is accepted that additional modelling is required as the overall IHM begins to develop and more information becomes available.

4.2.5 (IH)Model Assembly

The model must be assembled in such a way that the data contained within has the ability to be interrogated. In the IHM process the model author would invariably require an in-depth understanding of construction technology and how it relates to the specific building. Specific modelling styles dictate how the actual IHM is assembled but the approach most suited would mirror the process of how the building was constructed in reality, i.e. from the ground up. Therefore, the recommended approach is to construct the topography initially and then ground works, walls, structure, roof, intermediated floors and then apply components such as windows/doors and bespoke details.

If the building in question is considered large and there is a multi-disciplinary team engaged on the project, continuous testing regarding the accuracy of the collaboration should commence from the outset. In projects of this nature there are always initial conflicts within the file structure and normally revolve around naming conventions or corrupt file extensions. It is best practice to designate one individual (team) as Lead Author (identified in the IHMEP) for the federated IHM.

Initial problems are normally easily rectified but preventative maintenance is considered the most appropriate policy.

4.2.6 Preparing the IHM for Interrogation.

As the process is considered a *'live'* workflow it is suggested that the model is never truly complete. As a linear workflow the information moves horizontally through the three stages of *Information*, *Interaction,* and *Immersion* however it is two-way data transfer and the process must remain *'live'* for the duration of the project. If, for instance, new information is revealed during the *Immersion* stage that effects the original model than the IHM process is such that any alteration to that model will migrate through all stages. Therefore, once the initial model is at a point where it can be evaluated, as identified in the aims of the IHMEP, it is exported for the purposes of *Information*, *Interaction* or *Immersion* and is made available for consumption.

4.3 Consumption

The third part of the process is consumption of the data by the end user. The workflow for this stage is directly dependant on the desired outcome and correlates to the initial three stage philosophy of *Information, Interaction* and *Immersion.* The ability to extrapolate Information from the IHM is an absolute base requirement insofar as this is the ethos of BIM as a philosophy i.e. the sharing of information. The IHM process identifies that this information must be accessible and in a format that can be utilised by the end-user.

4.3.1 Information

To allow for the consumption of information the steps are outlined as follows;

– *Step Inf_01_Extraction*

In its simplest form and accepting that the information has been entered correctly in the previous steps, the extraction of base information is relatively straight forward. It involves the creation of schedules as simple tabulated documents that are readily produced as (Excel) spreadsheets. The categories of information required will relate directly to the categories of information supplied, i.e. quantities, area, volume and so on. In addition, if more in depth information is contained within the coding stage such as thermal performance, costings, manufacturers details then this can also be tabulated as a schedule for consumption.

– *Step Inf_02_Simulation*

If further analysis is required, again as stipulated in the original IHM execution plan, the IHM has the capacity to be exported to simulation-based platforms either within the Autodesk family of software or exported further to third party plugins and applications for simulations such as energy performance, structural analysis, lighting analysis or whatever the requirement of the author may be. In certain instances, not all plugins and apps are compatible to directly export direct from Revit and a *workaround solution* may be required utilising an IFC format (Industry Foundation Classes). In these scenarios the workflow may not permit bi-directional flow however this would be identified at the beginning of the process and mitigated against if it were to be a key output to the task at hand.

– Step Inf_03_Consumption of Information

Presenting the Information in a clear and concise manner for any given project is key. In its most illustrative form, multiple drawings can easily be created once the model is complete. As it is a 3D model, plans, sections and elevations, i.e. standard general arrangement drawings, are extrapolated by *'slicing'* through the model at selected levels and pre-determined views. In addition, internal and external perspectives are also possible through the placement of virtual cameras to capture a chosen view. Complimentary information regarding scheduling and inventory can be extrapolated using the process described above and applied to tasks such as maintenance scheduling, facilities organisation or simply to just identify building areas.

4.3.2 Interaction

To provide Interaction with the IHM workflow a bespoke platform is required that facilitates engagement. A host of *gaming* software applications where reviewed at an early stage and experimented upon to evaluate their appropriateness. Amongst the packages reviewed included Unreal, Unity, Stingray and Project Expo. Unreal and Unity both offered excellent platforms and are naturally geared to allow for interaction within a gaming environment as that is their core feature, however they did not have the capacity to import the meta/para data that had been coded into the IHM and such only offered limited functionality. Stingray (formerly BitSquid), a standalone gaming engine was also reviewed. It was consumed by Autodesk as a standalone platform and when originally reviewed and experimented upon it displayed restricted functionality in its early iterations and was deemed to be unreliable with data transfer from Revit. For this reason, it was not considered.

Project Expo was in beta version and put forward as a model viewer plugin, specifically designed by Autodesk to allow mainstream BIM users the capacity to navigate their models in a gaming environment and access the construction data. The beta version was supported for several years before being consumed into a complimentary product, called Autodesk Live. The table below identifies the key results from the cursory evaluation of selecting the appropriate platform to best facilitate *Interaction* with the IHM.

AutoDesk Live		Epic-Unreal Engine		Unity Technologies	
pros	***cons***	***pros***	***cons***	***pros***	***cons***
-displays BIM data	-Revit use only	-industry standard	-cost	-open source	-ltd. interop
-Revit Plugin		-render capability	- ltd interop.	-render capability	-learning curve(author)
-stingray support	-cost	-large user base	-learning curve		
-simple UI					
-cloud processed	-ltd. user group				

Fig 4.3.2.1 *– IHM Interaction platform selection.*

A priority was given to providing a '*live'* workflow that allowed for amendments to immediately permeate through the pipeline. It was decided to utilise software that engaged with Revit in a bi-directional capacity. Autodesk Live was selected to enable the interactive properties associated with the IHM approach. To allow for user *Interaction* with the IHM the steps are outlined as follows;

Step Int_01_ Set up navigational waypoints

As the general modelling of the building has been completed, attention then focuses on how to best engage with the user to encourage exploration of the IHM through the medium of a virtual environment. A system of wayfinding is incorporated based on the *blue plaques* initiative that is promoted by many heritage/tourist organisations. The *blue plaque* is normally placed on the outside of the building in a discreet manner with a brief historic anecdote/fact inscribed for the public to consume. The IHM process adopts a similar approach, albeit in a digital manner given that many users of the IHM would be familiar with the *blue plaques* from their own experiences and thus a level of continuity of understanding the process is readily achieved. The digital *blue plaques* are created as stand-alone families from a basic elliptical form that is extruded and coloured blue. The information that is then associated with that location is coded into the family and loaded into the IHM.

Step Int_02_ Linking the IHM to Interactive Platform

Achieving a '*live'* workflow is a key aim of the IHM process. Several platforms as highlighted above allow an import/export function from Revit. Linking the IHM file to Autodesk Live is a straightforward process where the user selects a 3D view of the model, activates the *'Live*' tab from the Revit ribbon which in turn presents a preference window to allow for the process to commence via a cloud-based transfer. Once complete, the user is notified, and the file is ready for consumption via the *'Live'* app.

Step Int_03_ Prepare for consumption

The *'Live'* app is a standalone platform that can be accessed via multiple digital devices. The user has limited ability to control certain features relating to lighting, time of day/year and how they wish to navigate the experience. Within the IHM process the Live app can be explored via laptop, workstation or mobile device. Early testing identified that engaging with the app with the aid of a computer mouse proved most successful in terms of navigation and accessing the information points within the environment.

4.3.3 Immersion

In choosing a platform that allowed for *Immersion* of the end-user followed a similar selection procedure to above. Several applications were explored and tested at an early stage. As above *Unity*, *Unreal* and *Stingray* were identified. At this juncture Autodesk Live had been also developed to incorporate a sideway step into Stingray (that since has been incorporated into *3D Max* and is relaunched as *3D Max Interactive*). This development, inspired by advances in the AECO sector, and in particular 4D site simulation, was to allow for the enhanced gamification of the environment prior to publishing to the Live platform.

A new product was also evaluated entitled *Enscape*. Enscape (www.enscape3d.com) is a dedicated plugin that was originally designed for acoustic analysis and evaluation of 3D models, however due to its real time rendering capabilities it quickly pivoted and migrated towards a rendering tool for architectural visualisation. Its major advantage is speed of rendering and its compatibility with the host software be it Rhino, Sketchup or Revit. It is packaged as a plugin and nestles conveniently within the interface. In addition, it supports virtual reality as a single click option and its myriad of textures and assets are entirely compatible with Revit's library. Graphic styles are easily interchangeable, and the surrounding environment can be manipulated in a user-friendly manner.

AutoDesk Live		Enscape		Unity Technologies	
pros	***cons***	***pros***	***cons***	***pros***	***cons***
-displays BIM data	-revit use only	-render quality	-cost	-open source	-ltd. interop
-revit Plugin	-import/export lag	-support audio	-ltd interop.	-render capability	-learning curve
-stingray support	-cost	-large user base	- ltd. user group	-VR ready	-
-simple UI		-ease of use		-Support audio	
-cloud processed	-ltd. user group	-VR ready			
-VR ready		-real time edit			

Fig 4.3.3.1 *–IHM Immersion selection*

It was decided that Enscape would address the requirements for IHM, primarily because it provided straight forward access to a VR platform, supported audio files and was directly attached to the authoring tool. Additionally, it catered for on-going editing and preserved the integrity of the IHM by maintaining full control of the data within the CDE and reducing the risk of corruption by third party platforms.

To allow for *Immersion* within the IHM approach the steps are outlined as follows;

Step Imm_01_ Select Enscape Plugin

Within the Revit Interface, the plugin Enscape is activated and launched on a separate display window. The operations between both platforms are synced simultaneously allowing for real time manipulation. If required, assets for additional entourage elements such as people, foliage, street furniture are inserted and placed appropriately. Render settings are adjusted to achieve the desired non-photorealistic graphic for reasons previously discussed (refer to ch.2.2.2 7 3.3.1). Atmospheric conditions are then manipulated for the desired environmental appearance including lighting, fog, depth of field and so on.

Step Imm_02_ Embedding additional data.

To further enhance the experience of being *immersed* within the virtual environment additional information is embedded within the IHM in the form of audio files. The IHM focuses on two such types, general background audio to create a specific atmosphere and targeted audio information that divulges aspects of *intangible* heritage associated with the building, in the form of speeches or narrations referencing aspects of the building’s past.

Step Imm_03_ Prepare for consumption

Preparing the model for consumption is the last step of the process and relatively straight forward within the Enscape plugin which was a major factor in deciding to utilise this application. Once final checks have been completed regarding functionality and performance the *'enable VR'* setting is instigated and launched. This creates a standalone VR experience as an executable file (.exe) that once connected to an HMD and suitable hardware it can be accessed by the end-user for interrogation.

4.4 Summary

This section has presented a roadmap in the form of a step by step guide to implementing the IHM workflow. It has provided justification for the myriad of decisions made during that process, particularly relating to software selection. However, the choice of software should not necessarily be construed as the underpinning the workflow. There is an acknowledgment that computer applications have a limited lifespan in terms of functionality. The software industry is constantly evolving both its architecture and platforms, whilst the transient nature of *plugins* and *apps* is all too familiar to users. To mitigate this, the IHM process is such that many variations of similar applications could be substituted into the workflow with similar outputs achieved. During the period of this research this was the case and the necessary actions taken. The selected software discussed above was deemed the most suitable tool at present. But it is just that, a tool. Like all tools it is envisaged that it can be upgraded as the technology further evolves.

Furthermore, it is noteworthy that the detailed technical workflow highlighted above is directly refencing historic buildings and will remain so for the remainder of this research. However, given the collaborative ethos of the IHM approach and its stated aim of harnessing *intangible* heritage, in theory it could be applied to both artefacts and historic spaces. This will be discussed in greater detail in chapter 8.3.

5.0 Establishing Integrated Heritage Modelling (IHM) as a workflow

The aim of this chapter was to demonstrate the first phase of the IHM workflow across a three-stage process of *Information*, *Interaction* & *Immersion*. In Chapter two the term Integrated Heritage Modelling (IHM) was introduced and defined within the context of this research. As stated, it is broadly based on the concept of BIM processes and is a re-working and evolution of what is currently referred to as HBIM. This section demonstrates this new workflow by applying it to a Test Study. Whilst this novel approach was intrinsic to the research it is worth stating that its purpose was to address a gap that currently exists in building conservation research that allows for the assembly of digital repositories that contain rich datasets for enhanced engagement.

5.1 Context & Overview

Waterford City, Ireland oldest city, is situated in the southeast and was founded in the 9th century by the Vikings who settled on the River Suir. It was further developed by the Anglo-Normans in the 12th century and was the most reputably loyal Irish based cities to the English crown of the middle ages. Throughout its long history, it has experienced sieges, invasions, famines, and economic turmoil. It remains the foremost city of the region (Walton 1996).

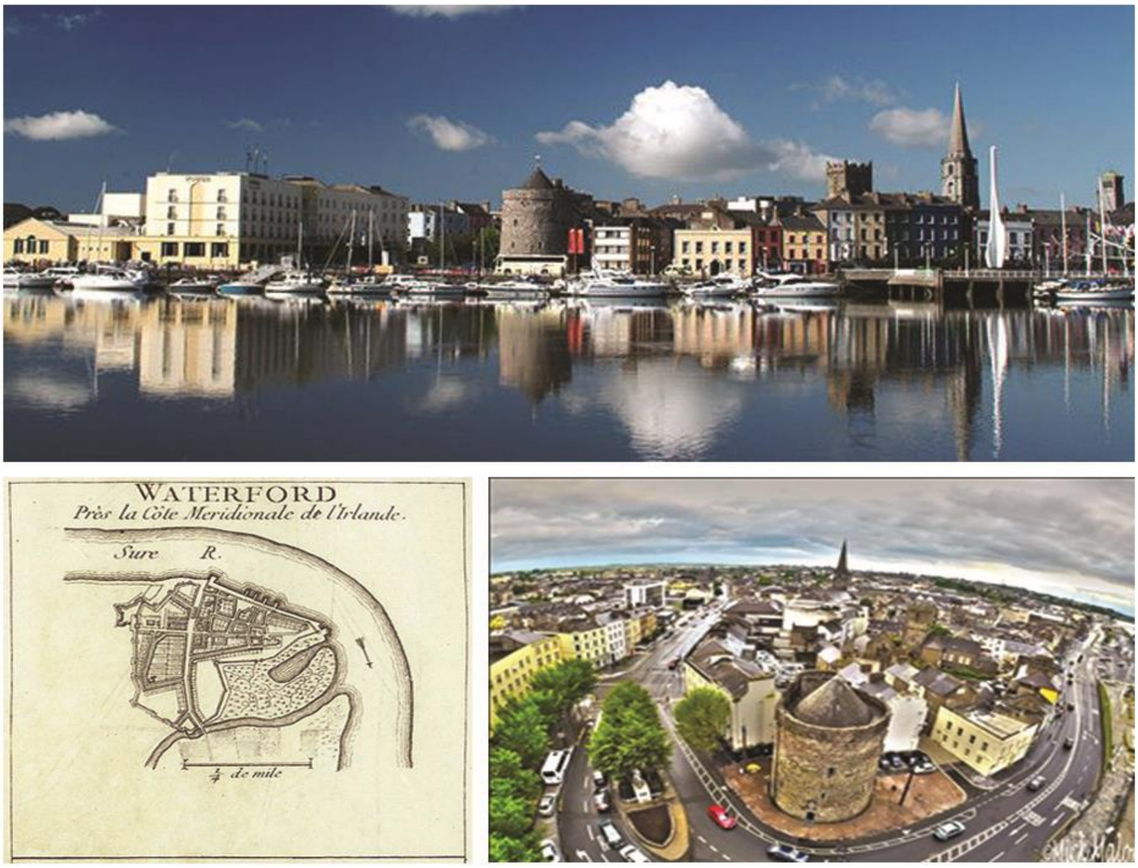


Fig 5.1.1 – Waterford City*: source www.waterfordcouncil.ie*

The Test Study selected for this section of primary research is located in an area referred to as the Viking Triangle, the original settlement of the 9th century. It is a compact historic area situated in the heart of the City and has been the subject of recent state funded urban regeneration due to its rich tapestry of historic buildings/places and the opportunity to promote cultural tourism. This area has remained at the heart of the City and it is only in more recent times the state authorities acknowledged this fact and set about celebrating this legacy. Intrinsic to this legacy is John Roberts.

Fig 5.1.2 – Images of John Roberts *(Buildings) source: www.christchurch.org*

John Roberts was born in Waterford on 26th January 1714 and baptised the same day in St Olaf's Church. His father, Thomas Roberts, was a prominent local builder and arranged for John to study architecture in London. On his return he married Mary Susanna Sautelle, the daughter of a Huguenot veteran. His first project of note in the City materialised when he was invited to complete the building of the Bishop's Palace on the Mall, which had been begun by the renowned architect Richard Castle but left unfinished on the death of Bishop Este in 1745. Roberts is responsible for the design of a number of exceptionally fine eighteenth-century buildings throughout the City and wider region. He designed and built the new Christ Church Cathedral (Test Study B) the Assembly Rooms (now City Hall), Theatre Royal, the magnificent courtyard at Curraghmore House (seat of the Marquess of Waterford), Newtown House (now Newtown School), Mount Congreve and a number of other country houses. The town house of William Morris (later the Chamber of Commerce), with its fine cantilever staircase, and the Leper Hospital (later the Infirmary) are also attributed to him. Towards the end of his life he was invited to build the Holy Trinity Cathedral for Waterford's Roman Catholic community. Founded in 1793, it was the first post-Reformation Catholic cathedral to be built and bought Roberts to greater prominence as the only architect to design two cathedrals, intended for different religious congregations, in the same city. Roberts was still working on it when he died on 23rd May 1796 at the age of 82 (Walton 1996).

In the context of this work it is noteworthy that the buildings selected for both Test Studiesare linked to Roberts. He lived with his wife and eight children at no. 1 & 2 Cathedral Square (Test Study A). They had many illustrious descendants most notably Field Marshal Lord Roberts, veteran of campaigns in India and South Africa, who died while reviewing troops on the Western Front in November 1914, also at the age of 82 (Laffan & Rooney 2009, 229-308). The social fabric of Waterford throughout this period and the legacy of Roberts are very much intertwined with the architectural history of the City. In more contemporary times, the Roberts legacy has been celebrated by both the heritage community and state bodies with the naming of prominent civic spaces (John Roberts Square) and a festival (John Roberts Festival of Architecture) celebrating his many contributions to the city.

5.2 No.1 & 2 Cathedral Square, Waterford City.

Test Study A was no.1 & 2 Cathedral Square located in the heart of the Viking Triangle. The rationale for selection was based on its scale, complexity and building typology. A dwelling has stood on this site since the 15thcentury and there is evidence still visible today such as the timber structure located in the basement. The current building however mostly dates to the mid-18th century (Hurley 2004). The styling of the building is somewhat domestic and modest; nevertheless, given the construction legacy of the property it was chosen as a suitable vehicle to demonstrate specific aspects such as energy performance and thermal comfort (a complete list is discussed in 5.5), two threads that were selected given their ability to demonstrate the *Information* stage of the workflow.

Fig 5.2.1 – Cathedral Square *source: Waterford archive.*

5.3 Aims

The key aim of this initial Test Study was to demonstrate the capabilities of the IHM approach to successfully embed information on the *tangible* fabric of the structure into a digital model. This is the first stage to enable greater engagement with the subject matter and identifies the possibilities of creating a single integrated source of rich datasets that can be evaluated and appraised accordingly. However, it also strives to achieve a number of parallel objectives, for example, this Test Study will identify *why* this approach is of significance within the context of older buildings and architectural conservation. By creating an in-depth digital repository of a building, it allows the user to put forward informed suggestions regarding multiple facets of the project from building management to future design interventions. In building refurbishment projects, there is a compromise to be achieved regarding conservation versus sustainability interventions and which route to pursue. As Giancola & Heras (2014) state; *'Starting from the fact that, retrofit of building heritage should not endanger the cultural, emotional and identity values that they represent. To ensure the built heritage conservation it will be necessary to develop new methodologies to support the decision-making process by establishing the optimal level of energy efficiency which is achievable without endanger the preservation of historic building values.'* This Test Study goes on to illustrate how this *decision-making* process can become better informed by integrating data for consumption and analysis.

In addition, the information extracted from the application of IHM to the Test Study was presented to a group of participants to gauge if the level of understanding relating to the building has been enhanced by the improved information that is now available and posed the question, *how* does understanding the fabric of a building help develop an increased level of understanding for conservation purposes?

5.4 Data Acquisition

Given the stated aims above, an emphasis was placed in obtaining data related to the physical condition of the building. Information such as the construction materials of the various constituent parts and the configuration of floors, roofs and walls. Compiling this data in a format that is compatible with the IHM approach was critical to the overall process. As discussed in chapter two the development of HBIM to date has largely focused on model creation, albeit on larger scale projects of a more complex nature. Murphy & Dore (2015), Fai (2015) & Boeklyns (2013) have developed thorough processes in the areas of HBIM and documentation management. There are lessons to be adopted from these approaches that can be applied in this scenario such as workflow and management of the information. It is worth highlighting that given the scale and complexity of their projects, that of large industrial/public buildings, that it was deemed inappropriate as the task at hand for Test Study A as it was focused on a domestic scale project. Therefore, a similar approach as adopted by Arnold (2013) was utilised due to the subject matter and building typology.

The study carried out by Arnold was to preserve the dwelling of Elias M Briggs, the founder of Springfield in Oregon, in its current condition for future generations. The underlying process ensured that if the model was properly structured it can be future proofed, and be the vehicle to monitor the behaviour, performance, and deterioration of a building, using meaningful metrics that can help its long-term preservation (Skarmeas 2010, 52). Arnold created a BIM by using 2D drawings and further on-site surveying of the building. All existing drawings where cross referenced and validated with the fieldwork to identify any discrepancies that were present in the existing drawings. The 3D model that was created was not designed for visual recreations but to demonstrate the capacity of a digital model to accommodate empirical information (Arnold 2013, 27). Arnold specifically focused on the physical information regarding the construction and stopped short of developing this process through to simulation of the BIM. In this Test Study the IHM process builds upon this work and further develops the notion of the model being a *'virtual sketchbook'* for updating additional information as it emerges, not just physical but also the non-physical.

Applying this approach to the Test Study commenced with the initial fieldwork and site visit for a cursory survey to gauge its suitability and access. The building was unoccupied as remedial works where imminent due to the Local Authority having recently acquired the premises. More in-depth site visits followed to conduct a detailed survey employing traditional measuring techniques, photography and a conditions survey. The required result was to evaluate the buildings fabric. Initial scoping procedures where undertaken to establish the building construction and where possible, the assembly techniques at critical junctions such as building plinth, intermediate floors, window cills & heads, eaves detail and roof structure. This information was then appraised, and cross referenced with existing material obtained from various archives such as CAD drawings, visual surveys, dendrochronology reports and varying building accounts that had been developed by private architectural practitioners and officers of the local authority. In addition, scholarly research regarding the living conditions of mid-18th century dwellings in the locality was also undertaken. This included exploring various local and national archive repositories to informal discussions with local historians.

It is pertinent to note that the integrity of the data acquired was considered at all stages to mitigate against simple recasting of exiting information which could possibly lead to further misinterpretation. Once all information was obtained and collated it was appraised and evaluated for inclusion and prepared in readiness for the subsequent stage.

5.5 Constructing the IHM

The technical process of constructing an IHM was fully detailed in chapter four and incorporated a fluid workflow that allows for variations in direction that may be required given the characteristics of the building being modelled. Outlined below are the specific stages of the IHM process that were deemed relevant in this instance to achieve the stated aims of demonstrating, *stage one-Information.* Multiple facets relating to the building could have been selected however it was decided to focus on data relating to three areas for the following reasons.

- Building construction/assembly

From the initial research, it was apparent from an early stage that sufficient information existed regarding materials and construction assembly of the building. In dealing with historic buildings, this is not always the case as such investigative works would normally require invasive surveying techniques such as removal of flooring and wall deconstruction. This scope of work had been previously undertaken on the structure and was duly recorded and published by the local heritage officer (www.waterfordcouncil.ie/departments/culture-heritage). Therefore, in this instance an opportunity was present that allowed for an accurate as-built IHM to be assembled from existing records.

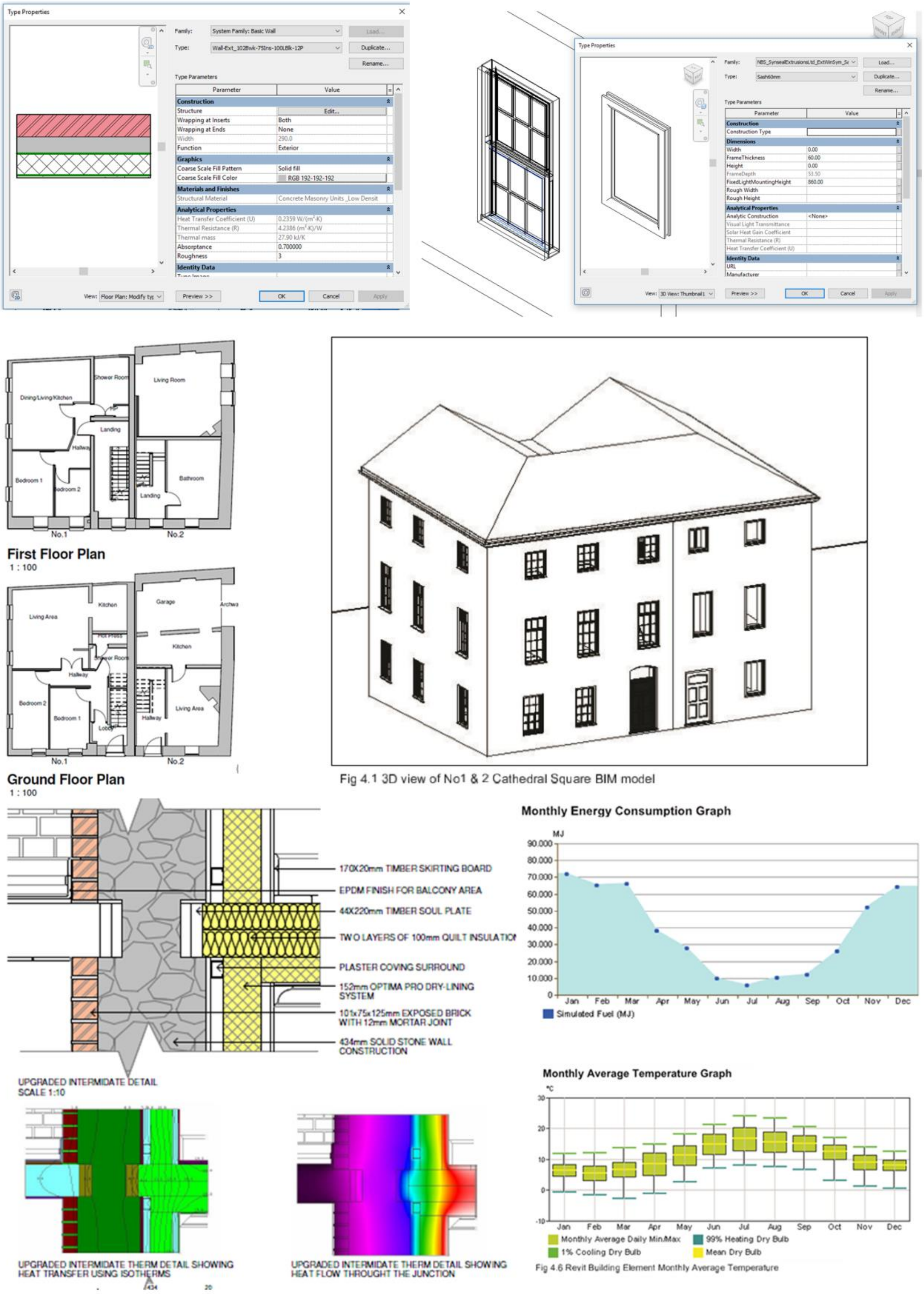


Fig 5.5.1 *-A selection of images of Cathedral Square IHM*

- Energy performance

Building conservation, given its theoretical underpinning is sometimes based on assumption and conjecture, particularly in relation to energy performance, i.e. a simple statement such as old buildings are always damp or draughty and so on. In certain instances, this (mis)information can be recast through multiple iterations of publications and soon becomes an unsubstantiated statement of fact. As the opportunity to develop and construct an accurate as-built IHM of no.1 & 2 Cathedral Square presented itself it was decided on this occasion to interrogate these claims and the validity of such assumptions. In assessing energy performance, the IHM process facilitated the simulation of heat movement through the fabric of the building and presented a scientific analysis of the building performance that enabled a more informed opinion.

- Thermal Comfort

Following on from building performance it was decided to focus on human comfort by simulating living conditions within the IHM. Calculating and demonstrating energy performance identifies accurate thermal conditions for the building which can support, or challenge, preconceived conventions that are associated with historic buildings. By coding and integrating back-stop values relating to user comfort threshold, further interrogation of the model provided an opportunity to comment from an informed viewpoint on 18th century living conditions.

With the decision taken on which avenues of interest would be pursued, the IHM was assembled in the following fashion. Below, is a brief synopsis of how each step of the process, outlined in chapter four, was applied to this Test Study.

Step 1 – Applying standards/ Completing the IHM Execution Plan

THE IHMEP was completed and contained the parameters that are required in structuring the project going forward, including software selection, naming conventions, file structure and so on. Given the complexity of the building a LoD of 300 was identified as appropriate prior to commencing the model assembly.

Step 2 – Collaboration

The initial step of the assembly process was to put in place a Common Data Environment (CDE) that would facilitate the IHM construction of no. 1 & 2 Cathedral Square. In this instance Autodesk A360(since superseded by BIM360) was utilised. A dedicated Central Authoring file was created from a bespoke template file that contains ancillary data and libraries that are present from the outset.

Step 3 – Setup Modelling Environment

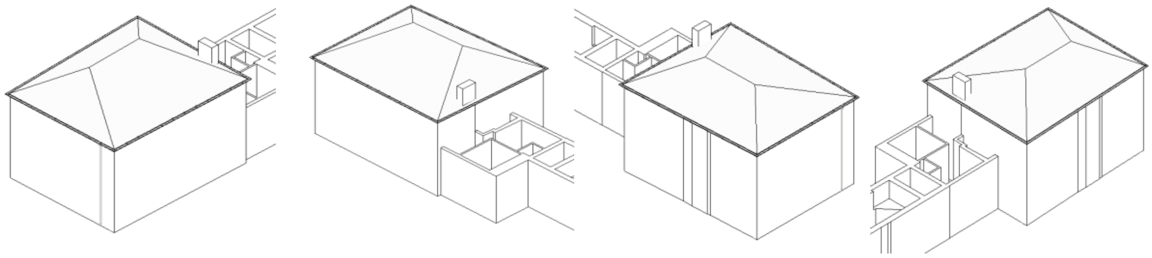


Fig 5.5.5.2 *-Model assembly*

Once the Project folder has been populated with the required sub-folders and placeholders containing the heterogeneous datasets and third-party information such as maps and existing reference drawings/documents, work commenced on authoring the IHM. A separate Revit file was then created with all necessary building datums/levels inputted to create a 3D environment with information obtained from the fieldwork and ancillary data files imported to the environment.

Step 4 – Creating Families.

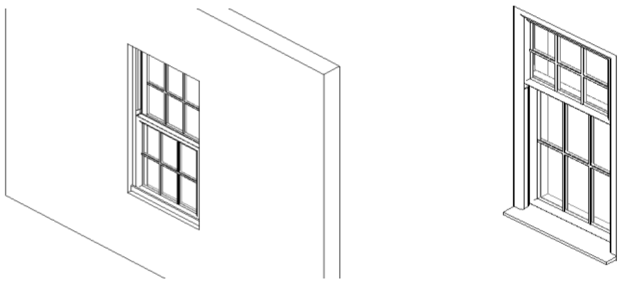


Fig 5.5.5.3 *-Window assembly*

For No.1 & 2 Cathedral Square the model development was relatively straight forward as the chosen building was of modest complexity in terms of construction and architectural styling. In this scenario the families contained data regarding material type, conductivity, and thermal resistance as they were the chosen threads of exploration. These families where created in isolation with the external envelope created first such as walls and roofs followed by building components such as doors, windows, and finally bespoke architectural detailing relevant to building.

Step 5 – Model Assembly

In conjunction with the raw data that was imported in step two, and the newly created families in step three, the model quickly developed. It was an iterative process that produces a draft IHM in a relative short time span. Once a draft model was developed additional coding of ancillary data was embedded where appropriate such as U-values for walls and thermal conductivity of building materials.

At this juncture the IHM was at an early stage of development but nevertheless was tested for robustness and accuracy at regular intervals. In this instance all linked files where cross referenced to external datasets relating to topography and ancillary models where federated to ensure model cohesion.

Step 6 – Preparing the model for Interrogation.

The Cathedral Square IHM was further tested and prepared for the next phase. The central file was federated and reviewed for data content with reference to the stated stipulations within the IHMEP. The process remains fluid at this junction. At no point did the Cathedral Square IHM become a standalone digital entity in the process.

Step Inf_01_Extraction

Based on the desired objectives within the IHMEP, the federated IHM was then exported to a suite of supporting analysis add-on/plugins, Revit *Conceptual Energy Analysis* initially and then further into Revit *Building Energy Analysis*. The resulting. gbXML file was then exported to Autodesk *Green Building Studio* for further testing. In addition, Thermal Bridge Assessments were also conducted of the construction details to complete the building performance evaluation through *Therm 5.2* (a 2D dimensional heat transfer modelling program utilised for analysing building heat transfer problems)

Revit Conceptual Energy Analysis is a tool that provides fully automated energy analysis based on the IHM. In part it is mostly based on conceptual construction parameters and is normally utilised in mainstream BIM processes with new builds. As a consequence, the performance values had to be adjusted for use on a historic building such *as high mass construction- no insulation* for the roof, floor and slab parameters were set to *low insulation – cool*, windows were assigned *single pane clear- no coating* and so on. As this step was conceptual, information relating to U-values and conductivity was not required. Results retrieved from the energy analysis were largely in graphical format containing graphs, charts, and tables. Building performance indicators were identified that provided information regarding carbon emissions, solar infiltration, and fuel usage.

To improve upon the conceptual findings and provide more depth to the investigation, *Revit Building Element Energy Analysis* was employed. In this case, the building was assessed utilising building components as opposed to massed objects, i.e. the plugin identifies elements such as walls, doors, roofs, and windows and so on. All elements contain individual layers of data, e.g. a modern wall has an external layer of render with a core containing cavity, insulation and internal layers of masonry and plaster. Individual layers contain specific properties and parameters relating to thermal conductivity, density, permeability, and porosity. The information was already present from the initial IHM. This encoded information produced accurate data relating to heat transfer coefficient (U-Value), thermal resistance (R- Value) and the thermal mass factor for each element.

Step Inf_02_Simulation

Conceptual data and more in-depth elemental data relating to heat loss and environmental performance can only provide a certain level of information. The loss of heat through filtration is an aspect of performance evaluation that is largely accepted in modern construction but is largely overlooked when dealing with historic buildings (English Heritage 2012).

Therm 5.2 is a platform that analyses heat loss through the actual building envelope. A building envelope is designed to protect the inner space from the harsh outdoor climatic conditions, hot and cold alike, and hence provides necessary thermal comfort to occupants. The software appraises the assembly and construction of components through two-dimensional analysis. It identifies boundaries of each component (building materials in this instance) and once all have been established, conditions are applied relating to whether the component is internal or external. (Al-Sanea & Zedan 2012, 1)

The IHM was then processed through *Therm 5.2*, and the subsequent results were provided in two forms, a two-dimensional illustration with isotherms that identify heat transfer through the junction and an infrared detail displaying the cold external temperatures to the warmer internal environment. Both options can then be overlaid for a complete picture of heat transfer through the junction.

Step Inf_03_Consumption of Information

To prepare the data for consumption by the end-user for Test Study A the information was presented in the first instance through the medium of general arrangement drawings, i.e. plans, sections and elevations. These drawings where support by additional illustrations such as charts/graphs and colour coded graphics that exemplified the scientific findings of the study.

Note - All environmental and simulation data relating to these steps of the process is available for review within the supporting digital deposition folder.

5.6 Data Analysis

Following the processing of the IHM through the evaluation platforms discussed above more robust informed observations where possible. For instance, the IHM provided a guidance of the quantity and energy consumed on an annual & monthly basis, based on informed assumptions regarding external temperature range of – 3 ^{o}C to 24 ^{o}C and an occupational load of 10-12 people. These values were based on information acquired earlier in the process. Annual carbon emissions from the burning of fires for both heat and cooking were a calculated (net) 28 tonnes of CO_2 in conjunction with 451,053 MJ of energy utilised in the building per annum.

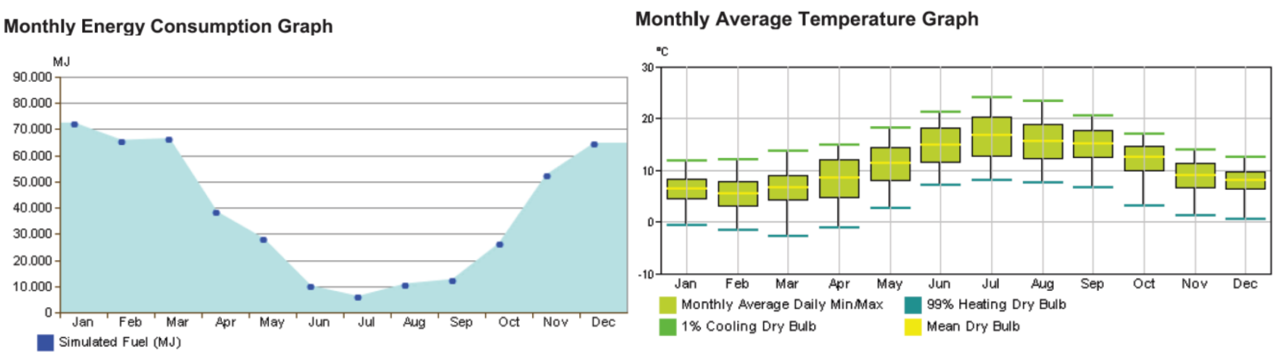


Fig 5.6.1 *-Energy Data*

The graph above (blue) identifies energy consumption (open-fires) on a monthly basis with January displaying the highest reading of 72,000 MJ and July the lowest at 7,000 MJ, whilst the second graph identifies a temperature breakdown for the building, also on a monthly basis. February was the month with the lowest average temperature with a reading of 7^{o}C, while December displayed the least fluctuation as it ranged between 8-10^{o}C. July was the highest temperature and displayed the greatest fluctuation with it varying from 14^{o}C to a high of 21^{o}C. The fluctuations in the values reveal both how the inhabitants occupied the space and how the building performed from an energy perspective.

Further analysis of the thermal resistance of the building fabric appraised how the external air transferred across the building skin to the internal surface and thus reduce the building temperature. Similar values regarding internal/external temperatures, based on the best available data, where put in place as default settings to process the simulation. As there were ten external wall thicknesses revealed to be within the construction of the building, ranging from 295mm to 800mm in thickness a sample of three were chosen to mitigate against unduly repetition of data. The selected wall thicknesses were, the thinnest at 295mm, the widest at 800mm and closest to the median of 495mm, each with a layer build-up of 12mm internal lime-based plaster, 265/465/770mm of random stone rubble and 18m external lime-based render. It is important to note that as the IHM was the basis for these simulations, this information was already present within the 3D model from the coding of information performed at the model authoring stage.

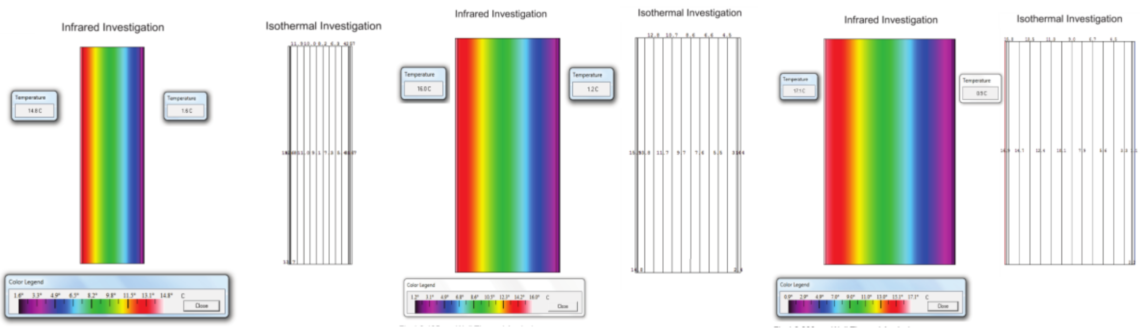


Fig 5.6.2 *-Thermal Analysis*

The isothermal analysis in the illustrations above where conducted and identify the rate in which heat transfers across the wall, each line indicates a change in temperature, the closer the lines the higher the thermal resistance of the wall. A temperature profile of evenly spaced isotherms represents a consistent heat transfer that is quite common in the absence of a dedicated insulation layer. In addition, the infrared analysis illustrates the heat transfer through a colour coded graphic, where deep purple represents the coldest and white represents the warmest value.

Analysis of the data suggests that as the mass of the external wall increases the internal temperature also rose. For instance, the thinnest external wall(295mm) had an internal temp of 14.8^{o}C, whilst the wider wall(800mm) had a reading of 16.2^{o}C. Internal temperature is a principal factor in determining comfort levels of the occupant however given the fact that the thinnest walls were constructed on the upper floors and the widest naturally at ground basement/ground level. In addition, due consideration must be given to air movement as hot air naturally rises.

Thermal bridging analysis can provide an enriched layer of supporting data. An assessment was conducted to appraise the assembly of key construction details with a view to establish heat leakage and the subsequent effect on thermal comfort levels.

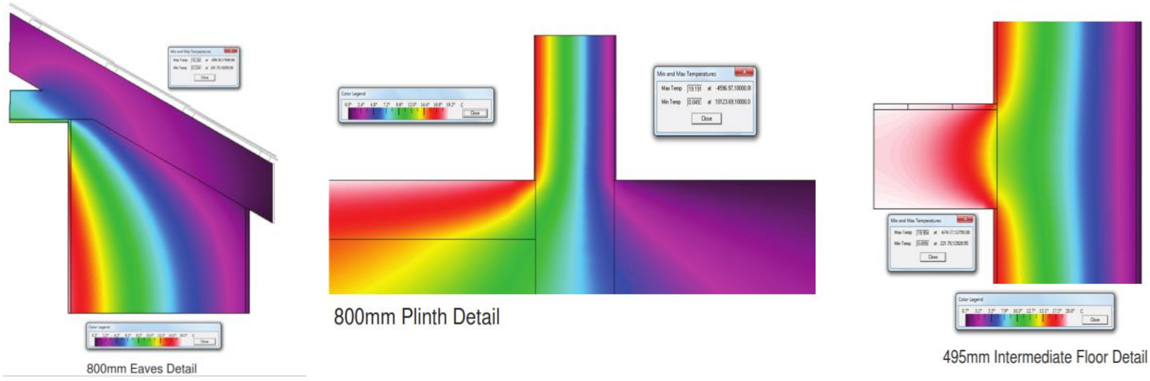


Fig 5.6.3 *-Junction analysis*

The graphs above demonstrate the existence of thermal bridges at all key junctions. The infrared colour flux`s curve significantly at the point of assembly. There is no fabric, or material, in position to enable thermal performance at these junctions (such as insulation board in modern construction) and as a result deter the cold air flow from entering the building. Specifically, in the plinth detail there is an additional reaction as the external ground/soil draws heat through convection away from the building. The result of the internal temperature is that the wall temperature was calculated at 16^{o}C, the actual temperature at the junction was 13.9^{o}C. Similarly, with the windows there is a clear thermal bridging issue. This is not uncommon as generally a window cill detail is difficult to thermally break since the frame is normally much thinner to the mass of an external wall and so it proves much more difficult to maintain thermal resistance across the construction assembly at this point. In this case a differential of c.5^{o}C (16-11.1^{o}C). The significance of this can manifest itself in the form of mould growth if not ventilated appropriately given that the dew point (point at which condensation occurs) is approx. 12^{o}C.

The intermediate floor junction displayed more consistent performance and closer to the internal wall temperature of 16^{o}C. The slight deviation indicates that the timber floor was absorbing cold air through the wall however the conductivity of the timber reduced the amount of heat lost through the minor thermal bridge at this junction. Finally, the eaves detail, that portion of the external envelope where the wall meets the roof was not expected to perform well as traditionally this junction would return poor results. The junction temperature of 9.6 ^{o}C produced a loss of 40% in temperature between the junction and the wall, in addition a ceiling temperature of 11.9 ^{o}C returned a 26% decrease. There are several factors for this poor performance such as the assembly of the construction in relation to the position of the wall plate, the position of the junction in the external building envelope and the fact the roof space is an un-insulated volume containing a myriad of cold surfaces that would quickly draw any warm air away from the top floor as hot air will naturally ascend.

An analysis of the data above provided insight regarding the performance of the buildings in terms of retaining heat and providing thermal comfort for its inhabitants. Given that there was an insufficient heating source that was unable to service more than a single room and the large consumption of fuel that was required to fuel that source due to the rapid heat loss through the fabric would indicate low comfort levels for the inhabitants. This coupled with the inability of the construction assembly to retain heat at varying levels (walls performed better than windows and roof) created fluctuations in room temperatures and as the building was not airtight the prevalence of drafts would be expected.

In certain aspects the building performed better than expected. For instance, it was discovered that the 800mm wall had a thermal mass factor of 106.49 kJ/K that relates to the capacity to store heat. To put in context, a modern cavity wall would have a value in the region 33.67 kJ/K due largely to the presence and positioning of insulation. Therefore, on a sunny day the 800mm wide wall has a large capacity to absorb and emit heat slowly to the internal volumes, some 66% more effectively than that of contemporary construction however most of this gain would be mitigated by the air leakage discussed above.

A more detailed observation relating to internal comfort relates to the position of the heat source, i.e. the open fires. As these where located in the corners of the room the heat emitted was localised to that area. The mass of the internal random rubble partition walls may have added some thermal inertia to the space however any heat released would have largely dissipated through the chimney (up to 70%) and provide little comfort to the adjoining rooms.

Internal temperatures of a building provide insight regarding the living conditions it directly effects comfort level (Ren & Chen 2018). In February, the internal temperature was noted at 5.75°C and range to 20.5°C at its peak in July. The higher summer temperatures would have provided the occupants with an uncomfortable night-time condition as the stored heat from the daytime sun would continue to be released throughout the night period. The reverse effect would have occurred in winter as no energy from the (lack of) sun would have been absorbed by the building envelope during the day period to be released throughout the much cooler night conditions

In a modern context the *CIBSE Guide A; Environmental Design (2007),* outlines a value of 22-25°C as an acceptable internal temperature to achieve an appropriate comfort level. The temperatures noted from the study are considerably less however it must be appreciated that the expectations of the inhabitants would also have differed (Ren & Chen 2018). Dwellings were perceived as places of shelter from the elements and the criteria for defining 18th century comfort levels vary to today's more stringent benchmarks.

5.7 Evaluating the Findings

The purpose of evaluating the findings from the various threads outlined above, that were derived utilising the IHM process, was to demonstrate the usefulness of such an approach. In order to disseminate this *information* to the selected audience that promoted engagement a series of Workshops were performed to multiple cohorts from various institutes of higher learning across the UK & Ireland. The structure and rationale for this approach is detailed in chapter 3.3 The first series of workshops commenced in April 2017 and consisted of 47 participants between Waterford Institute of Technology (WIT) and the Glasgow School of Art (GSoA). There were five sessions in total between both Institutes and each session was conducted in near identical fashion to ensure an appropriate level of consistency.

5.7.1 Workshop Series One – Information

The initial step was to gather a cohort of students into a lecture type environment and introduce them to the overall concept of the research. Once assembled and the necessary administration tasks concluded regarding Information sheets and participation consent, each participant was asked to complete a short questionnaire. Very selective information was sought at this point as data on each candidate was being collected and collated.

Below is an account of the findings for each question, firstly the pre-questionnaire, and secondly the post-questionnaire. A brief rationale for each question is outlined at each juncture to provide an immediate context to the results. The findings are put forward in both a quantitative and qualitative format where appropriate with an accompany commentary to further elaborate on the data. Following this an appraisal of these results is put forward for consideration.

**Note the figures are both in percentages/no. or respondents.*

1. What age bracket do you belong to?				
17-19	20-29	30-39	40-49	50+
30%/14	57%/27	8.5%/4	4.5%/2	0

Question one was a straightforward question with the purpose of gauging the age profile of the participant with five categories to choose from ranging between 17 to 50+. The purpose of which was to establish an accurate age demographic for the cohort of participants. Of the 47 participants in workshop series one 30% were in the age bracket 17 to 19 whilst ***57%*** where in the age bracket 20-29. This was an expected result considering the cohort of the students who were predominantly final year undergraduate students or first year postgraduate.

2. You are?		
Man	Woman	Other (please specify?)
64%/30	36%/17	0

Question two was to identify the sex of the participants in an effort to establish a more complete overview of the group dynamic. A result of ***64%*** for male and 36% for female would reflect the fact that majority of workshops for series one were conducted in WIT where the cohort of students would be largely enrolled on male orientated construction related programs. Interestingly, the GSoA session consisted primarily of females where the program was not directly construction related.

3. What term best describes your area of study?				
Architecture	Engineering	Construction	Heritage	Digital Humanities
68%/32	0%	4%/2	23%/11	4.3%/2

Given the nature and breath of the research it was important to ascertain the academic field in which the participant was currently active in. Question three sought to identify how the students aligned themselves to a particular area of study ranging from architecture to digital humanities. The aim of the IHM process is that it can be robust enough to be delivered to a range of diverse heritage related programs. For this series of workshops ***32/68%*** of the participants identify themselves as architectural whilst next most populous was 23% who identified with heritage, with 4.3% aligning to digital humanities and 4% to construction. Given the nature of the breakdown of programs involved this is not altogether a surprising result.

4. How often do you engage/interact with 3D computer modelling?				
Daily	2-3 times a week	Once a week	2-3 times a month	Once a month or less
47%/22	32%/15	4%/2	2%/2	15%/15

Question four was intended to probe the level of digital competency of the participants and specifically their experience to date with engaging with, and not necessarily just consuming, 3D digital modelling. Just under half of the participants ***(47%)*** engage with 3D modelling on a daily basis and a further 36% (32+4) combined would engage on a weekly basis. That accounts for ***83%*** of the cohort modelling on a regular basis which points to the influence that digital technologies are having on programs of this nature and how it has become a core skillset in most cases.

5. How "informed" would you consider yourself to be regarding the Built Heritage?				
1 (not at all)	2	3	4	5 (very much)
19%/9	49%/23	23%/11	8.5%/4	0%

Question five was intended to gauge what level of prior knowledge, regarding the Built Heritage, would the participant consider themselves to possess and grade it on a Likert scale of 0 (not at all) to 5 (very much). ***49%*** rated their knowledge to be on the ***low side,*** whilst 19% suggested they had little or no knowledge. None of the respondents considered themselves to be knowledgeable. This may be due to modesty on behalf of the participants, or it could reflect the level of importance placed by the particular programme design on heritage-based modules, alternately it could indicate that information being disseminated is not being delivered in the most efficient manner. In the AECO cohort, where heritage modules would be prominent but not significant in terms of accumulating credits, not one participant considered themselves above average in terms of their own knowledge base.

6. Have you experience in 3D modelling of Historic Buildings?	
Yes	No
36%/17	64%/30

Question six was designed to elicit a binary response in order to gauge if the two areas of 3D modelling and heritage studies had been combined in their experience to date i.e. on their programme of study. ***64%*** had ***not as of yet engaged*** in a project of this nature where both 3D modelling and the broader study of heritage had been combined. Of the 36% who experienced such projects, over half where students attending the postgraduate programme at GSoA which is unsurprising given the course title (MSc in Heritage Visualisation) and content.

7. Please explain briefly, as best you can, what you understand by the term 'Integrated (Heritage) Modelling'?

Question seven was the first of the open-ended style of questions where the participant was encouraged to define what they understood to be Integrated (Heritage) Modelling. Not surprisingly there was a myriad of answers put forward by the participants. Many identified that they had little or no knowledge of the term prior to the workshop, but quickly deduced that it was the *'integration of 3D models with architectural and building information'(WS1_GSA_112)* or *' a way of modelling which has in it more information that a traditional one. Thanks to this we don't have to know how something will behave'(WS1_GSA_103).*

Many of the AECO orientated students recognised the overlap with mainstream BIM and described it as '*a modern method of modelling buildings rather than the traditional 2D drawings on paper, often digitised and modelled electronically in 3D & 4D'(WS1_WIT_129)* or a technique for *'modelling which can be used in a lifelike fashion, the ability to use virtual reality to walk around a modelled building'(WS1_WIT_117)* whilst the digital humanities based students offered an alternative viewpoint and described it as *'modelling that incorporates layers of information that can be tailored for the needs of the audience'(WS1_GSA_104)* or *'integrated heritage modelling is a perspective discipline merging a mathematical approach and computer technology'(WS1_WIT_134)*and as a model *'with information (useable information) rather than just a simple 3D model. (i.e. more than just surface data)' (WS1_WIT_142)*

As noted above there was a correlation between those who had a background in BIM and associating the term with the collaboration and management of data, the notion that the model had contained more depth than just polygons and geometric data.

The pre-questionnaire was designed to establish an indicator as to the base knowledge of the participants. From the information gathered the cohort where ***predominantly male*** in the age ***bracket 20-29*** who were heavily ***engaged with 3D modelling***, however considered themselves ***not very knowledgeable*** regarding heritage. When asked to define IHM, a term previously unknown to them, the majority of responses were on the correct path indicating an underlying understanding of the rudimentary theory supporting the concept. Once all candidates had completed their questionnaires, they were invited to a presentation discussing no. 1 & 2 Cathedral Square.

The presentation, for reasons discussed heretofore (3.3.1), was a Prezi style demonstration and begun with a definition of IHM. As this was possibly the first time this definition was put to the candidates it was meant as a precursor to underpin the content of the presentation to follow. The presentation began with an overview of the architectural history, main protagonists, and the geographical area of the building in order to establish a context for the audience. The building was introduced and briefly discussed given its role within this context.

The workshops were intended to be discursive in nature and sought to engage with the participants from the outset. Questions were encouraged as the presentation progressed and answered directly. To further encourage engagement a hypothesis was put forward for the audience to ponder. The statement *'dwellings of the period where cold damp and uncomfortable by modern standards'* was deliberately vague, divisive and designed to encourage a reaction from the group. Most students agreed with the statement but when queried further to elaborate they quickly relied upon anecdotal accounts and common misconceptions. The debate was left develop for a brief period then paused as the process of IHM was explained.

A series of slides depicting the process were presented that explained the steps alluded to earlier in this chapter. Given the diverse nature of the cohort being addressed, greater emphasis was placed on the actual model assembly as the knowledge base regarding BIM authoring was not widespread within the wider heritage community. Following this, the process regarding the simulation and evaluation of the data was explained with the results of the fabric analysis discussed in detail. The presentation then returned to the earlier discussion regarding the veracity of the hypothesis and several assumptions where discussed that predicated the original statement. The point that the IHM process permitted these assumptions/statements to be now validated by a degree of technical analysis, in a virtual environment, was reinforced to the audience and further discussion ensued. Moving the discussion forward and having reviewed the *tangible* benefits of assessing an historic building through IHM the initial definition was re-introduced and discussed in terms of the workflow evolving to incorporate threads of the *intangible* and feedback from the audience was garnered. Finally, the participants where then asked to complete a post workshop questionnaire that contained more open-ended opportunities to collect opinions and commentary on the process, they had just experienced.

Question 1 – Please explain briefly, what you now understand by the term 'integrated heritage modelling'?

Question one for the post workshop questionnaire was specifically designed to ascertain if the term IHM had been explained in a clear and coherent manner for the participants. As this was a follow-on question from the pre-workshop questionnaire it provided a platform for the participant to fully define what they now understood by the term. In addition, it offered the opportunity to compare both answers and evaluate if the IHM definition carried any resonance. In the majority of instances this was the case. For those with a BIM background they provided a re-working of their earlier attempt and identified IHM now as *'….modelling that contains information from which can be used as metadata that provides detailed information..' (WS1_GSA_100)* or of '*applying a BIM methodology to a historic building to gain a better understanding of the building'(WS1_WIT_113)* and some went more in-depth and identified IHM as *'…to develop a 3D programme that can be interrogated by the end-user (WS1_WIT_121)* or as '..*integrated heritage modelling is a process of creating a 3D digital artefacts that can host/store information which can be used by the end-user for a variety of uses'(WS1_WIT_131)*

Not surprisingly, those from a heritage/digital humanities background provided an alternative viewpoint but could now identify with the intent of the IHM process and revised their earlier comments, *'clearly completely different from my assumption. It consists of creating a multi-layered digital model/artefact which can be explored. It embeds meta data and information into the model itself and hopefully, lends itself to interaction and immersion. Its use allows for more informed assumptions or aims to enhance knowledge'(WS1_GSA_106).* The notion of embedding information was also grasped and understood in that some expressed views along the lines of a '*model becomes a place of information through visualisation and location. A way of testing the integrity of the structure' (WS1_GSA_109)* and describing it as a '*scientifically informed modelling that can curb some of our own assumptions about buildings'(WS1_GSA_111)* or '*it`s a form of 3D model with metadata embedded e.g. door-material, density, wood type'(WS1_WIT_137).*

Question 2 – Have you experienced of utilising a similar approach in 3D modelling of historic buildings?

Question two was to identify if the students had experienced similar approaches during the course of their studies and if *yes* then asked to elaborate in question three and if answered *no* to proceed to question four and elaborate upon the benefits, they perceived from such an approach. Unsurprisingly only 6% had expressed the opinion that they had experienced a similar approach and ***94% had not.***

Question 3 – If yes, briefly describe the project

Question three presented the opportunity to expand upon their *yes* answer from the previous question. The rationale for this question was to investigate what is being delivered on programmes in similar areas of study and if such approaches are being employed then they would necessitate further investigation for this research. Only three of the participants could share a similar experience. The projects ranged from 3D modelling of an historic wooden church to an old train station whilst one participant had tackled a historic project and applied a level of BIM processes for energy analysis. The fact that ***only three*** participants at this early stage of the research had some experience of a similar approach was unsurprising given the non-prevalence of similar approaches within academia at present.

Question 4 – If NO, could you see a benefit in applying such an approach? Please elaborate

For the participants who answered 'no' in question 2 they now had an opportunity to contribute to the study and express an opinion on the possible benefits of the IHM approach and how they could see it being applied. The preconceived *benefits* that were assumed by the author may not necessarily be shared by the participants and thus their opinions could be evaluated and implemented. This information would prove most beneficial going forward in developing Test Study B.

94% of those who participated answered '*No'* to question two regarding experience of a similar approach. This figure alone was not surprising, or unexpected, with all participants putting forward a scenario where they felt it could be applied. Many focused on the technical advantages of such an approach and noted its ability to '*..understand how buildings were built…and the difference between then, and now..(WS1_WIT_121)* or as '*….access to meta data' (WS1_GSA_103)* or '*improve the understanding of the building make a building more economically efficient…retrofit..(WS1_WIT_139)* and provide '*greater knowledge and aid in the preserving of the building (WS1_WIT_141)*

Several participants offered more insightful feedback and saw the potential of the process for a deeper application to encompass the *intangible* by expressing that *' Yes there are definitely opportunities, not just in regard to practical information as in the Test Study prescribed but also for presenting different stages of development and unpeeling layers' (WS1_GSA_106)* or stating that *'a more informed and accurate representation of the information. A more rewarding experience for the end-user'(WS1_GSA_112).*

Access to the information, and the advantages this created, clearly resonated with the participants. *'Yes, having all metadata immediately accessible will be really useful for interpretation of models' (WS1_GSA_105).*and how this may be developed for other similar type projects *'I could, for personal preference attempt more creative projects which focus on entertainment rather than factual/data collection projects but can definitely see a profound benefit using this technique'(WS1_GSA_101).*

Reassuringly, applying the IHM process to building conservation was also noted by the students and how it could affect their own approach to historic buildings, as one put it, *'Yes, understanding old methods of architecture and technology will assist the preservation hugely'*

(WS1_WIT_122) or as a colleague stated *'Yes, I see benefits…as it will help determine what/how to conserve'(WS1_WIT_142)*

Question 5 – Do you now consider yourself more informed?

Do you now consider yourself more 'informed' regarding the Built Heritage?				
1 (not at all)	2	3	4	5 (very much)
0%	6%	40%	43%	11%

Question five was deliberately provocative in its wording. It was asked previously in the pre-questionnaire and its repeat was designed to assess if the participants had felt they had learned anything from the Workshop. A Likert scale was introduced as a simple yes/no would obtain an answer but not of real substance. An open-ended question would possibly have encouraged the students to merely outline specific facts about the Test Study building whereas a more practical assessment was required.

The results show an increase from the pre-questionnaire. Whereas 68% considered they had little or no knowledge and 91% regarded themselves as moderate or lower on the pre-workshop questionnaire, the results on this occasion had reversed. ***54%*** now consider themselves more *'informed',* whilst a ***clear majority (94%)*** of participants would now consider that they are more than moderately informed. Whilst this result seems very promising, due consideration to false modesty on behalf of the candidates in the first instance must be considered, but nevertheless a positive outcome going forward.

As a body of work, the initial Workshop that was designed to establish a benchmark and inform the future direction of this research, was deemed successful. A cohort of 47 participants with adequate variety and skillset proved a firm base to interrogate the formative research. In many cases the answers where not a surprise and, in some instances, expected in relation to current knowledge base regarding the topic. Learnings from the workshop series would include that the participants are aware of the limits of digital media in the context of the Built Heritage and this was more prominent than first assumed. There was still an eagerness to engage with traditional modes of learning and any re-imagined process should be cognisance of this. It was also encouraging to note that the participants identified the potential of the process to encapsulate the *intangible* and looked to more diverse areas of application than initially presented with. In addition, several respondents referred to the process as '*rewarding'* and *'beneficial'* to the end-user in terms of enhancing greater understanding.

The positives going forward address the realisation that their daily engagement with digital media can enhance their knowledge of the Built Heritage and the challenge was how to best harness this engagement to facilitate a more informed user experience.

5.8 Summary

Test Study A was intended to demonstrate the level of *Information* that could be integrated within a digital model utilising the initial stage of the IHM process. Three threads were explored namely, building assembly, environmental performance and thermal comfort however multiple other avenues could have also been investigated such as solar gain analysis, wind analysis, material performance, costing analysis, air movement and so on. Notwithstanding, the assembled IHM was evaluated to validate the reliability of the information produced and its robustness to cross interrogation by a selected audience. The Test Study was deemed a success in helping to further understand thermal performance for buildings of that period and typology and lessons were also garnered in terms of the workshop structure and refinement of the IHM process that proved invaluable going forward into the next phase of the research.

The digital model generated was a parametric IHM with embedded rich datasets that could be extrapolated for further use and leveraged towards multiple end-users. In addition, these datasets also provided an underpinning knowledge that allowed for discourse that engaged the end user. To this end the stated aim was achieved and put in place the structures to allow this research to progress the workflow further and explore the possibilities of incorporating the *intangible*. As stated previously *tangible* heritage is merely one aspect of the identity associated with an historic building and that the *intangible* fabric is of equal, if not greater, significance.

6.0 Enhancing the Workflow – Christ Church Cathedral, Waterford City.

Building upon the work developed in chapter five, this Test Study will demonstrate the capabilities of the IHM workflow and in particular stages two and three, that being *Interaction* and *Immersion*, by illustrating how virtual environments can assist in engaging the end-user further with the Built Heritage. Simultaneously, this Test Study outlines the capabilities of the process to establish a single digital repository for multiple rich datasets associated with the building of both a *tangible* and *intangible* nature.

6.1 Christ Church Cathedral

Christ Church Cathedral traces its origins to the Vikings who settled in Waterford during the 10th century. Although the first settlers were pagan, they were gradually Christianised as they integrated with their Irish neighbours. Saint Olaf's church was built nearby, possibly as early as the 990s, and a church dedicated to the Holy Trinity was built on this site around the year 1050.

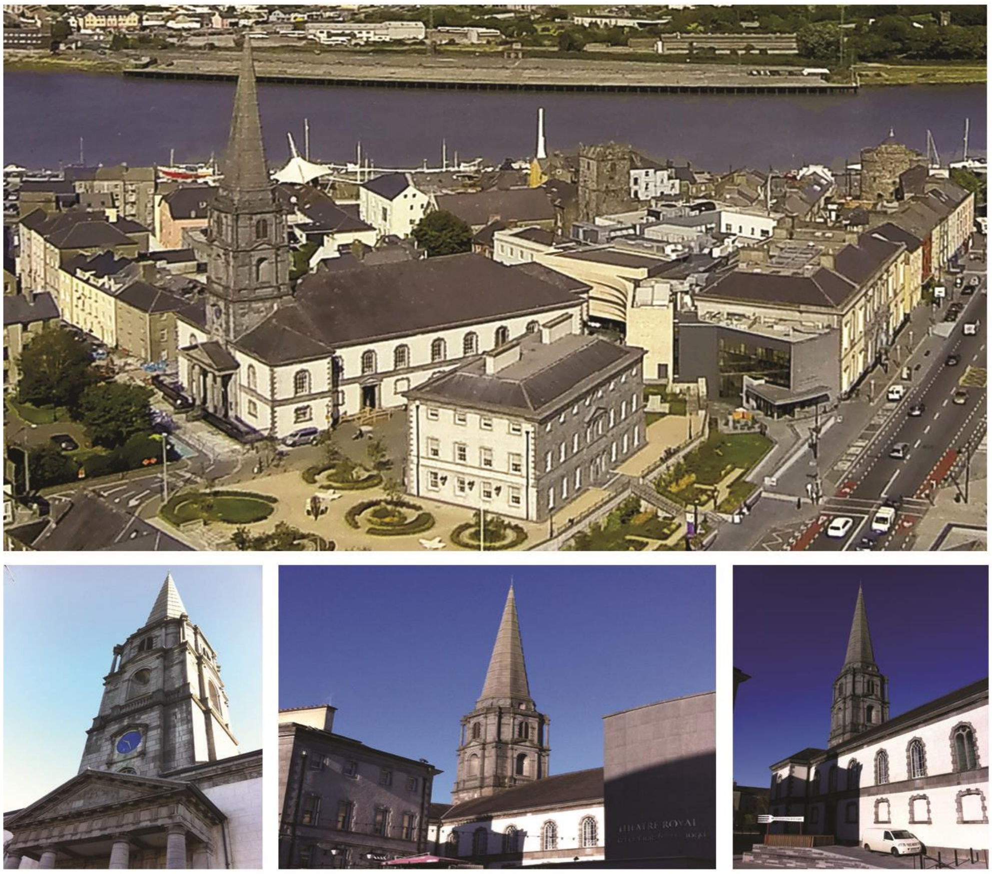


Fig 6.1.1 *– Christ Church Cathedral*

Although this cathedral's proper name remains The Cathedral of the Holy and Undivided Trinity, it is known as Christ Church - a term of Scandinavian origin meaning 'head church' or 'cathedral'. In 1096, Waterford became a diocese when Malchus, a Benedictine monk formerly associated with Winchester Abbey, was consecrated in Canterbury by St Anslem. Malchus was one of Ireland's first bishops, and Christ Church became the cathedral of the new city diocese of Waterford. (O`Donoghue & Walton 2013, 124)

In 1170, an invading force of Anglo-Normans seized control of Waterford from the descendants of the Viking settlers - the Norse-Gaels. Diarmait Mac Murchada, the deposed King of Leinster, enlisted their help to defeat his political rivals. To cement this alliance, Mac Murchada's daughter, Aoife, was married to the Norman leader Strongbow in the cathedral. The union provided Mac Murchada with Norman troops to reclaim his throne and Strongbow stood to inherit kingship after Mac Murchada's death. The Normans settled in Waterford and across much of Ireland, which formed a lordship tied to the English monarchy. Waterford prospered under the Norman's descendants, often referred to as the *'Old English'*, and was second only to Dublin in importance during the middle ages. Reflecting the city's economic and political prestige, the cathedral was rebuilt in the Early English Style in 1210. This cathedral stood for over 500 years, until 1773. It consisted of a nave and chancel (added in 1220), separated by a timber screen and with side aisles but no transepts. The cathedral was more than 40 metres long, and the nave was 14 metres wide. The nave was separated from the aisles by an arcade of eight pointed arches on each side, supported on clustered columns, surmounted by a clerestory. There was a large Lady Chapel behind the High Altar. The medieval cathedral was ornamented and expanded through the years by influential members of Waterford society. James Rice, who served as mayor eleven times, built a side chapel dedicated to Saints James and Catherine to house his tomb in 1482 (Smith 1746, 27).

The sixteenth century ushered in a period of religious change as western Christendom was fractured by Protestant and Catholic Reformations. In an age before religious pluralism, the contemporary axiom of '*Cuius regio, eius religio'*, which was agreed at the Peace of Augsburg to end conflict between Catholics and Protestants in 1555, meant that the religion of the ruler was to dictate the religion of those ruled. As a result, the medieval *'catholic'* church and its property became the Church of Ireland as established by law in the Irish Parliament. However, the Catholic Reformation built its own clandestine structures, and won the spiritual allegiance. By the eighteenth-century architectural tastes had changed, and the progressive City Corporation considered the medieval cathedral to be old-fashioned. Bishop Richard Chenevix initially resisted their proposal to build a new cathedral, and it is said that a ruse was devised to change his mind. As the bishop walked through the cathedral one day, some rubble was strategically dropped in his path. Understandably unsettled, Bishop Chenevix changed his mind on the grounds that he believed the existing structure to be unstable. Work started in 1773 when the Gothic cathedral was torn down, or rather blown down, as it was so strongly constructed that gunpowder was required (O`Donoghue & Walton 2013, 125).

The new cathedral was completed in 1779 at a cost of £5,397. As discussed in chapter five, it was designed by John Roberts, a local architect whose imagination gave shape to much of Georgian Waterford. Christ Church cathedral has been described by the architectural historian Mark Girouard as the finest eighteenth-century ecclesiastical building in Ireland. It was built in the neo-classical Georgian style, which drew inspiration from the architecture of Ancient Greece. Its spaciousness, sense of light, and restrained elegance contrasts with the ornate and dark interiors of Gothic cathedrals. The spectacular stucco plasterwork ceiling is similar to those found in many Georgian palaces and stately homes across Europe (Walton 1996, 22).

Today the cathedral varies slightly from its original design. In 1815, a fire destroyed the organ gallery along with a collection of music and much of the nave. The cathedral was closed for three years for repairs as a result. A ring of eight bells was installed in the tower in 1872, and the first bell peal to be rung in Ireland was performed at this cathedral in 1874 by the Ancient Society of College Youths. In 1880 the current spire was built to replace the original designed by John Roberts. (O`Donoghue & Walton 2013, 227).

By 1891 further improvements were deemed necessary by Sir Thomas Drew, a leading architect of the time who consulted on the restoration of Saint Patrick's Cathedral, Dublin, and was the first architect of Saint Anne's Cathedral in Belfast. The box pews and galleries were removed, pulpit shortened and relocated, ground floor windows blocked up, and oak stalls for choir and canons built in the chancel. During the renovations of the 1890s the organ was moved into the front left-hand corner of the cathedral, and the archway of Caen stone was added where the organ currently stands. The marble at the base of pillars and in the chancel was also added at this time. Roberts designed Christ Church cathedral as an aisled rectangle, 51.8 metres long, 17.6 metres wide, and 12.1 metres high, with a shallow chancel and seating for 1,100 people. The NIAH describe the building in its current state as a *'detached nine-bay double-height neo-Classical Church of Ireland Cathedral, built 1773 - 1779, comprising eight-bay double-height nave with single-bay double-height chancel to east, and single-bay four-stage entrance tower to west on a square plan with pedimented tetrastyle portico to first stage, polygonal spire over, and single-bay double-height flanking end bays'*(www.buildingsofireland.ie).

For over 1,000 years a cathedral has been perched on this elevated site overlooking the old city and recent works undertaken by concerned stakeholders ensure that Christ Church continues to contribute to the architectural narrative of the city going forward into the future.

6.2 Aims

Test Study B continued to address the gap that exists in current research regarding the ability to capture, consolidate, and consume *intangible* heritage within a 3D digital model. Based on the experience from the previous Test Study, due consideration was given to the complexity of information required to illustrate the final two stages of the IHM process.

Firstly, the scale of the building was dramatically larger than the domestic dwelling of the previous work and as such an improved approach was required. Secondly, the nature of the building also varied significantly in that ecclesiastical buildings normally possess more ornate and decorative architectural styling than a domestic dwelling, and thirdly the level of information required to demonstrate the capabilities of the IHM in capturing and storing *intangible* data would require more extensive scholarly research and evaluation. As alluded to briefly in the previous section, Christ Church cathedral has borne witness to an eclectic tapestry of historic events and in so doing was deemed a suitable subject for the purpose of this research to demonstrate the full capacity of the IHM process. The specific aims of this chapter are;

- to construct a digital repository, in the guise of a 3D digital model, capable of in-depth interrogation by the end-user.

- demonstrate *Stage 2-Interaction* of the IHM process by engaging the end-user with aspects of the building’s history.

- demonstrate *Stage 3-Immerssion* of the IHM process regarding capturing and consuming *intangible* heritage.

- evaluate and appraise the findings of the IHM process through a series of workshops to establish if further engagement has facilitated an increased level of interpretation by the end-user.

Test Study A duly demonstrated the capabilities of Stage 1-*Information* and therefore this was not repeated within Test Study B. Also, building upon the discourse outlined in chapter 2.2 there was further discussion regarding *why* this approach is of significance within the context of older buildings and architectural conservation.

6.3 Data Acquisition

Test Study A was an adapted hybrid version of that created by Arnold (2013). Improving upon this, Test Study B required a more expansive approach. To capture the measured data several approaches where adopted. An initial survey of Lidar data was acquired, from the Local Authority, to determine initial topography and building heights. This was then validated through drone aerial photogrammetry. The aerial work also provided an abundance of visual reference material that assisted in deciphering a myriad of building detail required later for digital family creation. The initial scaling and massing of the building was established and verified; multiple site surveys were conducted with measuring devises to capture the internal dimensions. Laser scanning was considered again given the scale of the building, however for reasons stated previously regarding the size of the raw data and desired outcomes, it was decided a blended approach of traditional methods and contemporary photogrammetry would suffice.

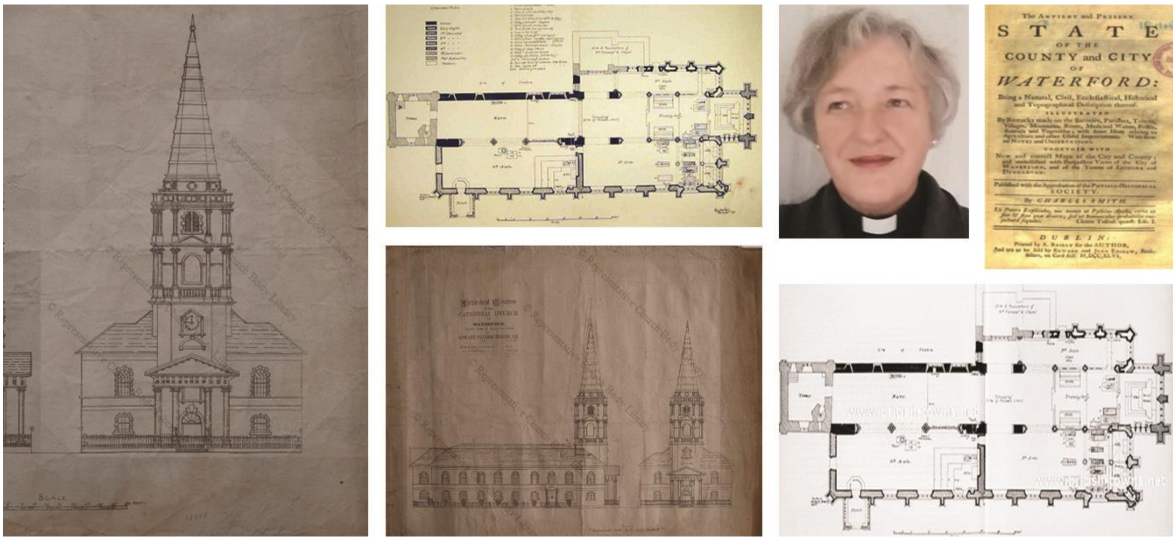


Fig 6.3.1 *- A selection of survey data.*

A fieldwork routine was established, and the process of acquiring data was somewhat iterative with constant referencing of previous surveys conducted by both private practitioners and heritage professionals. Any discrepancies where highlighted and duly reconciled where appropriate. On conclusion a comprehensive database of photography, measured sketches and written site notes accompanied by aerial photogrammetry, lidar data and third-party records was collated and evaluated in order for the IHM to be assembled. Obtaining data for the accompanying scholarly information required a similar blended approach of investigating multiple repositories including Cathedral records the RCB (Representative Church Body) library and supporting local history texts that were available.

6.4 Construction the IHM

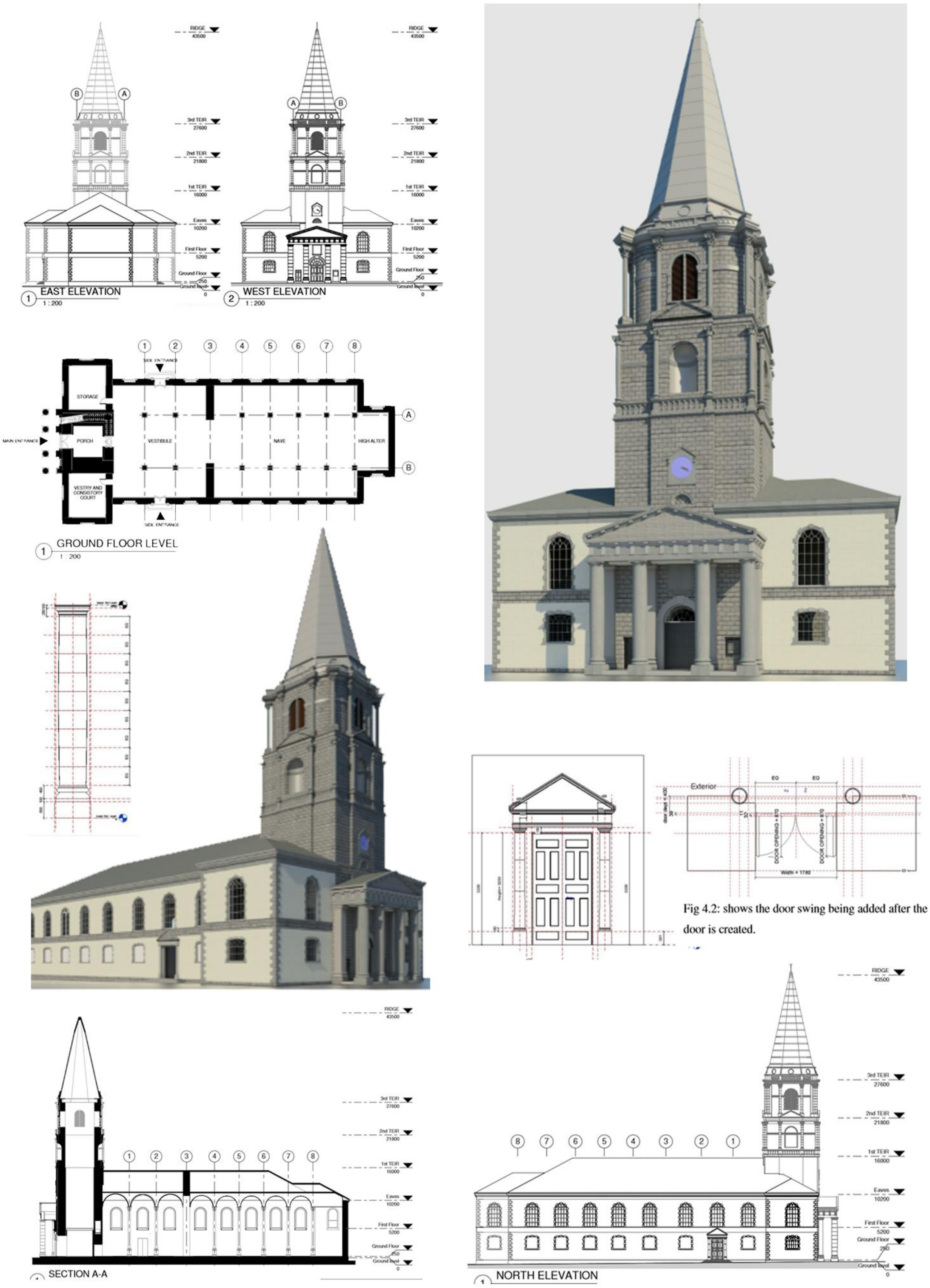


Fig 6.4.1 *Selection of images of IHM assembly*

Chapter four identified the procedural workflow that underpins the IHM process and explained the concept of the three stages *Information*, *Interaction* and *Immersion*. Chapter five then demonstrated the capabilities and functionality of the *Information* stage. As alluded to above, this section further reveals the mechanisms of both the *Interaction* and *Immersion* phase. In evolving the process from the Cathedral Square Test Study, the IHM had to possess the scope to not only contain information relating to the physical attributes of the building but must also demonstrate the capacity to host multiple threads of information relating to the *intangible* fabric.

Step 1 – The IHM Execution Plan

As before, the first step was to enable an infrastructure that facilitated the IHM assembly and to this end an IHMEP was duly created, populated, and applied. Key decisions regarding Level of Detail(LoD), desired outcomes, and specific datasets where collated for evaluation. An LoD of 300 was decided upon given the nature of the project and the desired outcomes required. The necessary file structure, containing the central authoring file, was then put in place with additional placeholders for the datasets that were to follow.

Step 2 – Collaboration

For this project, an Autodesk cloud-based platform (BIM360) was utilised. A dedicated Central Authoring file was created from a bespoke template file that contains ancillary libraries that were deemed appropriate for this work.

Step 3 – Setup Modelling Environment.

Once the Project folder had been populated with the required sub-folders and placeholders containing the heterogeneous datasets and third-party information such as maps and existing reference drawings/documents, work commenced on authoring the IHM. A separate Revit file was then created with all necessary building datums/levels inputted to create a 3D environment with information obtained from the fieldwork and ancillary data files imported to the environment.

Step 4 – Creating Families.

As the families required more complex data fields on this occasion, it was decided they be created at an earlier stage of the process to allow more time for testing. As a sequence, building features where modelled initially, followed by windows, doors and then bespoke objects that where selected to demonstrate the capacity to embed *intangible* information.

Windows.

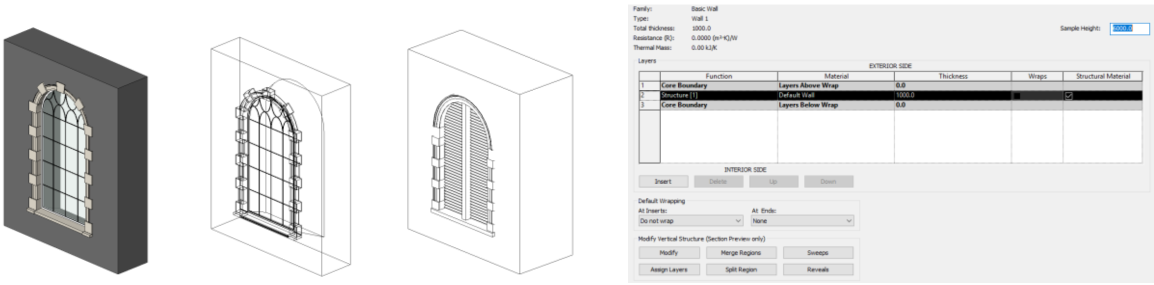


Fig 6.4.2 *-Window family assembly*

For instance, there were seven different window families created for the Christ Church model. To start modelling the window a new metric window family template was opened in a separate project. The standard window template consists of a wall at which the window is hosted. In a plan view the wall has a central x,y axis. This is the centre point from which the modelled geometry is constrained to. This process was carried forward by adding reference planes to the sketch and either locking the dimensions to the x,y axis or creating a parameter so the dimensions can be edited later in the process. Then the reference planes that define the windows height, width and at what depth it sits in the wall are inputted and the 3D geometry can be applied. All of the geometry created within the window family was sketched in 2D planes and sweeps are extruded along a single axis such as glazing bars or glass creating the window component, one section at a time. Once the first window was created it now becomes the template for the remaining windows. The base window family was saved, and subsequent iterations are edited to form the next window and the process was repeated until all the window families are created.

Interestingly, the niche and bell opening on the tower were both created as window families. Since the window template was best suited to their requirements, which was to be a wall hosted component and create opening cuts in the wall they are hosted to. The niche and bell openings have similar reveals to the created window family's which meant that time could be saved in the modelling process, by not replicating work already completed.

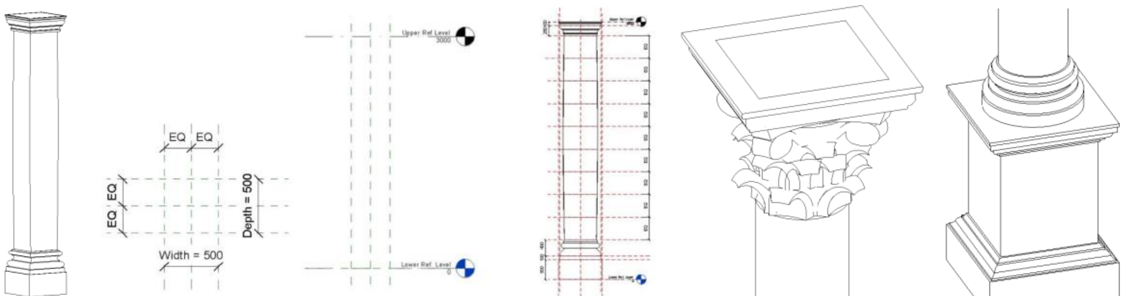


Fig 6.4.3 *- Column, Pilaster family assembly*

To create a column, a metric column family project was opened. The standard column template consists of a central x,y axis in plan view with a square reference footprint. Parameters are set to the central x,y axis to control the width and depth of the column. In an elevation view there is a reference base and reference top which control the level and height of the column when loaded into the project. There are multiple uses of column types in the Christ Church model. The round columns at the main entrance, pilasters at the main entrance and more ornate pilasters on both the second and third tier of the tower.

The circular columns at the main entrance were created first and would act as a template for the remaining column families. The base of the column was extruded in plan view and locked to the square reference footprint. In the elevation view a separate reference plane was sketched, 700mm above the base reference plane and locked to constrain its top. Two more reference planes were then sketched in elevation view, one 200mm above the extruded base and the other, 200mm below the top reference plane and both constrained. Between each of the divided sections the revolve tool was used to create the top and bottom profiles. A 2D profile was sketched in elevation view and revolves around the central axis to create the columns cylindrical profile at both the base and top. A series of reference planes were sketched between the bottom and top revolves. Following this, a dimension line was placed between the top and bottom revolves taking a running dimension of each reference plane, equalling the distance. Creating the remaining column families required the column bases and column heads to be edited in a similar fashion to the windows.

The Belfry

The external walls of the belfry were sketched in a 2D view over the image underlay (data from existing survey). The tower core was divided into four sections, the base section, second tier, third tier and roof, with each section stepping back as the tower rises. The base walls extend up to a height of 14m before tapering. This section of the model has two-metre-thick limestone wall which incorporates the stairs within the Belfry and also the main entrance to the building, located on the western facade.

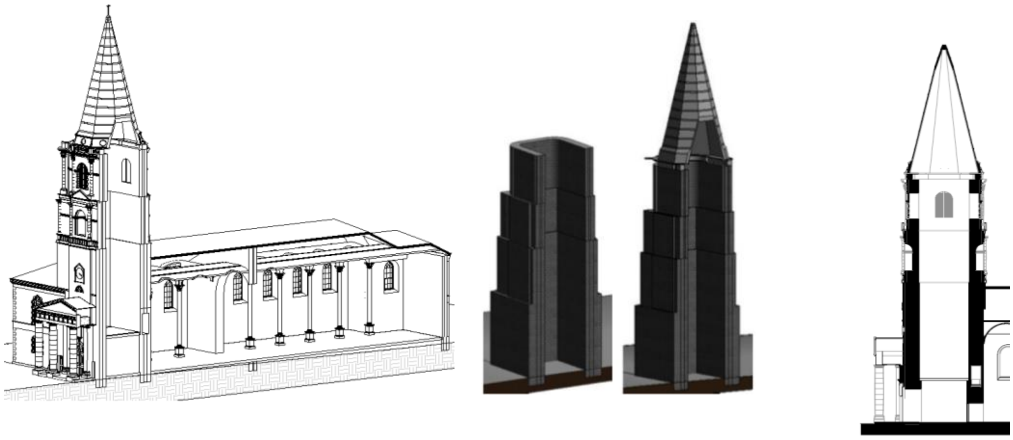


Fig 6.4.4 *-Belfry assembly*

The roof of the belfry was created by applying the blend tool within Revit, which requires two separate 2D sketches. At the base of the roof, a hexagon profile was sketched before scaling down the profile and transferring it to the peak reference plane, which then blends to give the roofs shape. To apply the finish a 2D sketch was drawn in a section view and swept around the blended profile. The circular features at the roofs base were created as metric roof-based families and was in keeping with the method of trying to create the majority of the model as parametric family components.

The Main Building

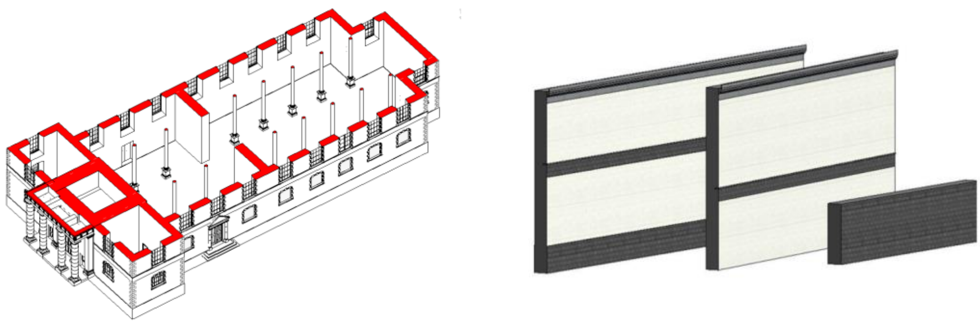


Fig 6.4.5 *-Wall assembly*

The next stage of the model was the assembly of cathedral nave and its walls, floors, and roof. The sequencing of materials in assembling the wall types was critical for future simulation and analysis, similarly with the floor and roof construction. In applying this method, the wall, floor, or roof within the model now becomes the source for the stored data. This provides the capacity to maintain the metadata as one single manageable file.

The external walls of the cathedral have a limestone plinth and a continuous exposed limestone course between ground floor level and first floor levels. At eaves level there was a second extruded course, similar to that at first floor level, which also incorporates a decorative moulding. This required the wall creation within the model to have multiple wall build-ups with constraints set to control what levels or heights the different build-ups would appear. The walls were created as a stacked wall which is two separate walls modelled individually but fused together to create a single wall. Any modifications to the stacked wall after it was created must be made to the individual walls which automatically updates the stacked wall. At approximately 800mm in depth, this section was finished in an exposed limestone soldier course with a top lip that aligns with the first-floor window cills. The lip was created using a sweep system edited within the wall type creation. Different parameters can be set to control the height its offset or allow the sweep to break when objects are placed in the wall later in the project.

Metric Generic Models

Metric generic models were created for bespoke elements that did not require parametric functionality. The appropriate template selection for a generic model was key, as if the component modelled was required to be placed on a wall, then a wall hosted template was necessary e.g. the clock on the west elevation required a wall host template and the circular profiles at the roof base required a roof host template.

Embedding the data

Whereas the previous Test Study focused on the physical fabric of the building in relation to thermal comfort and challenging fixed assumptions regarding living conditions, this Test Study endeavours to explore the *intangible* and illustrate the *Interaction* and *Immersion* capabilities of the IHM approach. Chapter four outlines in detail the technical steps involved in facilitating these aspects into the IHM workflow, in short it is a two-step strategy.

Firstly, multiple historic threads where researched and evaluated for inclusion. The stipulated criteria for inclusion require that the information be related to the building and reflect a facet of *'hidden-history',* that was not widely known or readily available. The second step explores how best to incorporate this information within the model that facilitates the user to interact with this information. Christ Church cathedral has a storied and diverse history that is inseparable from the development of the social fabric of the city. There are numerous historical accounts and anecdotes that are both engaging and insightful. On reviewing various such historical threads, it was decided upon the following for inclusion within the IHM, namely;

Consistorial Court

This was one of the last remaining consistorial courts of eighteenth-century origin in Ireland. Church courts were an important institution in medieval Ireland and continued to exercise jurisdiction over matters relating to religion and morality after the Reformation. Here the bishop, or his representative, wielded power to investigate offences against church law such as blasphemy, sacrilege, and adultery, as well as more routine matters such as granting marriage licenses and probate for wills. Given the rarity of its existence and the social history associated with this activity this information was deemed of great interest and would appeal to a diverse audience.

Cloth of Gold Vestments

Fig 6.4.6 *-Belfry with source: Waterford Treasures museum*

The only full set of medieval vestments to survive in northern Europe. They are considered to be Irelands only link to the Renaissance and were buried beneath the Cathedral. During demolition of the medieval cathedral, a chest containing vestments of Italian silk embroidered in gold were unearthed. The vestments were commissioned by Dean John Collyn in 1468, and almost certainly paid for by James Rice, one of Waterford's leading citizens who served as mayor several times. The vestments were hidden underground to protect them during the siege of Waterford and survived the 17^{th} century wars of religion because they were buried in 1650 before the city fell to the army of the republican general, Oliver Cromwell. They remained there untouched for 123 years.

The Waterford set of cloth-of-gold vestments are now regarded as one of the great treasures of late medieval Europe. These vestments are a symbol of many things but essentially, they represent the magnificence of the art that adorned the churches of late medieval Ireland. Bishop

Chenevix presented them to Waterford's Roman Catholic bishop sometime between 1797 and 1803. The robes have since been restored and are on display in the Medieval Museum. (Walton & O`Donoghue 2013, 124)

Trinity Arch

An interesting architectural building detail regarding a gesture by Irelands leading University, Trinity College Dublin. The stone architrave that frames the side entrance doorcase was gifted to the Cathedral in lieu of manuscripts that were stolen from the cathedral and found their way to the Trinity library. As an act of conciliation, a stone architrave was gifted to the cathedral.

Protagonists (John Roberts)

Naturally with a building of this age there are several prominent figures that could merit inclusion and fulfil the criteria having contributed to the development of the cathedral. For instance, Mayor Rice whom financed the building, whilst serving as a mayor on eleven different occasions and currently has a prominent mausoleum erect in his honour within the nave of the church or Oliver Cromwell whom was responsible for the destruction of the medieval cathedral that once stood upon the site. However, given his prominence throughout this research, a brief biography of John Roberts was chosen for inclusion due to his role as chief architect and is largely responsible for the building that now exists.

A.E. Child Stained Glass Window

Only clear glass windows were featured in John Roberts' original design. An interesting feature regarding the glazing of the cathedral was the fact that only one window contains stained glass. This 1930's stained-glass window was commissioned in memory of Charles E. Denny by the Denny family, parishioners who started their well-known sausage, bacon, and ham company in Waterford. Though out of keeping with the architecture of the cathedral in general, this window is widely thought to be A. E. Child's finest work and is representative of the work of the Dublin studio An Túr Gloine (Tower of Glass). Titled *'Sorrow and Joy'*, the text reads *'Sorrow may endure for a night, but joy cometh in the morning'.*

Fig 6.4.7 *-Childs Stained Glass.*

As the primary threads of *intangible* heritage were selected and to enable the user to access and interact with the information, this data was digitally coded within the IHM in the form of textual accounts that were located directly in relation to the feature of the building to which they correspond, i.e. the history relating to Childs stain glass window was embedded within close proximity of the digital object.

Step 6 – Preparing the model for Interrogation.

Once all data relating to the various threads of the building were embedded, the Christ Church IHM was further tested and prepared for the following phase. The central file was federated and reviewed for data content with reference to the stated aims and objectives within the IHMEP. The process remains fluid at this junction. At no point did the Christ Church IHM become an isolated digital entity in the process. The third aim of the process was to facilitate enhanced engagement of the information by the end user. The Christ Church cathedral IHM focused on the final two stages relating to *Interaction* and *Immersion.* To achieve the *Interaction* element, the following steps were applied as per the IHM workflow.

Step Int_01_ Set up navigational waypoints.

In order for the end-user to access and interact with these historic threads, the information relating to the historical account was coded within a blue plaque type object(mass) that acts as a unique identifier within the IHM. Briefly, for reasons stated in chapter four, a blue plaque was modelled within the IHM and intended to be similar to that promoted by heritage groups and found throughout Ireland and elsewhere. These plaques than act as a way-finder as the user navigates through the virtual environment.

Step Int_02_ Linking the IHM to Interactive Platform

Following further testing regarding the robustness of the federated IHM and undertaking a level of digital maintenance by means of removing any unnecessary noise regarding geometry and redundant families the model was than ready to be exported to the next stage. In this instance, Autodesk Live was chosen and the IHM, via an embedded control panel within the authoring software, enabled the model to be pushed to the cloud for processing. On completion the model was than accessible via the *Live App.*

Step Int_03_ Prepare for consumption

Within the IHM process the *Live* app can be explored via laptop, workstation, or mobile device. This then formed the backbone of the *Interaction* station that was present in the workshop series and outlined in greater detail below. Finally, to demonstrate the *Immersion* capabilities of the IHM it was decided to embed an element of *intangible* heritage relating not only to the building but also Waterford of that time and provide an insight into the lives of the city patrons of that era.

Step Imm_01_ Select Enscape Plugin

The plugin *Enscape* was launched on a separate display window. As alluded to in chapter four the operations between both platforms are synced simultaneously allowing for real time manipulation.

Step Imm_02_ Embedding additional data.

Additional entourage elements such as people and foliage were inserted and placed accordingly. Render settings were adjusted to achieve the desired non-photorealistic graphic (NPR) for reasons again previously discussed. Research at the RCB library unveiled a transcript (part of) regarding an announcement that was allegedly delivered from the altar, or similar region of the cathedral in the later 18th century. It regarded changes to the City Charter that effected trading law and amendments to byelaws. A voice actor was engaged, and a recording of the transcript was created. This recording was then embedded within the IHM of the Cathedral as an audio file. In total there were two types of audio file, one for the actual oration and another containing background noise for effect and ambience. Finally, the atmospheric conditions were set that included daylighting, haze, and depth of field.

It is important to note that whilst the *Enscape* plugin was developed by a third-party vendor it is embedded within the IHM and as such forms part of the federated model.

Step Imm_03_ Prepare for consumption

Once final checks have been completed regarding functionality and performance the *'enable VR'* setting was launched. The virtual environment was tested and several iterations regarding atmospheric conditions, volume, positioning of the spectator were sampled and explored before finalising the settings. In this Test Study it was decided that the spectator would remain static in a seated position amongst the brethren of avatars to ensure that focus would be firmly fixed on the audio and setting and thus enable engagement with the *intangible* knowledge being imparted from the pulpit.

Once all issues had been resolved the VR experience was then exported as a standalone executable application(.exe) and formed the basis for the *Immersion* station within the workshop format.

6.5 Data Harvesting

Whilst the intention of this particular Test Study focused on the latter stages of the IHM process it is important to restate that the model could have been developed to reveal similar findings regarding *Information* relating to the building fabric. Test Study A identified how the data could be analysed in order to evaluate the fabric of the building and specific aspects relating to building performance. In Test Study B this has developed into extrapolating data from the IHM. Notwithstanding, the digital model created was a data rich repository that contained multiple layers of coded information. In BIM *'Level 2'* parlance, it has become the *'as-built'* model and the outputs, both graphical and non-graphical, can populate a Common Data Environment (CDE). As a by-product of the process several alternative avenues to harvest information from the IHM process have been created and could be leveraged in multiple scenarios. For instance, in terms of a building (facilities) management there are multiple avenues for exploitation. A series of schedules could be collated and readily extracted for consumption. This data was based on shared parameters that have already been encoded into families and components in the previous steps. These shared parameters created for the model included, height, width, year of refurbishment, quantity and standard of customised glazing panes, alterations made, last maintained, maintenance required and URL`s as the dedicated data fields. This group of parameters could form the structure of a maintenance inventory along with standard default parameters such as description, level, keynotes, material, and glazing. Once the schedule was created, any subsequent alterations automatically update throughout the entire project due to the parametric nature of the data environment created. Furthermore, it is a two-way process. If the schedule is updated an alert will appear within the model outlining amendments have been made and actions are required. This data has multiple uses amongst a variety of stakeholders. For instance, the information can be linked via a URL address that is imbedded within the family. In this brief example a one-page website was created containing information regarding the history of one of the windows within the model and published online for the purpose of reaching new audiences.

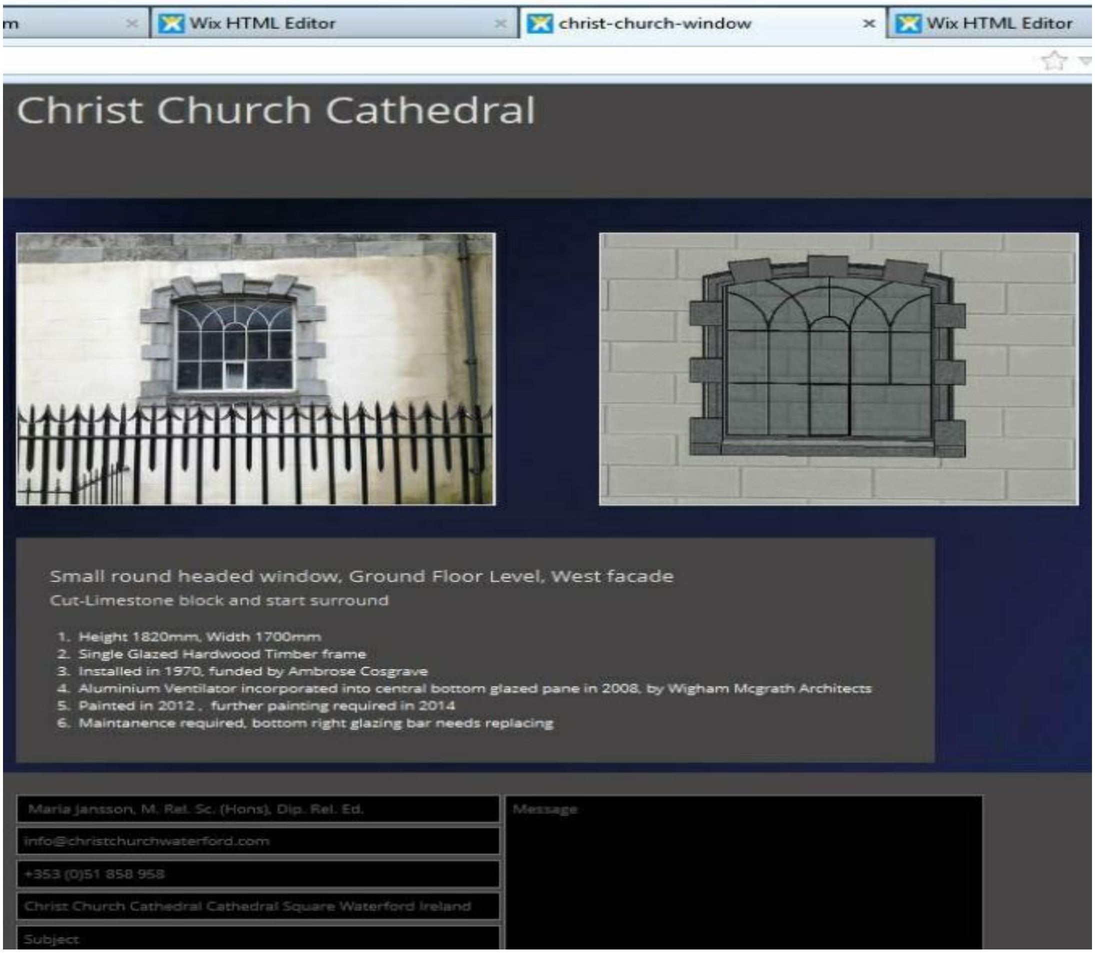


Fig 6.5.1 *-Sample website*

There are suggestions the internet is littered with dormant or *'zombie'* cultural heritage sites, but the functionality is possible to migrate the data from the initial source, that being the IHM model and reach a more diverse audience. These are just two examples of such harvesting and exporting of information for tertiary purposes with many more possible. The enabling factor that allows for further interrogation is the underpinning data and information that is garnered in the first instance. This is discussed in much greater depth in section 8.2 & 8.3

6.6 Evaluating the Findings.

The IHM process presents a framework for creating a single digital repository which was a key tenant of this work, however it must be of benefit to the end user. Access and consuming the data in a manner that promotes engagement and facilitates interpretation is essential. The second series of workshops investigated if this were the case and to highlight the robustness of the process. An evolved structure for the workshop series incorporated two additional demonstration stations, one for *Interaction* and one for *Immersion*.

By way of a caveat, it is important to note that the participants who undertook workshop series one are not necessarily the same participants who undertook workshop series two, due to academic calendars, availability, and a desire for a more varied cohort. The second series of workshops commenced in December 2017 and consisted of 100 participants from four institutes of higher learning, Waterford Institute of Technology, Cork Institute of Technology, Ulster University, and the Glasgow School of Art. The rationale for selection of the subject participants was clearly stated in chapter three. In total, there were four sessions between the Institutes and each session was conducted in near identical fashion to maintain consistency.

6.6.1 Workshop Series Two – Interaction to Immersion

As with the initial workshop series a process of gathering participant consent was adhered to. Following this a questionnaire was circulated with a series of questions as before and identical to workshop series one as a correlation between the cohorts was required for data evaluation purposes.

**As there was 100 participants the percentage figure equates to the actual number of subjects*

1. What age bracket do you belong to?				
17-19	20-29	30-39	40-49	50+
21%	68%	11%	0	0

68% of participants were in the 20-29 category, whilst a total of ***89% where under the age of 30***. Similar results (87%) to workshop series one, due in large part to the age profile of a student body attending third level and enrolled on courses of this nature.

2. You are?		
Man	Woman	Other (please specify?)

71%	29%	0%

An even ***larger proportion*** of males on this occasion at ***71%*** (previous 64%) possibly accounted for by the courses the students where sampled from. Although there was a wider range of programs in this instance both Ulster University and Cork Institute of Technology are pre-dominantly AECO related that traditionally would be a more male orientated profession in Ireland and the UK, the outlier being the GSoA where all but one were female.

3. What term best describes your area of study?				
Architecture	Engineering	Construction	Heritage	Digital Humanities
79%	0%	13%	7%	1%

Question three sought to identify how the students aligned themselves to a particular area of study ranging from architecture to digital humanities. Similar findings again to workshop series one (68%) with ***79%*** on this occasion aligning their studies to ***architectural*** and 8% combined for heritage and digital humanities.

4. How often do you engage/interact with 3D computer modelling?				
Daily	2-3 times a week	Once a week	2-3 times a month	Once a month or less
68%	26%	4%	0%	2%

Question four was intended to probe the level of digital competency and in particular their experience to date with engaging, and not necessarily just consuming, 3D modelling. A very high percentage of ***84% would engage with 3D modelling*** on a weekly basis, of that 68 % indicate they would engage on a daily basis. As the group has expanded and the make-up of the group is leaning towards AECO programs this was not surprising allowing for the digital nature of the architectural studio elements of their courses.

5. How "informed" would you consider yourself to be regarding the Built Heritage?				
1 (not at all)	2	3	4	5 (very much)
22%	51%	24%	4%	0%

Question five identified to what degree to the participants considered themselves informed in relation to the *'Built Heritage*'. ***Only 4 %*** considered themselves to be above average in terms of being *'informed',* whilst 22% considered themselves to have no underpinning knowledge whatsoever. As before, this could be due to false modesty on behalf of the participants and the fear if they had answered more positively that somehow they were going to be '*caught out'* later in the process, or, if could reflect the level of importance heritage based studies possess within their programmes and as a consequence they merely fulfil the obligation to attend and garner the required credits. More pointedly, it could be as a consequence of how cultural studies is presented as a subject area to the participants in a non-engaging traditional way.

6. Have you experience in 3D modelling of Historic Buildings?	
Yes	No
23%	77%

Question six was designed in order to ascertain if the two areas of 3D modelling and heritage studies had been combined in their experience to date, i.e. on their programme. ***77% had not*** as of yet engaged in a project of this nature where both 3D modelling and the broader study of heritage had been combined. Not surprisingly, ***100% of the GSoA*** students had answered in the affirmative considering that this is core to their program. In the remaining Institutes, where the composition of the programs ranges from architectural technology to interior design and into construction management ***only 23% had attempted*** a project of this nature to date.

7. Please explain briefly, as best you can, what you understand by the term 'Integrated (Heritage) Modelling'?

Question seven was the first of the open-ended style of questions where the participant was encouraged to define what they understood to be Intelligent (Heritage) Modelling. It was intended to identify had the participants been exposed to the concept beforehand and if so, what that had entailed. For those who had not, it was designed to highlight if they had considered in their own thought process the amalgamation of the two areas of information modelling (BIM) and heritage. Many of those who participated expressed a sentiment along the lines of *'not quite sure….nothing….not a lot' (various)* to more measured responses where the participants have had some exposure to BIM and stated *'retrofitting older buildings so they comply with building regulations'(WS2_CIT_140)* to *'modelling up heritage buildings, sites using advanced digital software technology' (WS2_CIT_125) and* some describing the process as *'BIM software for buildings that have historic features/old buildings'(WS2_UU_107).*

The results from the pre-questionnaire are in line with the findings from workshop series one in that the cohort, although spread over a wider range of institutes, have similar experiences in that they are engaging with digital technologies and 3D modelling on a regular basis yet are seemingly aware of the term (BIM)information modelling but nevertheless do not see a correlation between the two.

In a development from the initial workshop series that focused solely on the *Information* capabilities of the IHM process the primary focus on this occasion was to evaluate if this *Information* could be conveyed to the participants in a more engaging fashion and would that increase their level of interpretation of what they were experiencing. Therefore, on completing the pre -questionnaire the participants were invited to attend a brief lecture regarding Christ Church cathedral and then experience the two dedicated virtual environments, *Interaction* and *Immersion*. In order to evaluate their experience, a second questionnaire was completed and, in addition, the proceedings were recorded to gain further insight through observation.

For reasons previously explained a Prezi style production was delivered to the cohort, outlining a context to the research project prior to commencing the discussion relating to Christ Church Cathedral. In this instance the provocative statement put forward to encourage group discourse was that '*(BIM)modelling is only suitable for new builds and not relevant to older buildings*' Following a discussion around this topic, the IHM process was outlined with the various stages relating to data acquisition and model assembly explained, leading onto the possibilities of simulation and evaluation of the subject matter. A series of assumptions where again put forward and discussed with the group. On completion of this, the *Information* stage, participants where then asked to proceed to the *Interaction* demonstration.

To demonstrate *Interaction* with the subject matter, each participant was invited to take a place at a dedicated digital workstation where the IHM had been developed into an interactive virtual environment. As outlined in chapter four, it was processed through *Revit Live*, an additional cloud service offered by Autodesk, that allows BIM information to be retained within the virtual environment whilst allowing access to the data in a game-like fashion. The cathedral was positioned within a larger scale whiteboard model of the city with all adjoining building features removed, as it was meant as merely a massing model for context. The cathedral was developed to a higher level which illustrated the building detail and material however as for reasons previously discussed a non-photo real (NPR) graphic was utilised to ensure *Interaction* with the key components of relevance and to dissuade the user from being seduced by *'absolute realism'*. In order to increase understanding in the case of general audiences, previous studies (Pujol & Economou 2007, 157–76) suggest that VR-mediated experiences need to display dynamic human characters or, even better, aim at an *'enhanced virtuality'* (e.g., hotspots, metadata/paradata, storytelling, etc.) rather than at pure reconstruction.

To assist in this process, Blue Plaques, containing information relating to the historical narratives where located around the perimeter of the building and the user was asked to discover and explore the immediate environment with the task to locate the plaques. The intention was to for the user to self-direct their learning experience, whilst seeking out the blue plaques the users have also been exposed to the building itself and observing the architectural detail. The information delivered within the blue plaque was very straight forward and written in precise text relating to both *tangible and intangible* information associated with that feature. To aid the navigation each student was given a brief tutorial regarding the interface and subtle indicators were provided to encourage a pathway around the exterior of the building. In this case groups of people were located closely to the blue plaques acknowledging the plaques, similar to how a tourist might behave.

Fig 6.6.1.1 *-Workshop series two - Interaction*

It is noteworthy that the participants were restricted to the external perimeter of the building at this point for several reasons. Firstly, it allowed for a clear path to demonstrate *Interaction* as there was no internal obstacles to negotiate in the form of pews, columns and so on. It also provided context for the building by presenting an aerial perspective of the city, thus allowing the user to zoom in on the cathedral and journey through the immediate vicinity whilst all the time inadvertently focusing on the building. The participants were permitted considerable time to explore and *Interact* with the IHM, naturally this varied from student to student. Once completed they were then invited to be subjected to the *Immersive* experience.

This was provided by the user sitting at a Virtual Reality enabled workstation and utilising a head mounted display (HMD). Within the virtual environment the user was in a static position amongst fellow practitioners in a central location within the nave of the cathedral. The intention was for the user to listen and reflect upon the message being orated from the pulpit/altar area regarding amendments to the City Charter and how it affected the inhabitants of Waterford in c.1785. The speech was approximately forty-five seconds in length and played on a loop. The graphic chosen for the Cathedral interior was NPR with an emphasis on creating an atmosphere of a late 18th century church as opposed to accurately recreating the architectural detailing of the building. This decision was predicated on a similar rational previously discussed. As the participant was restricted from navigating the building's interior the only viable action was to engage with the content of the speech. To further promote engagement the user cannot distinguish any features of the orator or indeed the entire congregation. As argued previously it is not beneficial to recreate a supposedly accurate representation of the building as it would present a scenario that may never had existed and is subject to bias conjecture. What is not conjecture are the words from the Charter extract and the amendments being announced given insight into the social history of the both the building and lives of the city inhabitants at that time.

To conclude the workshop the participants were asked to complete a final questionnaire that was split into two sections *Interaction* and *Immersion* that contained questions which allowed for a commentary and opinions to be put forward by the students.

The first section of the questionnaire focused on *Interaction;*

1. When Interacting with the model how easy did you find it to navigate the environment?				
1 (difficult)	2	3	4	5 (straight forward)
0%	7%	12%	37%	44%

Question one focused on the participants experience of how easy the interface was to navigate whilst within the virtual environment. The intention was that the experience was designed to be as user friendly as possible as to not take away from the user experience. A streamlined interface was put in place with a minimum of controls including wayfinding and an information button.

93% indicated that it was relatively ***straight forward*** to operate whilst only 7% experienced a moderate level of difficulty. This would suggest that the interface was appropriately designed and allowed for the user to navigate and interact without too much onus on the technicalities of the platform. Given the high percentage of participants who engage with 3D models on a regular basis this was not a surprising result in that context.

2. Did you feel by interacting with the environment your experience was more beneficial to learning?	
Yes	No
95%	5%

Question two was somewhat binary in nature as a precise answer was sought from the participant regarding if they felt the experience, and by default, the process, was more beneficial to learning. ***95% answered in the affirmative*** with only 5 % answering no. This a strong result in terms of achieving a key aim and reinforced how the premise that the application of technology, in an appropriate manner, can have a positive outcome on the learning experience.

3. If Yes, briefly describe how.

Question three gave the opportunity for the participants to explain how they felt their learning experience was enhanced. There was, as expected a myriad of descriptions submitted. One student suggested *'the information in the model gives you a more understanding of the make-up of the building' (WS2_UU_101)*, whilst another alluded to the fact that *'it was made more interesting interface (with the information) than just reading'(WS2_GSA_159).* Some enjoyed the gamification aspect of the experience and suggested *'that instead of just aimlessly walking around, knowing there were waypoints of information to explore made it game-like and the information felt like a reward'(WS2_WIT_192).*

Of the 5% who answered 'No', although in a small minority, their comments were of value. One participant stated that the *'lack of a realistic graphic was too off-putting and as a consequence the experience was somewhat dull'(WS2_GSA_164),* whilst another noted that *'same as the other stuff I tried!'(WS2_CIT_129).*

Notwithstanding, the significant majority found they could meaningfully interact with building and alluded to the fact that it provided *'great integration into the built environment and can see great potential for advancements in future research and education' (WS2_WIT_172)* and the point *that 'interaction with the model made me want to explore and learn more within the virtual space' (WS2_UU_124)* or as one individual simply outlined *'it made it easier to understand'(WS2_WIT_182).*

As there were 100 participants in the workshop series it was not feasible to recount all commentary at this juncture. On this occasion, in order to evaluate the answers in a more scientific way all text was transcribed into *Voyant Tools (*https://voyant-tools.org) an open-source, web-based application for performing text analysis. This provided further insight into establishing patterns and the terminology employed regarding the participants input.

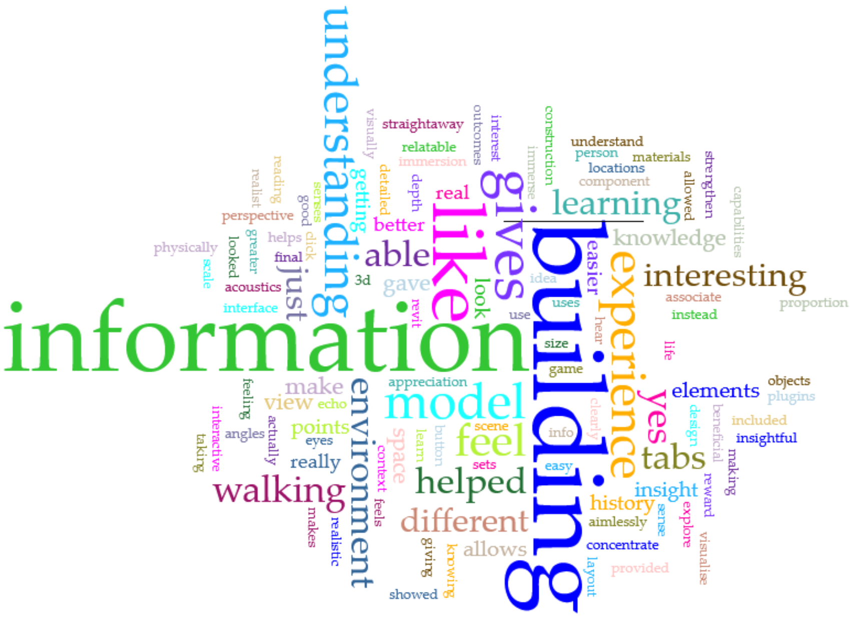


Fig 6.6.1.2 -Wordcloud compiled in Voyant tools (www.voyant-tools.org)

The word cloud above gives an indication that the words '*information'* and *'understanding'* featured prominently in the participants response which was encouraging. Not surprisingly perhaps the most common words were '*building'* and '*information'*, possible owing to the fact that a substantial amount of the cohort had a construction related background.

The second section of the questionnaire focused on *"Immersion";*

4. While in the Virtual world, how much did you feel you were engaging with the environment?				
1 (not at all)	2	3	4	5 (very much)
0%	1%	18%	37%	44%

Question four was intended to garner a greater depth of the opinion from the participant in how they felt engaged, not necessarily with the model, but with the available information that was contained within the virtual environment. 44% felt that yes, it was very much an engaging experience whilst a further 37% also rate the experience quite highly. In total ***99% felt it was of a beneficial*** nature whilst 1 % rated it on the lower end of the scale.

A positive result in terms of demonstrating a key objective of the IHM process and in terms of participant feedback the empirical data suggests that the desired level of enhanced engagement was being provided by the IHM approach.

5. How would describe the experience to a friend?

Question 5 was intended to obtain a greater depth of the opinion from the student in how they would describe the experience to a friend and further expand on their answer from question 4. By and large the response was positive with one participant describing it as *'how very cool. The sound and the ghostly figures inhabiting the cathedral worked well together in creating an immersive world'(WS2_CIT_150).*The audio and lighting aspects of the experience also featured heavily in the comments with one stating *'the lighting really struck me as visually compelling, liked having the sound as it added to the feeling of immersion' (WS2_GSA_162).*whilst others where more specific and commented that *'immersive mostly for the audio, sounded like being in a cathedral'(WS2_WIT_192).*

As can be expected not all participants shared the same viewpoint. One referred the experience to *'standing in a museum as opposed to standing in an actual* building' *(WS2_UU_115)* and there were several constructive comments regarding the *'characters as being too static'(WS2_CIT_152).*

As question 4 above highlighted the vast ***majority (81%)*** identified with the experience as being engaging. Research of this nature will always solicit subjective views which can be of much benefit going forward.

6. Please explain briefly what you now understand by the term "Integrated (Heritage) Modelling"?

Finally, the last question was to determine, having experienced the IHM process, had the participants gained an understanding of what it entailed and how they would see it applied. As with all open-ended questions the responses where varied but largely encouraging in the context of the research. One subject member described it *'as the ability to show both tangible and intangible information'(WS2_GSA_162).*whilst another referred to it as *'creating an artefact digitally that is multi-dimensional'(WS2_UU_110).*The comments continued along these themes with further descriptions such as *'interesting, not just with buildings that exist but also the memories that come with it, the history'(WS2_WIT_170).*

Tellingly, when compared to the answers to the same question from the workshop series one it is noteworthy that the added steps of *Interaction* and *Immersion* have had the desired effect. The commentary put forward recognises the ability of the IHM process to encapsulate the *intangible* and as one student described it *'it is giving the tangible and intangible elements of a building/site within a digital model'(WS2_UU_110)* or as another quite simply stated it is *'a model that contains all the knowledge we have of the building'(WS2_WIT_169).*

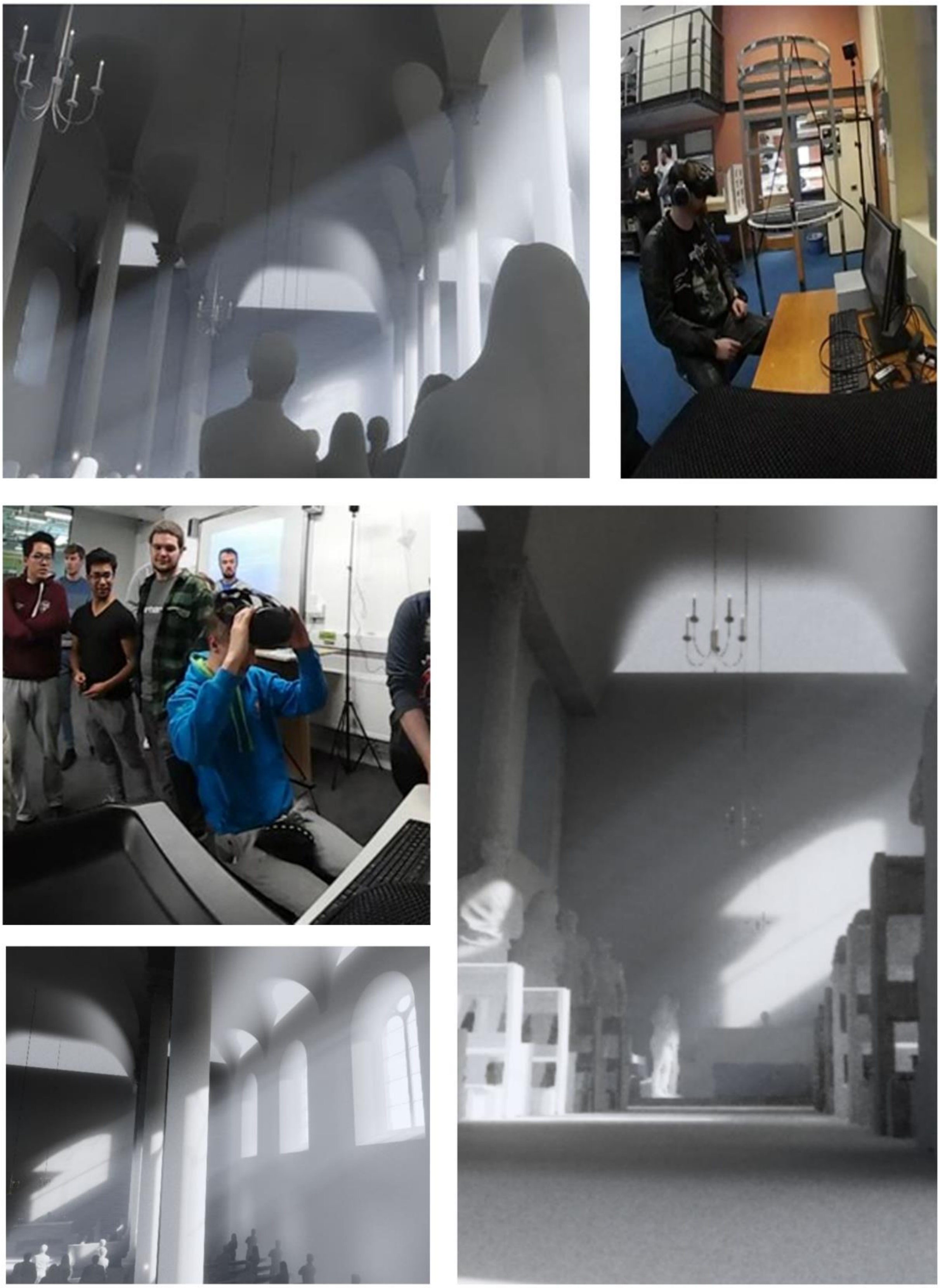


Fig 6.6.1.3 -Workshop series two - Immersion

6.7 Summary

The stated aim of this chapter was to demonstrate the capability of the IHM process to not only assemble rich datasets of information pertaining to an historic building but to also facilitate a greater level of interpretation to the end-user of the building's historic fabric through enhanced engagement within a virtual environment. The three-stage process of *Information, Interaction* and *Immersion* has revealed that the functionally of a digital model, once coupled with the appropriate workflow, is capable of acting as single repository for both *tangible* and *intangible* facets of the Built Heritage. Having conducted and appraised the IHM for Christ Church cathedral, allied to the feedback received from an extensive series of workshops, the conclusion reached was that this aspirational goal has been achieved.

In effect, the '*how'* has been answered, the discussion regarding *'why'* this workflow is relevant now moves forward to place the IHM process within the heritage sector and benchmark its usefulness when compared to similar workflows from cognate areas of study.

7.0 Evaluating the IHM approach

Virtual environments have the potential to serve as a platform that facilitates cultural learning (Ibrahim & Ali 2018, 1). Similarly, the importance of interaction methods for virtual environments to enable engagement and cultural learning has been emphasized on numerous occasions within the digital heritage community (Tost and Economou, 2009; Champion et al. 2012; Caputo et al. 2016). The purpose of the IHM approach was to channel that potential and address a gap that exists in the current body of knowledge of how to meaningfully apply BIM processes to heritage buildings in a robust way that integrates both *tangible* and *intangible* heritage and therefore enhance engagement and cultural learning.

The technical workflow outlined in chapter four, established in chapter five, and enhanced in chapter six is a framework for the creation of data rich digital repositories. To evaluate if the level of interpretation of the end-user had been enhanced, an approach was put forward, based largely on the work previously undertaken within the wider digital humanities community. Present day scholars of digital heritage have been adopting varying approaches ranging from; hermeneutic environments with game style interaction (Champion 2003; Champion & Dave 2002) to Embodied Interaction through semantic impulse (Flynn 2008) or haptic devices (Roussou 2008) to MUVEs (multiple user virtual environments) with dynamic content to greater immersion through augmented stereographic panoramas (Kenerdine 2008) or immersive displays (Tan 2007). This is not an exhaustive list, but it does highlight important and innovative approaches that are being developed on a continuous basis to develop engagement.

Engagement is related to the ability of the virtual environment to permit engrossing experiences as a result of the combination of immersivity and intuitive interaction with the historical element of significance. Several existing applications rely on interaction methods such as immersive headsets to engage with the relevant *tangible* aspect of cultural context but not necessarily the *intangible*. For instance, combining a *tangible* interaction method with highly immersive virtual environment and a relevant cultural context can be as engaging as a physical visit to museums and heritage sites (Katifori et al. 2019). Hence, approaches that balance cultural context, interaction, and immersivity can lead to enhanced cultural learning. The ethnographic techniques used by these researchers may be effective in recording activity, but they do not directly indicate the potential transformations of perspective that result from being subjectively immersed in a different type of cultural environment. How can users learn via interaction the meanings and values of others—do we need to interact as the original inhabitants did? How can we find out how they interacted and, through the limited and constraining nature of current technology, ensure interaction is meaningful, educational, and enjoyable? How do we know when meaningful learning is reached? (Grimshaw 2013, 278). This research, through the application of the IHM approach has endeavoured to contribute to answering some of these questions.

The aforementioned LEAP (Learning of Archaeology through Presence) project, spearheaded by Pujol-Tost (2014) was a European funded imitative with the stated aim; *'to research, implement and evaluate a new conceptual and technological framework, Cultural Presence, aimed at enhancing the understanding of past societies by experts and audiences through the experiencing of immersive, populated, interactive reconstruction of sites'* was developed in three phases that culminated in the development of a user experience based on the Neolithic settlement of Çatalhöyük (Turkey). With its closely-built mud-brick houses, the mother-goddess figurines, the in-house burials and the innovative archaeological approach adopted to uncover them, this impressive archaeological site, declared World Heritage by UNESCO in 2012, has become a reference both for the expert community as well as non-expert audiences within the digital humanities community (www.upf.edu/leap). The LEAP framework put in place for evaluation, which was informed by the earlier works of Economou & Tost (2009), a multi-nodal approach that was both quantitative and qualitative in that it addressed the common issue of asking users to express something that is visual and experiential with words, which is not an easy task. The approach developed within LEAP widened the scope of evaluation to include observational with *pre* and *post* testing in order to measure cognitive gain.

Similarly, research projects such as REVISIT, a collaboration between the GSoA and Hull University, looked at the teaching and learning potential of pre-existing immersive 3D models with reference to pre and post primary students. It reflected on moving away from recording *'how'* to understanding *'why'* users are interacting with digital resources (Gouseti et al. 2020). In evaluating this a similar approach to the works of Economou & Pujol was adopted to appraise the collected data that also incorporated observing the subject whilst interacting with the digital platform. It has been suggested that learning in virtual environments may not be achieved if the interaction method is not easy to operate or if the novelty of the interface overshadows the content (Economou & Pujol 2007).

For this research, the Test Studies and consequent evaluation tools were developed in clear stages. To begin with, each Test Study was designed and constructed to ensure three key components were present with the intention to provide a level of enhanced interpretation i.e., i) learning ii) provocation and iii) satisfaction (Rahaman & Tan 2010). A series of questionnaires were developed to appraise the user`s credentials and their pre and post workshop experience. The objective of the questionnaires was to ascertain information such as; what was their existing knowledge? A specific question about factual knowledge relating to IHM and a specific open question describing their experience. Certain questions were asked on both questionnaires to benchmark any alterations. The questionnaires were primarily based on the Likert-scale style grading to allow for quantitative processing; however, several questions were left open ended to allow for the users to share more freely their comments. In addition, the proceedings were recorded, and an observational sheet was compiled on each subject in order to gauge their interaction at various stages. This approach ensured that the end-user remained engaged in the subject matter in order to enhance the interpretative experience.

Evaluating interpretation in this sense requires a mixed method approach. Building upon the works alluded to above a hybrid approach was employed ranging from demonstration to observation from quantifying *tangible* metrics to semi-structured qualitative analysis in order to ascertain the integrity of the IHM approach. The merit of the three key stages of *Information*, *Interaction* and *Immersion* have been demonstrated via the Workshop series and proved successful based on the participant feedback but require further discussion.

Information. Appraising the success, or otherwise, of the initial stage of the IHM process was relatively straight forward given the binary nature of the task at hand. The supposition was that increased levels of Information can be contained within the 3D digital repository. In this instance the IHM approach demonstrated to the selected audience this objective via the study of no.1 & 2 Cathedral Square and the data related to building performance. The findings from the questionnaires established that the participants acknowledged the merits of the approach.

Interaction. Assessing the next stage was more complex as each subject reacted differently towards a virtual environment based on past experiences, level of IT competency, knowledge of the subject, and self-awareness. In this regard a mixed approached was deployed. The questionnaires were utilised to gain initial feedback, however, to further evaluate the proceedings were recorded in order to observe how the users interacted with the virtual environment. Informal observation notes, as discussed in chapter three and available for review on the supporting digital deposition associated with this research, recorded data relating to how long each participant engaged with the VE, what navigation pathway was chosen and how they interacted with the user- interface. These observations allied with the findings from the questionnaires proved most valuable.

Immersion. Providing an Immersive experience was intended to demonstrate how facets of *intangible* heritage can be contained within the digital model. Whilst each participant completed a series of questionnaires to establish if there had been cognitive gain, an emphasis was placed on observing the participants. The view was that until now asking users to express something visual and experiential with words was quite a challenging task. Therefore, it is possible that there was learning, but it is not measured in the correct way and by observing gestures, expressions, and comments it will provide greater insight. A similar approach adopted by the previous referenced LEAP project conducted by Pujol-Tost (2014).

The final part of the evaluation involved interviewing the lecturers/professors who are currently engaged in delivering the relevant heritage modules to gauge their opinions on, and insights into, such an approach. The participants input, which is student focused, reveals one perspective but for a more complete picture (of current academic approaches) the comments and opinions of the knowledge provider must also be appraised.

7.1 Workshop series – An effective platform for data collection?

The Workshop series proved very beneficial as a practice in testing the receptiveness of the IHM approach as it offered an opportunity for the theoretical knowledge to be examined and tested on a large and varied group. Reflecting on the results of questionnaires and the participant experience from the workshop series provided an insight as regards the efficacy of the approach. It also presented an opportunity to challenge the process in respect to the stated aims and objectives i.e. enhanced engagement with the historic built environment. Several aspects of this approach are noteworthy and warrant further discussion, such as;

Participant selection

The decision to select a statistically valid cohort from a variety of academic programs with differing interest levels in building conservation allowed for a myriad of responses from the participants. For instance, the students at GSoA approached the subject matter differently, partially due to the fact they were on a higher academic level (MSc) program in a dedicated heritage visualization course, but also as they were the only cohort who were not of an AECO persuasion. Their answers identified with the term *digital heritage* and were more aware of the concept of *intangible* heritage. The students of both WIT and CIT were studying Architecture and

Architectural & BIM Technology, whose primary focus is design, construction assembly and digital construction. Their building conservation/ heritage modules are in some cases electives, which would suggest that those participated where genuinely interested in the heritage aspect of their chosen career paths. In Ulster University the student's study Architectural Technology and Construction Management, again providing an alternative approach to building conservation that is more associated with adaptive re-use of historic buildings.

As highlighted in chapter three, this decision was intentional to ensure a representative cohort of participants given the large number. Interestingly, despite the diverse nature of the cohort, there are similarities across the group in certain areas such as familiarity with conservation guidelines, historic building details, building typology and so on. However, the most significant common trait was the digital literacy displayed by all groups. All participants where extremely comfortable with the process and displayed little or no difficulties in understanding the concept of a single digital repository or, when presented with the VE`s, had little issues with navigation or immersion. The concluding sentiment would be that the greater the assortment within the subject cohort allowed for more insight and provided greater scope in attempting to answer the research question.

Workshop Design

The evaluation was designed to allow for meaningful progression and in-depth understanding from workshop series one to workshop series two. Chapters five and six delved into greater detail on the specific responses to each question and discussed the relevance of the results. In this section a more theoretical overview is given regarding the workshop as a platform for conveying the IHM process and the associated outcomes.

On completion of the initial workshop series a full re-evaluation was conducted to establish what features were successful and what would require improving on as the second series was being developed. Positive learnings from the first tranche of workshops included the audience response to layout and format of the presentation, the decision to explain the IHM process through a hypothetical question engaged the audience as the process demonstrated how this position could be defended or challenged accordingly. Less successful feedback included elements of the subject matter. For instance, the decision to explore building performance was possibly too concise and scientific by ways of demonstrating a novel approach that not all the group had encountered previously. Similarly, the overuse of acronym`s was also highlighted e.g. BIM, AECO, HBIM and so on. Participants were unaware of certain terms that were assumed as *'known'* by the researcher and as a result caused them confusion on their behalf. Of the 47 participants who engaged with the original series there was substantial success in the workshops objectives as ultimately over 80% considered themselves more informed regarding the Built Heritage.

Workshop series two was more ambitious in its stated aims. In short, workshop series one aimed to investigate the utility of a digital heritage model that could contain diverse datasets of information regarding an historic building. Whereas workshop series two was aspiring to take this a step further and suggested the process would not only allow for interrogation of these diverse datasets but also increase engagement by the end-user. The learnings from the initial series were acted upon and put in place but did the workshop mechanism provide a platform to accurately demonstrate that there was enhanced engagement? I would suggest that yes this was the case. Participants responded positively to the various workstations and could relate to the three-stage process of IHM *Information*, *Interaction & Immersion*. *Information* in the form of a formal lecture with scientific results being presented, *interaction* via the gaming platform and finally *immersion* through virtual reality. The concept of the three stages was largely understood and acknowledged in the written responses to the questionnaires. Of the 100 participants who took part over 82% commented positively that IHM process increased their level of understanding and they felt more engaged with both the *tangible* and *intangible* heritage associated to the building in question.

These results, where only possible through the comparison of both *pre* and *post* questionnaires and proved most beneficial in obtaining statistical findings. Overall, the participants were positively receptive of the workshop design and the blended approach of questionnaires, lecture, demonstration, experimentation (by users) and further questionnaires. This has proven to be a successful and appropriate platform of evaluation for the IHM process

7.2 Evaluating the IHM Approach through observation

As stated in the methodology it was decided for evaluating the IHM process that the *'observer as participant'* technique was most suitable as the researcher was known and recognized by the participants and in the majority of cases, the participants were made aware of the research aims and objectives. Tabulating and recording the findings for this section of evaluation involved the compilation of an informal observational sheet on each participant which was broken into two sections of *Interaction* and *Immersion* (refer to appendix D). In total, 100 participants from the four participating HEI`s where individually reviewed and categorised in accordance with the criteria outlined in the observational analysis sheet (refer to ch.3.3.3) as they navigated the *Interaction* and *Immersion* phases of the second workshop series. The key findings were as follows;

Interaction

- The participants scored very high in terms of engagement with the interface as the majority (85%) scoring in between 4 & 5 on the Likert scale for engagement with UI. This score was consistently high throughout the four cohorts and was to be expected given the age profile of the sample set.
- Users predominantly selected the aerial view to commence their navigation, a birds-eye view of the scene. This was particularly relevant to the architectural based students who are predominantly trained about spatial awareness through the medium of 'plan' (an overview) to establish context and setting.
- The concept of the *'blue plaques'* and navigating towards clusters of spectators resonated with the users and following a short demonstration there were no observable issues in this regard.
- The majority of the students plotted their journey eastwards and navigated towards the larger clusters of peoples standing at the plaques and followed from group to group.
- Interestingly, as the students engaged with the '*blue plaque'*, their tolerance level varied in terms of persevering and reading the historic information. There appeared to be an eagerness to progress to the next plaque and further interact with the model. In certain cases, participants would visit a way finder than navigate around the building and return to a plaque of individual interest.
- The average time each participant interacted with the model 2:27 minutes. This figure is somewhat misleading given the time pressures associated with hosting the seminars and workshops and may be affected by an eagerness for the participants to complete the task given the classroom environment.
- The ability to self-navigate was apparent throughout as a major positive for the users. Most participants were enthralled about the prospect of exploring the surroundings and not the building itself and basically to test the assembly of the model.
- The design decision to deliberately underplay the contextual model, with an NPR render style, resulted in their '*off-piste'* voyages of exploration being cut short and they returned to the building in question.
- Important to note this urge to explore as it empowers the user with a sense of discovery that may be harnessed in future iterations of the IHM workflow.

The *immersion* aspect of the study proved more challenging to evaluate. By observing the participants in both VR mode and externally, as a passive observer trying to establish reactions was somewhat subjective. Utilizing the approaches developed in LEAP, and similar projects, it was possible to gauge certain commonality that was displayed by the participants. The key findings were as follows;

Immersion

- The figures state that over 90% of participants engaged with the VE with a score of 4 or better recorded on the observation notes.
- Participants where by and large quite happy to remain static for the duration and resisted the desire to explore by getting up walking around.
- On entering the VE each participant would immediately look around again to gain context of their surroundings, the first response is to look up at the ceiling to see the height of the Cathedral and then look around and behind to see if they are seated next to anyone of interest.
- Once the initial scanning has been completed, they then become aware of the audio and try to decipher what is being said. *Note: The audio was set at a level that necessitated the participant would have to concentrate and listen. It was relativity short at 40 seconds but played on a loop.*
- The timed average length of *immersion* for each participant was 75 seconds.
- This was accounted for by 15/20 seconds of familiarization within the VE, 35/40 seconds of listening to the information via the audio stream and then a further period awaiting further audio of which there was none.

To summarise, the subjective nature of informal observational analysis must be seen in context of the quantitative findings that were presented in greater depth in the previous chapters. The points highlighted above, when viewed with the statistical analysis obtained from the questionnaires and cross referenced with the open-ended commentary from the participants create a more complete picture of the success or otherwise of the workshop series. I contend that the observational approach proved extremely beneficial in its stated aims of providing greater insight into the IHM process and clearly illustrated the capacity of the workflow to enhance the level of engagement by the users.

7.3 The Knowledge Providers View

The workshop series were deemed successful in demonstrating the process to the selected audience, and the subsequent findings have been argued above to suggest that an increased level of engagement is attainable by adopting this approach.

However, this approach is predicated on the information been delivered to the end-user in the first instance by the knowledge provider in the form of module lecturer/professor. The issue is that there is not a generic approach to lecturing that all knowledge providers ascribe to as each individual has a unique approach that they feel best suits their topic and overall programme learning outcomes.

As described in chapter 3.3.4 a series of semi-structured interviews were conducted over a six-week period spanning May to June 2018 with several academics in this area of research from the contributing universities with additional input from further afield. The conversations where recorded and processed in order to benchmark the IHM process against existing approaches that are currently being employed across the courses. There was common ground amongst those interviewed on certain issues however, as expected, each individual provided further insight into their methods and processes. Refer to appendix E for a full transcript of all interviews.

In Ulster University, as outlined by Mr. David Comiskey, it was interesting insofar as that disruptive digital technologies where being fully integrated into their mainstream modules regarding construction and architectural technology where a *'collaborative approach to design and project management it to the core of what we teach'*, whilst when dealing with heritage module a *'more traditional approach is favoured for delivery due to the content and who is delivering the content'.* The *'applied approach'* to construction related modules had *'most definitely increased engagement'* of the students with the course materials and that students where *'adapting to the new technologies such as VR headsets and interactive cloud-based platforms'*.

In Cork IT, Dr Garrett O`Sullivan would have a more traditional background rooted in Building Conservation theory. His approach is to use *'the city of Cork as their classroom'* and although he is a faculty member of the Department of Architecture, his academic background would be more Humanities based with an expertise in building history. He contends that the *'traditional approach of formal lectures, building visits and an applied building survey'* still has merit in the digital age. However, *'he was not oblivious to the changing dynamic and profile of the contemporary third* *level student'* and that most advances in his view had been *'driven by the interested students who were very comfortable with the technologies'*.

Dr Stuart Jeffrey, from the School of Simulation and Visualisation at the GSoA , (who should be noted is also the primary supervisor for this PhD) identified that their programme was somewhat of an outlier and unique in that it *'challenged the underlying presumption that digital technologies enhances engagement'* and identified a clear distinction between *the 'traditional approach of the theoretical content'* and the innovative approach of how this is applied to fieldwork in that they *'are teaching technologies within the context of heritage'*.

In University of Wolverhampton, Dr David Heesom, whom is a reader in BIM and involved at both undergraduate and postgraduate levels has applied his approach at both levels with apparent success. The *'collaborative nature of BIM has allowed for several industry-academia collaborations on heritage-based projects'*. He points out that *'at postgraduate level the application of technologies is almost expected by the students'* given the nature and title of the programme (MSc BIM for Integrated Project Delivery) this is hardly surprising but as he further states *'the programme was designed with digital technologies in mind and as a direct result of industry needs'*. Within the context of the undergraduate programme a similar approach to the other Institutes is adopted in that the theoretical aspect is delivered through formal lectures whilst fieldwork has gradually begun to adopt the latest laser scanning technology and the *'bim-ification of the area'*

When specifically questioned regarding the relationship that exists between the traditional approach and the effects such disruptive digital technologies were having on their programs there was a common theme expressed that a sense of inevitability existed as such technologies are ever present but as Dr Jeffrey pointed out in GSoA there was a concern regarding the *'student collegiate experience'* in the broader context of virtual learning environments (VLE`s) he expressed concern *'that many institutions will gladly adapt digital technologies in the form of VLE`s or similar platforms whilst this may not be necessarily the most beneficial for the student'*. A balance between '*digital technologies and human contact, socialisation and learning communities'*, needs to be maintained.

Dr O`Sullivan in Cork IT had expressed similar concerns in that '*the traditional approaches had still a lot to offer in terms of student engagement and the practice of visiting, touching and experiencing a building should not be lost in a haze of hi-tech equipment'* whilst in Ulster University and looking to future course developments to their programme they were *'fully aware* *the positive impact this has had on the existing core modules and would look to integrate similar technologies into the conservation/heritage based and other subject modules'*.

In this context, Dr Heesom in Wolverhampton is currently experimenting with his postgraduate students in adopting the collaborative approach to a funded BIM project at the Springfield Brewery on a *'12-acre Springfield site is located towards the northeast of the city and originally built in 1873'.* As the buildings fall further into disrepair and in order to preserve the remainder of the heritage of the buildings due to impending redevelopment '*the creation of a heritage BIM (HBIM) of the site is being undertaken to preserve the history of the site. The site contains a range of individual buildings to be included as part of the overall BIM, and subsequently a team-based approach to developing the model was developed as some of the students were working remotely.*' The project is still not yet complete but as Dr Heesom commented *'after early teething problems regarding technical issues the project is progressing smoothly, and the model is coming together but still a lot of work to complete'.*

In summary, the interviews mostly centred around the theoretical ideology towards the subject area and how that informed their specific pedagogical approach but there was also reference to more practical concerns regarding such digital technologies, particularly in reference to resources. As Dr O`Sullivan alluded to as his core issue with the advancement of technology was *'the cost required to provide such resources was a constant frustration for both students and staff'* as the *'computers are never fast enough' and* the *'software always require updating'* Similarly in Ulster, Mr. Comiskey stressed the *'constant frustration of dealing with IT services and constant updates regarding software, equipment and indeed the computer labs'.* Whilst not such a concern in Wolverhampton as they are '*privileged that the research work undertaken at master's level has provided financial infrastructure to fund a bespoke BIM lab and ancillary equipment and software'*, however when pushed further Dr Heesom did identify that the teething problems associated with the on-going Springfield Brewery were *'IT related'.*

Although the interview sample was quite small, but diverse, they proved beneficial in terms of reinforcing opinions that were assumed regarding experiences in other Institutes and experienced by knowledge providers. Clearly, not one approach is commonplace, and opinions differ regarding the implantation of such technologies, but has it ever been any different in academia? There has always been a state of constant flux regarding dissemination of knowledge to students as society evolves and in certain cases the subject content. Is this not just another situation where we are at a watershed moment with heritage-based modules?

The predominant trend at present it appears is a hybrid approach of theoretical content being delivered in a lecture format and traditional fieldwork surveys adopting more innovative practices. Possible recommendations for educational providers, be it undergraduate or postgraduate, from this research could see the IHM process aligned to this approach by;

- addressing the gap of where this data is stored for the students, both the theoretical and the *tangible* fieldwork, i.e., a single digital model.
- provide an opportunity, and platform, to turn data into insight by making it readily accessible to the student in an engaging manner by the application of virtual environment platforms at all stages.
- widespread accessibility to all data as the project is being developed by the student cohort as they would all be contributing to not only a common (central) model but also a common data environment based on a digital cloud.

7.4 The IHM process, in comparison to other approaches

Where does the IHM process stand in relation to what is currently being deployed within the relevant subject areas? The supposition put forward throughout this work is that it addresses a gap in the research area of building conservation that has, as of yet to be tackled. Reference is constantly made to cognate areas of research such as Virtual Archaeology, (H)BIM, Cultural Heritage and so on, that have developed processes in order to address this question. In an attempt to position the IHM process a comparison was conducted with alternative approaches in two of the most relevant fields to this study, namely (H)BIM and Virtual Archaeology. The selected approaches reviewed proved very interesting with contrasting styles and underpinning theoretical frameworks ranging from digital humanities to a more orthodox mainstream AECO approach.

The HBIM approach was discussed earlier in chapter two but the current state of development generally in relation to heritage and computer modelling identified a divergence between a scripting computer science approach and the less developed adoption of mainstream BIM approach. The leading researchers in this area are considered to be Murphy & Dore (DIT) who devised a novel approach to conducting laser scanning on historic buildings was originally commenced by Murphy and McGovern (2011), further developed by Murphy and Dore (2017) in Dore's PhD and more recently refined by Dore, et al (2018) by applying their approach to refurbishment works at Dublin Forecourts.

The workflow that is based on a linear pipeline that commences with a laser scan that in turn proves the blueprint for creating the digital model by applying both procedural object creation techniques and the parametric library of architectural components. The completed model is then cross referenced with the original scan and a process of geometric digital validation ensues for the purpose of building pathology. The process proves extremely accurate and provides a detailed account of the physical condition of the existing historic building. Evaluating its effectiveness is relatively straight forward as the approach has been adopted by several scholars, most notably Fai et. al (2018) and their on-going projects recording the parliament buildings in Ottawa as part of the CIMS (Carleton Immersive Media Studio) at Carleton University Canada.

In contrast to the research and development relating to HBIM the approach adopted by archaeology, and in particular virtual archaeology, provides a different insight. The published 3D-CoD (Pujol-Tost 2017), a methodology for capturing and evaluating digital archaeologically, is an example of contemporary research with an alternative but complimentary view of the Built Heritage, more focused on the narrative and the human experience of place as opposed to focusing solely on the built fabric of the artefact. The origins of this methodology commenced with earlier collaborations with Economou (2011) and further developed in The LEAP (2014) project and is focused on the user experience of visiting virtually created historic environments.

The primary aim of the 3D-CoD methodology is establishing the effectiveness of such VR mediated experiences in engaging with the end-users. The studies underpinning theory is quite comprehensive. As the field work collected nine questionnaires and nearly five hundred observation entries, the data analysis was meticulous and followed different methods: qualitative for questionnaires and quantitative for observations. In the first case, for each question, the universe of possible answers was reduced to a set of categories. In the second case, the observations were transformed into a database. The experts' speeches were broken down into themes (topics), articulated through basic, subordinated units of meaning (subtopics), for which different characteristics were recorded (Pujol-Tost, 2017)

The qualitative findings from the research presented would suggest that this approach has borne results in terms recording metrics that display enhanced engagement with the artefact by the end-users and in turn is assisting in forming the basis to develop a new version of *'3D-CoD.'* The author states the possibilities, *'On the one hand, we could keep the basic methodology and include more user actions for designers to take into account and more corresponding "building" materials for the mock-up 3D model. However, it is possible that such strategy, based on a descriptive, reconstructive concept of 3D modelling, generates again the same kind of experiences found currently in Digital Archaeology'* (Pujol-Tost 2017, 14)

In positioning the IHM process relative to HBIM, as it is currently evolving and 3D-CoD, I put forward that it perches on a branch of research that relates directly to the subject area of building conservation or more pointily *'virtual building conservation'*, in that it adopts the best practices of BIM processes regarding structure and collaboration and is underpinned by theoretical framework that allows for the capture and engagement with multiple aspects of the Built Heritage, similar to a humanities based approach. The uniqueness of IHM is that it strives to reconcile these two, sometimes opposing, but generally complimentary approaches. This proposed synergy, that the IHM approach offers, is recognised within these communities. The concluding summary of the 3D-CoD highlights this as a possible avenue for further research and Pujol-Tost (2017) openly discusses that *'the alternative possibility (is)to change completely the approach and focus on intangible heritage, human experiences, and actions',* albeit in the context of VR mediated experiences for general public consumption. Similarly, with (H)BIM, scholars such as Heesom (2020) regarding the on-going Springfield Brewery site project and Fai (2018) with the further refinement of works relating to the Parliament Buildings in Ottawa.

This development of a blended approach that is multifaceted in nature as alluded to by previous scholars such as Stubbs (2015), Pujol-Tost (2017), Fai (2018) and Heesom (2020) is not only discussed within academic circles but is now being adopted by regulatory bodies. Agencies such as Historic Environmental Scotland (HES), with their work on translating BIM Levels to Heritage (refer to section 8.4), and English Heritage (EH) who have also begun publishing guidance documents relating to the application of BIM processes to heritage, the most recent being, *BIM for Heritage, Developing the Asset Information Model (2019).*

7.5 Summary

In summary, the three-stage process of IHM allows for multiple layers of the Built Heritage to be digitally accessible. The workshop series has demonstrated that by incorporating immersive reality technologies that can be accessed through virtual environments, it can enhance cultural learning and enable users to possess their own interpretative experience of an historic building. By employing observation as a key evaluation tool, it has revealed levels of insight that were not previously recorded and could possibly have been overlooked. As alluded to above in comparing the IHM approach to cognate areas of research there is a requirement for this multifaceted approach that can facilitate a collaborative approach if and when required. In appraising the IHM process I have argued that a robust novel approach has now been devised that achieves the stated aim (refer to 1.2.1) of providing an enhanced interpretative experience for the end-user.

Assessing the views of the knowledge providers highlighted factors relating to the current delivery of digital aspects in heritage-based modules and to this end recommendations were put forward as to how the IHM process could be applied in enriching content delivery. In addition, assessing the views of the knowledge providers highlighted factors that whilst outside the realm of the IHM process are within the wider heritage community such as, data security, resources and environmentally sustainable issues relating to data storage. These insights gained from the knowledge providers assisted in forming the basis of the discussion for the subsequent chapters and help guide the remainder of this research in determining future work and research goals.

8.0 Discussion

A cornerstone of this research has been to inform the debate of not only *how* computer modelling can assist in the digitisation of the Built Heritage but also the benefits and rationale for *why* it is advantageous to the end-user. A parallel exists within Building Conservation theory that focuses on *Conserve* or *Repair*, a debate which commenced in the mid-19th century and continues in various guises to this day and discussed at length in chapter two (refer 2.1.1). The similarities are that one group felt that they knew *how* to repair, therefore they '*should'* undertake the work, whilst the opposing viewpoint was to consider the position of *why* they should repair, where conserving or consolidating the artefact may prove to be more appropriate.

To recap this argument, central to the opposing views was how they perceived the artefact, in this scenario a building, should be treated. One group felt it should be honoured and left to decay, *'that restoration so-called is the worst manner of destruction…'* and *…'the spirit of the dead workman cannot be summed* (i.e. summoned*) up (Ruskin 1850)'* whilst the opposing standpoint called for measured interventions that facilitated the prolonging of the artefact, '*regarding ancient monuments, it is better to consolidate than to repair, better to repair than to restore, better to restore than rebuild, better to rebuild than to embellish; in no case must anything be added, and above all nothing should be removed'.* A.N. Didron (1839).

Anatole France (1880) who shared many of Ruskin's beliefs, compared old buildings to ancient manuscripts where each page is written in a different hand (palimpsest). This complimented Didron's view that nobody ever considers correcting or completing say, the *Aeneid*, or other famous masterpieces from the past, so *why* would this be appropriate in the context of buildings? Therefore, in contemporary research *why* is it commonplace to photo realistically re-create artefacts in a condition of completeness which might never have existed at any given time? Is the answer perhaps that because it can be technically achieved, therefore it should be done? This ignores the larger question in the first instance of *why* it should be done.

This research identifies that this gap exists in current discourse and attempts to enrich that argument. Firstly, there is an obligation to establish an underpinning explanation of *why* (or should) this research is relevant to the wider community of heritage professionals. To reiterate the point in relation to the Built Heritage it was during the Renaissance that the modern profession of architecture was developed largely through the musing of Leon Battista Alberti in his work *De Re Aedificatoria* (Scheer 2014, 2). It is centred on the premise that before *we* build, *we* must appreciate why *we* build. The point being that the *how* of construction was relatively straight forward, but the *why* was more reflective and required a greater level of meaning and interpretation of form and space. It is suggested that a comparable situation now exists relating to the digitisation of the built heritage, hence the justification of the IHM process to a wider heritage community.

I have demonstrated the *how* through utilising the IHM approach in the preceding case studies. Additionally, there are alternative hybrid approaches to the *how* that exist in terms of visualising historic buildings and artefacts by employing laser scanning and manipulation software that takes advantage of the cross over to the entertainment industry. Interactive virtual environments are becoming common place and readily available in various platforms from handheld apps to more bespoke visitor experiences. The *how* has been demonstrated quite satisfactorily within the community, this however, still leaves the question of *why*?

Here it is argued that the *why* question requires further debate. *Why* are artefacts being digitally reconstructed in the first place? What is the desired output for this digital reconstruction? Is it not to inform, or reflect, the fabric associated with the artefact? Would it not be more beneficial for the digital reconstruction to possess the ability to be cross interrogated by the end-user? Is there merit in trying to unpick or enhance levels of perceived authenticity relating to the artefact (Jeffrey 2018, 49)

As this discussion develops it contributes to this debate further and expands upon the theoretical framework that underpins and informs the future digitisation of the Built Heritage.

8.1 The *Why* answered.

The IHM workflow, as presented, is a significant development of the processes that are currently being deployed. It has identified a gap that currently exists in addressing, to a large degree, a workflow that will enable the capture of both *tangible* and *intangible* datasets within a single digital repository, but *why* is this of significance in the context of the Built Heritage and how can it be of further use?

Firstly, the requirement to record buildings digitally is many folds. To create an accurate 3D digital model has many benefits as alluded to previously. The issue is *why* a particular methodology was utilised in creating the digital model, what decision process was undertaken or was the model created based upon conjecture? For instance, is it satisfactory that models can be enhanced and replicated with artistic licence that may not be factually accurate? I would say Yes, in certain situations this is acceptable. For example, the movie/entertainment industry. Hollywood blockbusters are a subset of movie theatre that require the spectator to suspend belief and be entertained. People would not normally attend the movie theatre for accurate historical documentarian narratives, they attend to be entertained and indulge the director's interpretation of events. Similar to attendees of classical theatre and plays. When attending such events, you are asked to bear witness to a live performance and possess the ability to again, suspend belief, in order to have a story told to you. So yes, in certain scenarios the creation of artistically enhanced interpretations through CGI, may be plausible.

In scholarly research, I argue that this is not the case. The recreation of historic buildings in the form of digital models that have in some way being dictated by conjecture and bias is misleading as it presents an *'absolute realism'* of a period/state that may never have existed and is a flawed approach that is subject to the bias of the model author. Furthermore, these virtual recreations nearly always depict a completeness to a place and ignore the fact that a building, or place, is a living evolving environment and that there is never one static moment in time when all buildings are fully intact and perfectly completed. In real terms there is always a cycle of new-build, dereliction, and under-construction present.

The developments in data capture technology, which enables the process, has to be discussed further. Developments such as the creation of point clouds, via TLS or aerial photogrammetry. The fact that these approaches provide an excellent, robust, and verifiable data capture technique for obtaining accurate information is not being disputed. What is being argued is the usability of the raw data, in that a point cloud survey will produce a large dataset of what is, in an actual effect, a 3D representation in the form of *'digital dust'*. They (point clouds) can be cumbersome to manipulate and extremely time consuming. Given the large datasets only certain agencies/offices/ organisations have the capacity to manipulate into a form that can be workable going forward. In addition, given the advances in the technology many of the original file formats are quickly becoming obsolete which in turn has provided another repository to be curated.

Just as Pliny discussed the virtues of how and *why* in ancient Rome the dichotomy still exists today albeit in a different context. The question now is *why* is IHM important and unique, how does it answer the *why* question any more convincingly than existing approaches?

In an attempt to answer this more clearly, I propose to revisit the three stages of the IHM process to interrogate further and begin with *Information*. The *Information* section of the workflow focused on creating a data rich digital replication of an historic building. As the Test Study has demonstrated in chapter five, this involves coding and embedding multiple data sets relating to all aspects of the building from window construction to thermal performance of materials to construction assembly and so on. As the evaluating workshop series has highlighted by having a such a detailed digital repository of a building it allows for a deeper analysis of the building physics and in so doing enables us to challenge pre-conceived assumptions that have previously gone unchallenged, such as living conditions, building performance and by extension, user behaviour. Therefore, one reason for *why* the IHM process should be applied is to provide for more accurate and scientifically grounded interpretations.

Previous scholars have attempted, or discussed, a similar approach but not with a similar level of success or depth. Murphy et al. (2011, 311-327)) did propose that a 3D digital geometric model could contain historical information about the creation, origin, and chronology of heritage objects. This was further developed by Murphy & Dore (2019, 16) to a process that could be linked to historical documents in different formats i.e. manuscripts, 2D floor plans and sections, photos or voice recordings, however it did neglect the *intangible* and was only ever discussed and not implemented or evaluated. Chow et al. (2019, 425) did suggest that BIMs could contain non-graphical *intangible* data such as photographs and oral histories on their work relating to Canadas Parliament Hill project, however again this was not implemented into the project being discussed as the focus was establishing appropriated LOD`s and data management structures. It has also been noted that many HBIM models do not follow this approach and do not add information that is non-architectural (Saygi 2013). As Tobias (2016) noted, the potential reasons for this limited uptake is the lack of a comprehensive solution specifically designed to model and manage semantically enhanced 3D models of historic buildings. In this regard, The IHM process has greatly contributed to a viable solution.

Progressing onto the *Interaction* and *Immersion* stages of the workflow that focus on how the information is distributed to the end-user, the IHM is unique in this regard as it focuses on more *intangible* information. As highlighted throughout this work, the adoption of virtual environments, through its many platforms, is not necessarily unique but the inclusion of *intangible* information through these mediums that is related back to one single repository is novel. Chapter six highlighted such an approach and both the quantitative and qualitative findings from the workshop series support this. Participants testified to an enhanced level of engagement which improved their level and ability to interpret the building.

Looking forward and outlining one such reason *why* the IHM approach may be of significance to real-life scenarios in how it could be implemented. IHM is important and unique in that it presents an infrastructure for enhanced engagement with the historic building. A successful application of the IHM process could be utilised to enable practitioner's /scholars, in certain instances, implement more informed design and technical interventions when dealing with historic buildings given that more in-depth information would readily be to hand for such decisions to be made, e.g. architectural retrofits and refurbishments of historic structures. Current practice would involve a survey, historic appraisal and perhaps a detailed AHIA (Architectural Heritage Impact Assessment), as requested under government legislation such as the Planning Act 2000 in Ireland, with a statement of significance on conclusion. Applying the IHM process would not only enrich this workflow but enable the practitioner to engage with the model prior to deciding on any possible design interventions. The capacity to have all information located in the one instance would be of benefit and providing another scenario of *why* IHM is significant.

The above has outlined the contribution as to *why* IHM is important within research regarding the Built Heritage and how it possibly could be applied in real world situations. Needless to say, IHM is not a definitive solution but it has contributed to the wider heritage research area in question and produced evidence as to why it is of significance.

8.2 A single digital repository.

As Eastman et al., (2006) declared, BIM as a paradigm is focused on the philosophy of creating a database containing connected 3D geometric and informational data about the objects. The notion of a *'single source of truth'* as discussed throughout this work is an underpinning ethos of the BIM philosophy and has been explored in HBIM circles. Garagnani (2015) and Marzouk et al. (2016) both emphasise a requirement for a similar approach within the heritage sector that can capture history and culture in a single repository, where all model elements, data and entities are integrated. Previous to this, Pauwels et al. (2013) noted that in order to fully encapsulate a heritage asset, disparate information should be integrated with existing BIM tools that will document and combine all heritage information with accurate visualisations providing a holistic dataset that can be easily understood. Furthermore, Tommasi et al. (2016) concurs with this philosophy suggesting that an advantage of integrating a range of data sets enables the management and conservation of archaeological areas, monuments, and artefacts. These rich data sets provide the ability to undertake a more enhanced analysis of cultural heritage sites (Baik et al. 2015) and as such the 3D models created can be used for more than just visualization (Dore et al., 2015). The issue that the above referenced scholars have not discussed surrounds the robustness of such a repository. Borrowing from mainstream BIM processes the emphasises has evolved from *'cradle to grave'* approach towards '*cradle to cradle'*, i.e. full lifecycle and on-going management of the asset (building) right through to upcycling of data as necessary (Sachs 2011, 42). A similar approach within building heritage would go towards mitigating issues relating to data legacy problems as the information may be constantly reviewed and curated. This is not a new concept within heritage studies.

The Euorpeana Collection (www.europeana.eu/portal/en*)* is one such project that has attempted to maintain a non-static flow of information albeit in a more analogue fashion and the information is cumbersome to access. The alternative and quite common approach at present is a static repository where information is accurate on the day of posting but maintaining the information is not specifically managed and as a consequence the data contained within can become outdated within a given timeframe. The prevalence of *zombie websites* is commonplace throughout the web. The expected lifespan for research funded website relating to digital heritage is quite limited once institutes are void of funding to maintain and they simply occupy bandwidth to be possibly re-discovered at a later date (Jeffery 2012, 553-570)

There is an opportunity that IHM could enhance this approach even further through the ability it has already demonstrated to contain *intangible* information and thus garner greater stakeholder input from the wider community. UNESCO (2003) first highlighted the need to record *intangible* data and have this geo-referenced including Web 2.0 recordings. Counsell and Taylor (2017) have stated at the present time the inclusion of *intangible* data is based on a push of data from expert to participant and this can often require management to be maintained. However, with the emergence of social media applications and the now pervasive use of tagging by applying the *'hashtag'* and other approaches there exists a methodology to have more dynamic data aligned to the geometric objects within a HBIM. One issue surrounding the use of *'uncontrolled'* participatory input is the level of certainty of the information and the management of the quality of the data (Donatao et al. 2017). Furthermore, Counsell and Taylor (2017) proposed a novel framework for HBIM and cultural heritage, that was building upon the work of the EU funded Valhalla Project (cordis.europa.eu/project/id/IST-2000-28541) in 2003, that explored integrating additional *tangible* heritage data through the use of sensors and recording of materials. In this, they also advocate the development of *intangible* aspects through inclusion of location-specific *intangible* cultural heritage and using the HBIM for community engagement and community-based bottom-up readings, albeit more for its capacity to produce visualisation as opposed to a de-facto repository for information.

The IHM process is ideally positioned to greatly enhance this approach by taking advantage of the developments in disruptive technologies particularly in relation to the IoT (Internet of Things) and develop the IHM repository as a live source for not only housing information but also for gathering information. Issues relating to GDPR and security of data is something that must be considered but the opportunity to further develop the process is worth discussing.

8.3 Developing the workflow.

This research, through IHM has demonstrated an approach for capturing and implementing *intangible* heritage data through a bi-directional linear workflow. Key to this workflow has been the information that is uploaded and embedded within the IHM. In chapter two discussion took place regarding Level of Detail/ Level of Information (LOD/LOI) that helped classify the information that would be encoded within an IHM. This was further discussed in chapter three by means of a dedicated execution plan to establish the metrics of any such classification (IHMEP). Chapters five and six then went on to demonstrate this approach prior to evaluation in chapter seven. As this research has developed it has become apparent that the wider heritage community is acknowledging that *intangible* heritage is of equal importance in terms of developing digital repositories. This presents a further opportunity to re-imagine and develop the IHM workflow. At present IHM allows for information to flow through the three stages of *Information, Interaction* and *Immersion* efficiently. How can this be improved upon?

Consider this, at present there are prominent historical reconstructions of international significance currently underway, notably Notre Dame in Paris and the Elizabeth Tower (Big Ben) in London. Due to the prominence of these buildings, they have captured the imagination and engaged the general public insofar as developments are reported by mainstream media on a regular basis. Both projects have implemented bespoke approaches. In the case of Notre Dame an online community has been formed organically with the function of collaboratively modelling the Cathedral through a BIM authoring tool from previously published drawings and models and so on(gravity.blogspot.com). It has to date proven successful in terms of understanding the physical structure and assembly of the building whilst also proven a beneficial exercise in working collaboratively via a cloud platform. This work is followed by not only heritage academics and professionals but also the wider public. As regards Big Ben, the approach is more structured as it is a high-profile commercial project. In this instance they have applied a strict BIM data management system and have catalogued all components of the not only the build, but also the sub-contractors, workflows, costings, performance metrics and so on. This will, in time create a thorough repository of current works and will be invaluable going forward for any future works.

Whilst both approaches are novel and moving in the right direction, they are still focused on *'building better models'* as opposed to building *smarter* or more *intelligent* models as they have neglected to acknowledge the richness provided by capturing the *intangible*. As a result, the completed digital models may be relevant for a short period hosted on a web platform before descending into the abyss of a digital wasteland inhabited with similar zombie websites as alluded to throughout this work (refer to ch. 3.4 & 8.4).

Initiatives such as *VSim* facilitates the real-time exploration of highly detailed, three-dimensional computer models in both formal and informal educational settings. Funded by a Digital Humanities Implementation Grant from the National Endowment for the Humanities, this software addresses the greatest challenge for building knowledge through the use of three-dimensional computer models by providing scholars and educators the mechanism to explore, annotate, craft narratives, and build arguments within the 3D space – in essence, facilitating the creation of virtual learning environments that can be broadly disseminated to educators and learners across grade levels and humanities disciplines (www.vsim.library.ucla.edu). Beyond real-time interaction with three-dimensional content, the software offers two critical functions for academic use of interactive computer models: the narrative feature that allows users to create linear presentations within the virtual space (think PowerPoint or Prezi within a three-dimensional world), and the embedded resources feature that allows users to embed annotations and links to primary and secondary resources within the virtual environment (Snyder 2014)

There is an opportunity to adopt practices and process discussed above in terms of developing the IHM workflow from a linear into an iterative circular pipeline that has the capacity to utilise the disruptive technologies that now exist in order to gather the initial data from various communities. Additionally, the ability to review and evaluate new information as it is presented once a project becomes live, via an open source for observers' contributions.

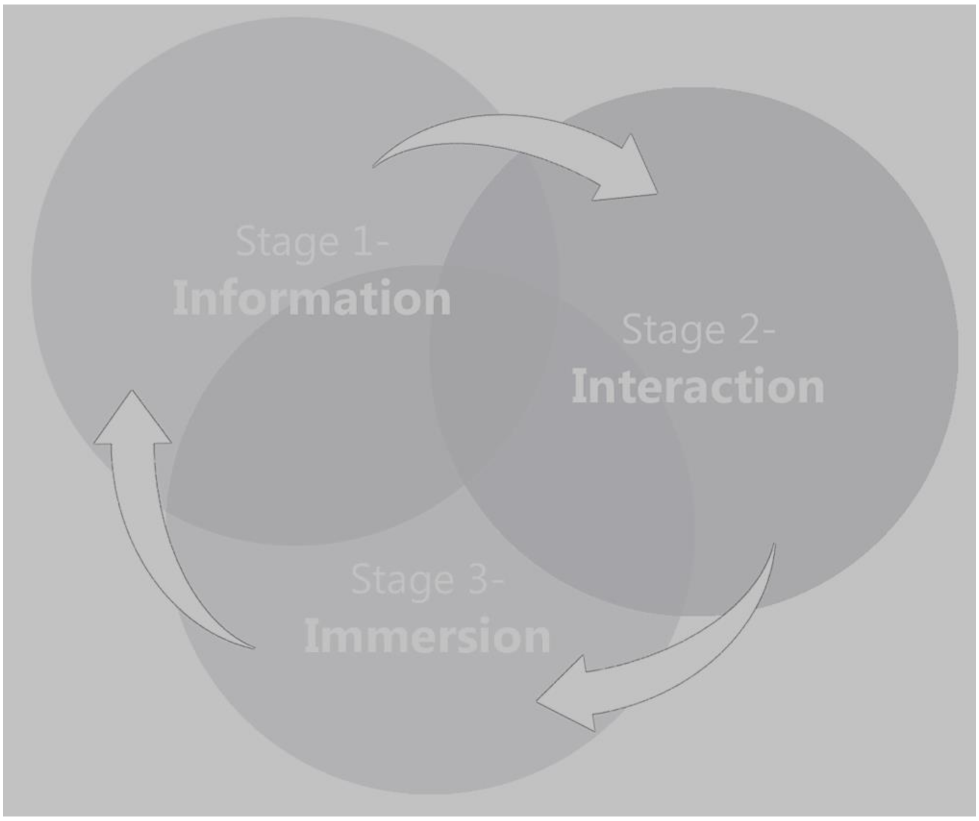


Fig 8.3.1 *-IHM Workflow, a circular pipeline*

This in reality is describing an *Open-Source* Digital model that has multiple access paths for importing and exporting data. The possibility for such an approach does not readily exist at present and it would be fraught with issues relating to data protection, accessing networks, file sharing formats and so on. There are multiple technical problems, as mentioned above, associated with providing Open-Source information, however is this the only issue?

As Huggett (2014) states *'Increasing access to open data raises challenges, amongst the most important of which is the need to understand the context of the data that are delivered to the screen'* and poses that the existence of *Provenance metadata* (Information concerning the creation, attribution, or version history of managed data) *can address the lack of contextual information associated with data.* Diara & Rinaudo (2018 ,303–309) have reignited this conversation and looked at providing an Open Source HBIM for Cultural Heritage in order to test *'flexibility and reliability and an open-source prototype'.* It was intended as a starting point for future researcher to develop however they outlined familiar problems associated with open-source information that are still as of yet unresolved however there is progress being made, particularly in the area of data classification which would enable an Open source approach. Heesom et al, (2020) have begun to explore categorising i*ntangible* heritage utilising a similar methodology to mainstream BIM processes and refers to it as Intangible Heritage Information

Requirements (IHIR). Within the mainstream BIM process developed for the UK (refer to 2.3.3), the Level of Information (LOI) refers to the amount of non-graphical (attribute) information attached to graphical objects within the model. Donato et al. (2017) discuss the issue of Level of Information with respect to HBIM and how this can be used to attach appropriate historical information to geometric objects in the model. Specifically, the initial prototype framework discussed develops the concept of categorising information according to; who, what, when, where and why. This approach serves to provide some discussion on how this data could be stored and in a database format, which could be searched using database query techniques to support the use of the BIM in reconstruction events. Fassi, et al. (2016) articulated that more interactive functions within 3D models would be required to enhance the uptake and thus could support the inclusion of *intangible* heritage data within the context of HBIM. The authors suggested a *'read and write'* mode where the model could be asked questions and VR could be used to compare present and past, and to assess and quantify the changes caused by time.

Categorising intangible heritage is a challenging task as it is fluid by its very nature and constantly evolving (Cang 2007). Using the definitions from UNESCO (2003), Heesom (2020) employs eight types of *intangible* heritage to develop a toolkit for specifying the Level of Intangible Cultural Heritage (LOICH) in a model. Furthermore, to rationalise this fluidity into a form, which could be defined and subsequently aligned with the LOICH, three potential sources of data were defined to provide data for objects in the model and categorised according to their source of origin. The overall approach to recording, and subsequently naming *intangible* heritage data, drew inspiration from the current processes identified in BS1192:2007+A15 (www.thenbs.com). By adopting a similar approach, a level of consistency can be maintained across both *tangible* and *intangible* aspects of the model and can also support a more standardised naming convention for all digital data stored in the Common Data Environment.

The requirements for guidelines are something that has not gone unnoticed by the regulatory bodies. For Instance, Historic Environment Scotland (HES) *'translates'* this definition into a heritage-specific language that relates back to the previously discussed Levels of BIM in that;

- Level 0: this could refer to a scenario where survey information is manually obtained on site using tapes and dumpy levels, drawn up using a CAD package in an unstructured format, and then communicated using paper plots.
- Level 1: this could be a scenario where the site data is obtained digitally with an EDM (electronic distance meter, commonly known as "Total Station") and then transferred to a 2D or 3D CAD environment that uses standardised data structures."

- Level 2: this could be a scenario where the site data is obtained digitally in an-inherently 3D format using a laser scanner, for instance, which is then transferred to a discipline-specific, standardised, parametric 3D modelling environment, but communicates and collaborates with other disciplines using industry-standard interface tools (e.g., IFCs).

Similar documents and guidelines have also been produced by English Heritage (refer to ch 2.3.3 & 3.4) that have begun to countenance the categorisation and application of BIM protocols to heritage projects. While the industry definitions of these levels include non-structural information such as cost, their heritage equivalents concentrate exclusively, at present, on the geometry of the building, the *tangible* and not necessarily the *intangible*. Tendencies in BIM for heritage are to create HBIM models that have a maturity level of 2, i.e. which geometrical data have been derived through automatic procedures—such as laser scanning sessions—and the BIM model is created through parametric objects.

This then raises the question of data compatibility and transfer. Currently the IFC format, as discussed in section 2.3.3 & 4.3.1, is considered the language of Opensource BIM. However, the IFC format would require an expansion to incorporate quantitative and qualitative assets and connecting *tangible* and *intangible* data (Pauwels et al. 2008; Arayici 2008). Counsell and Taylor (2017) discuss the potential for improving on this with a novel approach of BIM Collaboration Format (BCF) and how this could provide a platform for interactive participation in a HBIM to provide richer *intangible* content, however they concluded that an extension of the IFC Schema in this regard would provide a more robust and neutral approach that would be of greater benefit to the wider community rather than a bespoke solution.

I contend that the provision of open-source access to the digital model is the direction in which this type of community-based heritage research should develop. The overriding reason for this is to provide untethered access, to the information, for the consumer without unnecessary technical or commercial barriers. But how sustainable and secure is such an approach and is it achievable?

8.4 Sustainability and archiving the data

Despite recent European and North American moves to create archives and digital humanities infrastructures, 3D models have not yet been fully incorporated into these new infrastructures while allowing full public access (Huggett 2012, 538-552). Although there are interesting prototypes and selective web-based prototypes, such as 3DS Icons (www.3dicons.com) and online commercial suppliers of 3D models of varying quality and accuracy such as Sketchfab (www.sketchfab.com) which publishes a large range of 3D interactive models that can be viewed in different context. In many other regions there are very few accessible 3D models of heritage sites that use a common, stable format. Recent European trends are to create archives and digital humanities infrastructures, but 3D models have not kept up with the progress achieved for other formats of cultural heritage, they are still in silos.

Thwaites (2013, 327-348) summarized key critical issues for virtual heritage infrastructure, *'In the very near future some critical issues will need to be addressed; increased accessibility to (and sharing of) heritage data, consistent interface design for widespread public use and re-presentations of work, the formalization of a digital heritage database, establishment of a global infrastructure, institutionalized, archive a standards for digital heritage and most importantly the on-going curation, of work forward in time as the technology evolves so that our current digital, heritage projects will not be lost to future generations. '* He goes to further state that *'…we cannot afford to have our digital heritage disappearing faster than the real heritage or the sites It seeks to ›preserve‹ otherwise all of our technological advances, creative interpretations, visualizations and efforts will have been in vain..*.'

Key features of 3D models should be that they engage the audience, are formative (allowing the audience to create test and share hypotheses), can be recycled and reconfigured, and are amenable to preservation. However, researchers have cast doubt on the ongoing reliability of 3D data for long-term preservation and as Haveman (2012, 145-162) have warned: '*The possibility exists for precious and costly data sets to be lost on failed hard-drives, destroyed in floods or fires, or simply thrown out'.* It may appear that the overall number and difficulty of technical issues is the major problem to resolve, but if there is no public involvement, understanding and appreciation, the virtual heritage project has failed despite any technical brilliance or infrastructure support. Indeed, infrastructure that is not used is not really infrastructure; it is merely equipment. Previous scholars have written convincingly about the importance of archives but there is another important step, ensuring the archive is effectively used. As Garnett & Edmond (2014) state, there are many issues with APIs, but one critical issue is how to get enough people to use them. The success of virtual heritage projects as both a communication and preservation medium depend on community involvement, which includes scholars, students, the wider public, but also the original shareholders and owners of the cultural content simulated. Shared understanding requires clear aims, methods and terms, but above all, it requires a comprehensive methodology. Otherwise, the field will not scale, and it will not progress. Pujol (et al 2012, 77-90) had a similar viewpoint and stated back ;'*There are research groups now so concerned at the silo mentality of earlier virtual heritage projects that they are developing technology that either allows people to create their own content using free and open source technology such as the EU Chess project, or they are developing technical exemplars using free software that others can download and modify and thus learn from, for example, CINECAs APA reusable game assets-serious game project using the free Blender 3D software.*'

Indeed Pujol-Tost & Champion (2011, 83-102) argued that virtual heritage projects should demonstrate: care, accuracy, sensitivity, effective and inspirational pedagogical features, collaborative, and evaluation-orientated. Extrapolating from these aims, the following features are desirable for designing 3D virtual heritage models or developing an infrastructure that can support virtual heritage models for the purpose of classroom teaching and public dissemination. They went a step further and prescribed specific criteria for a model online;

- Data accuracy: the level of accuracy and type of data capture method should be associated with the model, as well as the geographical location.
- Format limitations: any known limitations or required conditions due to the digital format or way in which the data was created, should also be associated with the model.
- Provenance: the record of ownership and scholarship and community input should be recorded and accessible (the source and the ownership rights).
- Community protocols: social, cultural, and institutional protocols that guide who access the sourced cultural heritage and how that should affect the transmission, distribution, and dissemination of the digitally simulated model.
- Authenticity: the known, extrapolated, omitted, simplified, and imagined areas and components of the model should be identified in some form of thematic (and preferably standardized) schema.

The issue here however is that these guidelines and statements were published back in 2011. Given that there have been technical advances in this period, why is the sector not proliferated with Open Access models for the heritage community to consume? A fact reinforced by a recent survey paper undertaken by Champion & Rahaman (2019) where they surveyed 1483 digital heritage papers published in 14 recent proceedings. Only 264 explicitly mentioned 3D models and related assets; 19 contained links, but none of these links worked. This is clearly not sustainable, neither for scholarly activity nor as a way to engage the public in heritage preservation.

To countenance this, Historic England have been active in publishing guidelines in what is effectively data management for historic buildings. The most recent publication BIM for Heritage (in 2019) deals specifically with the developing of the Asset Information Model. The premises of which is to ensure that the information's is not lost but continues to be harvested after initial completion of the project. The cradle-to-cradle concept.

This concept of cradle-to-cradle approach highlights the issue of archiving the data and ensuring a sustainable framework for its use. Due consideration should also be given to the environmental cost of archiving large datasets. It is all very well to be espousing the virtues of cloud collaboration and open access of data, but it is worth noting that this comes at an environmental cost. Andrae & Edler (2015, 117-157) highlighted that in a worst-case scenario, communications technologies could account for up to 23% of greenhouse emissions by 2030 and a recent Irish Times (www.theirishtimes.com) article, titled *High-energy data centres not quite as clean and green as they seem'* by Bresihan and Brodie shone a light on the energy consumption of Data Centres. In layman's terms the Data Centres are the physical manifestation of this mysterious *'cloud'* we keep referring to as if some mythical platform floating in the ether. In the article they state that '*Eirgrid (national energy provider in Ireland) reports that by 2027, electricity demand from data centres will have risen to 31 per cent of total demand'.* These figures are attention grabbing and naturally not all of these emissions can be attributed to data storage within Digital Heritage, 33but the issue remains that the digitizing of the Built Heritage must be viewed in this context and the consequence such proposals have on society in a much broader context.

I propose that to ensure some level of data security and sustainability, guidelines must be devised that ensure a framework with the necessary safeguards in place from the outset of the project and be regulated by a national regulatory agency. The following recommendation are put forward for consideration to policy makers in this regard;

- Full life-cycle analysis relating to the establishment of any digital repository to include security, legacy, and data management structure.
- After an agreed period (statute of limitations) all digital repositories to be published on an open- source cloud platform.
- Prior to publication, a full audit of the data contained within the digital repository to be undertaken to ensure that all unnecessary data is removed from the database in order to mitigate against duplication and excessive storage requirements.

8.5 Summary

This chapter commenced with an attempt to answer the recurring theme of *why* the IHM process is relevant and what is the theoretical context in which it is set. Essentially, the *why* can be more specifically separated into two clear questions; why it is important to incorporate the built heritage to digitisation in the first instance? and *why* is *intangible* heritage deemed so noteworthy in a theoretical context. Both these questions have been considered with through a thorough discussion and given the ubiquitous use of digital technologies it is suggested that architectural conservation must reflect this through its various platforms of dissemination or possibly loose relevance.

Similarly, I have on numerous occasions alluded to the notion that *intangible* heritage is every bit as important as *tangible* heritage, but why is this? There is consensus regarding historic buildings as relics of our past and this is a concept that the general consumer of heritage, normally in the form of tourism, can identify with. Through exploring and discussing the notion of a revised single digital repository and attempting to further develop the IHM workflow, key issues regarding data security and sustainability have also been thoroughly discussed. It is not the intention of this chapter to offer definitive answers but to further the debate. In that regard I suggest this work has achieved that goal.

9.0 Conclusion

In the preamble of the Venice Charter (1964) it states '*Imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses of their age-old traditions'.* This thesis commenced with questioning how this *message* was being conveyed to an audience that is increasingly digitally literate but also increasingly digitally reliant. The existing practices of applying digital tools to the Built Heritage has focused on key areas of delivering the *tangible* aspect of that *message,* but what of the *intangible*, where the real depth of understanding and legacy associated with a historic building resides? I identified earlier in this work that the reliance on the written word and the risk of re-casting (refer to 2.1.1) of information was a concern within the Built Heritage community of scholars and that a novel digital approach was required as there was a gap present in how digital technologies and building conservation were aligned. I suggest that, through this body of research, there has been a substantial contribution in closing that gap.

Integrated Heritage Modelling (IHM), as both a concept and a process, has provided a platform for enhanced engagement with the Built Heritage by demonstrating the possibilities that technical digitisation can provide. This work has developed an approach that not only allows interrogation of data associated with an historic building but delivers this information to the consumer via a user-friendly platform. To demonstrate this approach two Test Studieswhere created that required digital modelling, data collection/collation and, the development of complex virtual environments in order to facilitate a series of interactive workshops to a selected group of 147 participants. This was preceded by a thorough evaluation process that included semi-structured interviews, observational analysis, and a comparative study. In completing these activities this work has identified a clear roadmap for future implementation in order to access, store, and engage with historic information that has not previously existed. Furthermore, this IHM approach now provides an opportunity to provide a more in-depth management framework to enable decision making based on scientifically grounded interpretations regarding the significance of historic buildings.

This body of research has achieved its initial aims but as with all things digitally related, I would argue that this is just another milestone reached on a journey as opposed to a final destination. Digital technologies continue to evolve and with it so should current practices. It is vital as a community of heritage professionals and academics that we continue to evolve simultaneously in order to retain relevance.

9.1 Future work, where to next?

Building upon the findings of this research and based on personal experience of implementing the IHM process through my own teaching practice and presenting at conferences/workshops over the past several years, I see a clear opportunity in developing the IHM process into an iterative circular workflow that has the capacity to utilise the various disruptive technologies that are readily accessible. If the primary aim of this work was to harness and promote the virtues of *intangible* heritage associated with a building or place than accessing the source of this *intangible* heritage is key. One potential source is to harness the ubiquitous use of social media as an opportunity to mine this information (as discussed in chapter eight) that has public engagement from the outset.

Envisage a scenario where there is a high-profile historic refurbishment. At the outset of the project the public are engaged in a structured format for the purpose of data collection regarding all aspects of the building via social media platforms. Information is sought from all individuals who have had an experience of the building (or place), be it history enthusiasts, practitioners, or former employees. The more diverse the cohort the wider the spectrum of data gathered. This information, with the capabilities of contemporary computing hardware could be coordinated within a cloud based CDE for evaluation and appraisal. As the digital modelling commences and this information is gradually encoded within the model, sporadic releases of the IHM are made available for review. This model is then published, via an open-source platform, and is viewed by a wider more diverse audience that could contribute user generated content, such as personal photographs of the buildings, verbal accounts of time spent working there by ex-employees and so on. This approach would not only validate information as it is presented but could safeguard against the legacy issue as the project is *returned* to the community. If such a complex and integrated repository was maintained as a live platform with constant input and outputs than it is constantly being updated and renewed as wave upon wave of users access the data and contribute, update, rectify, and validate. There are undoubtedly issues to be considered, from data ownership, GDPR and data security but nothing that is insurmountable.

This research has contributed to the process of creating a meaningful relationship between building conservation and digital technologies and, in response, we must continue to unearth various novel ways to engage a wider audience with the Built Heritage. If this relationship can be successfully managed it will continue to contribute to the protection and security of our shared heritage for future generations.

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https://www.buildingsofireland.ie/buildings-search/building/22504095/christ-church-cathedral-cathedral-square-waterford-city-waterford-county-waterford (last accessed on 12/05/2020)

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Appendices

Appendix A – Ethics Clearance

THE GLASGOW
SCHOOL OF ART

Visualising Heritage: Re Interpreting the Built Heritage: Ethical Approval Notification

21st March 2017

Dr Alison Hay,
Research Developer,
a.hay@gsa.ac.uk
0141 566 1408

To Whom It May Concern,

Robin Stubbs, is a postgraduate student registered for a doctoral degree with The Glasgow School of Art. His thesis title is given above and he is supervised by Dr Stuart Jeffrey of the School of Visualisation and Simulation.

All students registered for a doctoral degree must comply with the GSA Research Ethics Policy, a copy of which can be accessed online at:

http://www.gsa.ac.uk/media/861048/gsa-research-ke-ethics-policy-2016.pdf

Robin has complied with the GSA Research Ethics Policy and gained approval for this current phase of his doctoral research, approval was granted 20th March 2016 and is in place until the completion of his studies.

If you have any questions in respect of this or our procedures please do not hesitate to get in touch.

Yours sincerely,

Alison Hay 2017.03.2
1 11:24:46
Z

Dr Alison Hay
Research Developer

PROF. TOM INNS
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Director

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Waterford, Ireland.
T: +353-51-302000
www.wit.ie

REF: 17/ARCH/01

23rd October, 2017.

Mr. Robin Stubbs,
Department of Architecture,
School of Engineering,
WIT.

Dear Robin,

Thank you for bringing your project *'Virtual Environments – re-interpreting the Built Heritage'* to the attention of the WIT Research Ethics Committee.

Based on the revised WIT ethical approval application form and supporting documentation, I am pleased to inform you that we now fully approve the conduct of this project.

We will convey this decision to Academic Council.

We wish you well in the work ahead.

Yours sincerely,

[redacted]

Prof. John Wells,
Chairperson,
WIT Research Ethics Committee

cc: Dr. Stuart Jeffrey, University of Glasgow

Appendix B – Workshop Series One

Workshop – Stage One - Information

THE GLASGOW SCHOOL OF ART

Research Participants Information Sheet:

Study Title: Virtual Environments – Reinterpreting the Built Heritage

The purpose of this research is to identify a novel approach that utilises the advances in intelligent building modelling processes and their application to the built heritage. This research contests that by incorporating and engaging with virtual environments through intelligent modelling that the level of interpretation can, and will be, greatly enhanced for the end-user. In this workshop, I propose to undertake an evaluation regarding an element of this approach. I would like you to take a few minutes to read this information sheet before making up your mind about whether or not you would like to help with my research.

What is the purpose of the study? The aim of the workshop is to evaluate the level of interpretation of the subject matter by each participant and identify the overall strengths and weaknesses of the approach. To achieve maximum feedback from the workshop I will digitally record proceedings. The information garnered from this workshop will inform the future direction of the research.

Do I have to take part? Your participation is voluntary. I would like you to consent to participate in this study as I believe that you can make an important contribution to the research. If you do not wish to participate you do not have to do anything in response to this request. I am asking you to take part in the research because you are a stakeholder in the target audience for the implementation of this research and I believe you can provide important information to me that may be relevant to the evaluation that I am undertaking.

What will I do if I take part? If you are happy to participate in the research I will ask you to read this information sheet, sign the consent form and return it to me. At that point I can confirm your participation and begin to conduct the workshop.

What are the possible disadvantages and risk of taking part? Whilst you may be asked to answer questions regarding your personal opinion all information provided by you will be kept confidential at all times. All responses to my questions and information provided by you will be anonymised i.e. no personal details relating to you or where you work will be recorded anywhere.

What are the possible benefits of taking part? Whilst there may be no personal benefits to your participation in this study, the information you provide can contribute to the future development of enabling a better understanding of the built heritage.

Will my taking part in the study be kept confidential? All information you provide to me will be kept confidential. I will be the only person to have access to it. All data collection, storage and processing will comply with the principles of the Data Protection Act 1998 and the EU Directive 95/46 on Data Protection. Under no circumstances will identifiable responses be provided to any other third party. Information emanating from the evaluation will only be made public in a completely unattributable format or at the aggregate level in order to ensure that no participant will be identified.

What will happen to the results of the research study? All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by myself research based at Glasgow School of Art (GSA). The results from this analysis will be available in one or more of the following sources; PhD dissertation, scientific papers in peer reviewed academic journals; presentations at national/international conferences.

Who is organising the research? The evaluation is self-funded and is being undertaken as part fulfilment of PhD research at the School of Simulation and Visualisation, Glasgow School of Art, Glasgow, Scotland, UK.

PARTICIPANT CONSENT FORM

Reference Number:

Participant name:

Title of Project: **Virtual Environments – Reinterpreting the Built Heritage**

Name of Researcher: **Robin Stubbs**

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I agree to take part in the above study.

The following statements could also be included on the consent form if appropriate:

1. I agree to the workshop being audio recorded
2. I agree to the workshop being video recorded
3. I agree to the use of anonymised quotes in publications

____ ______________________

Signature of Participant

Date

_______________________________________ ___________________

Name of person taking consent

Date

____

Signature of person taking consent

**** When completed, 1 copy for participant & 1 copy for researcher site file***

THE GLASGOW SCHOOL OF ART

INFORMATION	INTERACTION	IMMERSSION

Workshop 1 – No. 1 & 2 Cathedral Square - INFORMATION

Pre- Workshop Questionnaire

Questionnaire Number

1. What age bracket do you belong to?

17-19	20-29	30-39	40-49	50+

2. You are?

Man	Woman	Other (please specify?)

3. What term best describes your area of study?

Architecture	Engineering	Construction	Heritage	Digital Humanities

4. How often do you engage with 3D computer modelling?

Daily	2-3 times a week	Once a week	2-3 times a month	Once a month or less

5. How "informed" would you consider yourself to be regarding the Built Heritage?

1 (not at all)	2	3	4	5 (very much)

6. Have you experience in 3D modelling of Historic Buildings?

Yes	No

7. Please explain briefly, as best you can, what you understand by the term "Intelligent Modelling"?

THE GLASGOW SCHOOL OF ART

INFORMATION	INTERACTION	IMMERSSION

Workshop 1 – No. 1 & 2 Cathedral Square - INFORMATION

Post- Workshop Questionnaire

1. Please explain briefly; what you now understand by the term "Intelligent Modelling"?

2. Have you experience of utilising a similar approach in 3D modelling of Historic Buildings?

Yes No

3. If Yes, briefly describe the project.

4. If No, could you see a benefit in applying such an approach? Please elaborate.

5. Do you now consider yourself more "informed" regarding the Built Heritage?

1 (not at all)	2	3	4	5 (very much)

Appendix C – Workshop Series Two

Workshop – Stage two - Interaction to Immersion

Research Participants Information Sheet:

Study Title: Virtual Environments – Reinterpreting the Built Heritage

The purpose of this research is to identify a novel approach that utilises the advances in intelligent building modelling processes and their application to the built heritage. This research contests that by incorporating and engaging with virtual environments through intelligent modelling that the level of interpretation can, and will be, greatly enhanced for the end-user. In this workshop, I propose to undertake an evaluation regarding an element of this approach. I would like you to take a few minutes to read this information sheet before making up your mind about whether or not you would like to help with my research.

What is the purpose of the study? The aim of the workshop is to evaluate the level of interpretation of the subject matter by each participant and identify the overall strengths and weaknesses of the approach. To achieve maximum feedback from the workshop I will digitally record proceedings. The information garnered from this workshop will inform the future direction of the research.

Do I have to take part? Your participation is voluntary. I would like you to consent to participate in this study as I believe that you can make an important contribution to the research. If you do not wish to participate you do not have to do anything in response to this request. I am asking you to take part in the research because you are a stakeholder in the target audience for the implementation of this research and I believe you can provide important information to me that may be relevant to the evaluation that I am undertaking.

What will I do if I take part? If you are happy to participate in the research I will ask you to read this information sheet, sign the consent form and return it to me. At that point I can confirm your participation and begin to conduct the workshop.

What are the possible disadvantages and risk of taking part? Whilst you may be asked to answer questions regarding your personal opinion all information provided by you will be kept confidential at all times. All responses to my questions and information provided by you will be anonymised i.e. no personal details relating to you or where you work will be recorded anywhere.

What are the possible benefits of taking part? Whilst there may be no personal benefits to your participation in this study, the information you provide can contribute to the future development of enabling a better understanding of the built heritage.

Will my taking part in the study be kept confidential? All information you provide to me will be kept confidential. I will be the only person to have access to it. All data collection, storage and processing will comply with the principles of the Data Protection Act 1998 and the EU Directive 95/46 on Data Protection. Under no circumstances will identifiable responses be provided to any other third party. Information emanating from the evaluation will only be made public in a completely unattributable format or at the aggregate level in order to ensure that no participant will be identified.

What will happen to the results of the research study? All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by myself research based at Glasgow School of Art (GSA). The results from this analysis will be available in one or more of the following sources; PhD dissertation, scientific papers in peer reviewed academic journals; presentations at national/international conferences.

Who is organising the research? The evaluation is self-funded and is being undertaken as part fulfilment of PhD research at the School of Simulation and Visualisation, Glasgow School of Art, Glasgow, Scotland, UK.

PARTICIPANT CONSENT FORM

THE GLASGOW SCHOOL OF ART

Reference Number:

Participant name:

Title of Project: **Virtual Environments – Reinterpreting the Built Heritage**

Name of Researcher: **Robin Stubbs**

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

4. I agree to take part in the above study. ☐

The following statements could also be included on the consent form if appropriate:

4. I agree to the workshop being audio recorded ☐

5. I agree to the workshop being video recorded ☐

6. I agree to the use of anonymised quotes in publications ☐

____ ______________________

Signature of Participant

Date

____ ______________________

Name of person taking consent

Date

____

Signature of person taking consent

**** When completed, 1 copy for participant & 1 copy for researcher site fil***

THE GLASGOW SCHOOL OF ART

INFORMATION	INTERACTION	IMMERSSION

Workshop 2 – Christchurch Cathedral

Pre- Workshop Questionnaire

Questionnaire Number	

1. What age bracket do you belong to?				
17-19	20-29	30-39	40-49	50+

2. You are?		
Man	Woman	Other (please specify?)

3. What term best describes your area of study?				
Architecture	Engineering	Construction	Heritage	Digital Humanities

4. How often do you engage/interact with 3D computer modelling?				
Daily	2-3 times a week	Once a week	2-3 times a month	Once a month or less

5. How "informed" would you consider yourself to be regarding the Built Heritage?				
1 (not at all)	2	3	4	5 (very much)

6. Have you experience in 3D modelling of Historic Buildings?	
Yes	No

7. Please explain briefly, as best you can, what you understand by the term "Intelligent (Heritage) Modelling"?

THE GLASGOW SCHOOL OF ART

INFORMATION	INTERACTION	IMMERSSION

Workshop 2 – Christchurch Cathedral

Post- Workshop Questionnaire

"Interaction"

1. When Interacting with the model how easy did you find it to navigate the environment?				
1 (difficult)	2	3	4	5(straight forward)

2. Did you feel by interacting with the environment your experience was more beneficial to learning?	
Yes	No

3. If Yes, briefly describe how.

"Immersion"

4. While in the Virtual world, how much did you feel you were engaging with the environment?				
1 (not at all)	2	3	4	5 (very much)

5. How would describe the experience to a friend?

6. Please explain briefly what you now understand by the term "Intelligent (Heritage) Modelling"?

INFORMATION	INTERACTION	IMMERSSION
Workshop 2 – Christchurch Cathedral		

Observation Notes - Interaction

8. Level of engagement with user interface – Laptop/Tablet				
1 (not at all)	2	3	4	5 (very much)

9. Comments from observing subject relating to reaction, navigations difficulties, visual evidence of understanding, etc, etc

Observation Notes - Immersion

1. Level of engagement with the Virtual Environment				
1 (not at all)	2	3	4	5 (very much)

2. Comments from observing subject relating to initial reaction, receptiveness, exploration of space, etc

Appendix D – Workshop Series Evaluation

Workshop – Evaluation Results

Evaluation of Quantative Data

Workshop 1 - Pre Q	Par	Q1					Q2			Q3					Q4					Q5					Q6	
		a	b	c	d	e	a	b	c	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e	a	b
GSoA - 20/04/2017	13	0	9	2	2	0	6	7	0	0	0	0	11	2	7	5	1	0	0	1	4	4	4	0	11	2
WIT - 24/04/2017	7	0	6	1	0	0	6	1	0	5	0	2	0	0	5	2	0	0	0	3	3	1	0	0	1	6
WIT - 26/4/16	5	4	1	0	0	0	3	2	0	5	0	0	0	0	5	0	0	0	0	1	4	0	0	0	2	3
WIT -21/11/17	11	9	1	1	0	0	10	1	0	11	0	0	0	0	3	5	1	1	1	1	5	5	0	0	1	10
WIT - 21/11/17	11	1	10	0	0	0	5	6	0	11	0	0	0	0	2	3	0	0	6	3	7	1	0	0	2	9
Total	47	14	27	4	2	0	30	17	0	32	0	2	11	2	22	15	2	1	7	9	23	11	4	0	17	30
Percentage		30	57	8.5	4.3	0	64	36	0	68	0	4	23	4.3	47	32	4	2	15	19	49	23	8.5	0	36	64

Workshop 1 - Post Q		Q2		Q5				
		a	b	a	b	c	d	e
GSoA - 20/04/2017	13	1	12	0	1	4	5	3
WIT - 24/04/2017	7	2	5	0	0	2	4	1
WIT - 26/4/16	5	0	5	0	0	0	5	0
WIT - 21/11/17	11	0	11	0	0	6	4	1
				0	0	6	4	1
WIT - 21/11/17	11	0	11	0	0	6	4	1
				0	0	6	4	1
Total	47	3	44	0	0	6	4	1
				0	0	6	4	1
Percentage		6.4	94	0	0	6	4	1
				0	0	6	4	1

Evaluation of Quantative Data

Workshop 2 - Pre Q

	Par	Q1 a	Q1 b	Q1 c	Q1 d	Q1 e	Q2 a	Q2 b	Q2 c	Q3 a	Q3 b	Q3 c	Q3 d	Q3 e	Q4 a	Q4 b	Q4 c	Q4 d	Q4 e	Q5 a	Q5 b	Q5 c	Q5 d	Q5 e	Q6 a	Q6 b
Uni Uls - 7/12/2017	27	0	25	2	0	0	25	2	0	24	0	3	0	0	17	8	2	0	0	4	17	7	0	0	4	23
CIT - 6/03/2018	31	0	27	4	0	0	21	10	0	29	0	2	0	0	25	4	2	0	0	9	16	6	0	0	5	26
GSoA - 15/03/2018	9	0	6	3	0	0	1	8	0	1	0	0	7	1	3	6	0	0	0	3	2	3	1	0	9	0
WIT - 25/04/2018	33	21	10	2	0	0	24	9	0	25	0	8	0	0	23	8	0	0	2	6	16	8	3	0	5	28
Total	100	21	68	11	0	0	71	29	0	79	0	13	7	1	68	26	4	0	2	22	51	24	4	0	23	77
Percentage		21	68	11	0	0	71	29	0	79	0	13	7	1	68	26	4	0	2	22	51	24	4	0	23	77

Workshop 2 - Post Q

	Par	Q1 a	Q1 b	Q1 c	Q1 d	Q1 e	Q2 a	Q2 b	Q4 a	Q4 b	Q4 c	Q4 d	Q4 e
Uni UIs - 7/12/2017	27	0	0	1	12	14	27	0	0	0	1	14	12
CIT - 6/03/2018	31	0	0	3	14	14	31	0	0	0	2	15	14
GSoA - 15/03/2018	9	0	5	3	1	0	6	3	0	1	6	2	0
WIT - 25/04/2018	33	0	2	5	10	16	31	2	0	0	9	6	18
Total	100	0	7	12	37	44	95	5	0	1	18	37	44
Percentage		0	7	12	37	44	95	5	0	1	18	37	44

Appendix E – Semi-Structured Interviews

Semi-Structured Interviews

PARTICIPANT CONSENT FORM

THE GLASGOW SCHOOL OF ART

Reference Number:

Participant name:

Title of Project: **Virtual Environments – Reinterpreting the Built Heritage**

Name of Researcher: **Robin Stubbs**

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

5. I agree to take part in the above study. ☐

The following statements could also be included on the consent form if appropriate: ☐

7. I agree to the workshop being audio recorded ☐

8. I agree to the workshop being video recorded ☐

9. I agree to the use of anonymised quotes in publications ☐

_______________________________________ ______________________

Signature of Participant

Date

_______________________________________ ______________________

Name of person taking consent

Date

____

Signature of person taking consent

**** When completed, 1 copy for participant & 1 copy for researcher site file***

THE GLASGOW SCHOOL OF ART

Research Overview:

Study Title: Virtual Environments – Reinterpreting the Built Heritage

The purpose of this research is to identify a novel approach that utilises the advances in intelligent building modelling processes and their application to the built heritage. This research contests that by incorporating and engaging with virtual environments through intelligent modelling that the level of interpretation can, and will be, greatly enhanced for the end-user.

Semi Structured Interview Questions:

Q1 - Can you state your name, academic post, academic institute, and experience to date of teaching/lecturing in the area of BIM/Heritage based modules.

Q2 – How would you describe your approach to lecturing this topic?

Q3 – In your opinion, has the development of digital technology assisted your teaching in anyway.

Q4 – In your opinion, has the introduction of digital technologies enhanced, or hindered, the level of engagement of the end-user, i.e. the student.

Q5 – In your opinion, how do you see the future of heritage studies and digital technologies evolving.

Transcript of Interview – Dr Gareth O`Sullivan – CIT – 18/05/2018

Robin Stubbs **(RS)** - Many thanks for taking part in this semi structured interview as part of my PhD. I'd like to inform you from the outset that the conversation is being recorded. Hope you have no problems or issues with this and if you would require a copy of the transcript, feel free to contact me at the email address stipulated on the information sheet I sent you or my primary supervisor is Stuart Jeffery at the Glasgow School of Art. So are you happy to proceed on the basis that this is being recorded Gareth?

*Gareth O`Sullivan **(GO`S)** - Yeah most definitely.*

(RS) OK, we'll jump straight into it. So just to get things rolling. Can you state your name, academic post, and experience to date as a lecturer on heritage-based modules?

Yes my name is Gareth O`Sullivan and I am lecturer here at the Cork Institute of Technology y and in terms of my experience in the field I have been teaching here in the Department for the past 19 years. My teacher concentration in front with the architecture technology program, and on the program I teach from first to current year essentially in the area of functional architecture representation and context. Basically, you have to take into account the historic dimension and themes. The themes are quite varied, everything like structural systems to infinity to culture and technology. I would say that in terms of the actual research concentration in my work in the field here is very much with the fourth years on the architecture technology. Program very much in the area of a conservation module. Do I look at the theory again of technology that can be applied again to conservation work. And then in a second project that we have the applied building survey that would give them an opportunity to apply both of the benefits and some of the upcoming technologies and it's very much applied again to the fourth year research dissertation. As we develop on the interview, I will certainly develop on the attributes that could especially concentrating at on heritage in the Department

(RS) Brilliant Gareth, thanks for that. So how would you describe your approach to lecturing to date?

(GO`S) *Most definitely. I would say basically because we have a very rich heritage here in the city more often than not what we actually do it just as a commencement point within the various modules that we have a very informed walk about around the city here. So what I do is actually prepare a very defined tour with a booklet resource and something traditional for me to adopt and generally what we do is we walk through the various configuration and design traditions throughout the City and everything against the things that the very order traditional classical references to the more complex Romanesque references to modern or post-modern.*

We do go out again and depending on the module concentration we impress an idea of good adaptation and retrofitting. And then when we actually go back into class we are working to our lecture materials. We have a lot of activity to YouTube illustrations again I'd go back to the obligations in this class as well. We also to try and build in an element actually into the assessment because basically we are continuous assessment here we try to give the brief out around week six or seven of the Semester an we're introducing applied elements so the students aren't necessarily commenting essentially on the historic nature of the building or the theme application. We also *suggest again that there are some elements of the design development in the eventual production as such and critiquing what's being done in the context of buildings and making suggestions of how their design can go forward to begin work with any upcoming technologies.*

(RS) In your opinion as the developments of these digital technologies assisted your teacher in any way. Almost definitely. I would say it does. Very much in the fourth year particularly.

(GO`S) *Most definitely and I would say very much in the fourth year, particularly in the area of conservation under the themes of re-adaption and re-use. Two elements in that there is two modules, firstly the theoretical where new technologies are coming on stream and again being introduced the idea for heat mapping and eye tracking etc.. And then the second module where they're focus is on adaptation that needs to be view within the applied survey. I did say earlier in the interview that resources are quite limited but we do have things like thermal cameras, we do have things like the Oculus Rift and we farm them out to students and get them involved and we give them an opportunity basically to come up with some form of it. Primary apparently investigation and how it might inform again a concentration of design development as such. The other area certainly in the 4th years was very much in the recent project where the students that they're very tech savvy who are encouraged to incorporate the technology and modern technologies into kind of historic references. We've had Michael Flitting last year but I have to say this year I think you're actually, possibly spoke to Cian Daly. Yes. He was looking at in site VR analytics in reference to St. Mary's Cathedral Church in Youghal so effectively what he was doing was basing it on a studio simulation and then using technology such as things like eye tracking, heat mapping to inform, again the design going forward. So there is a lot there and I would say to compliment him as well. What he actually did is he tested this simulation with a cohort of students from the third year. So, the benefit of that is that ii to bring about building awareness certainly in the earlier years*

(RS) About what was the purpose of eye tracking. You are talking.

(GO`S) *Basically. What he actually did in his fourth-year Interior studio was develop an assimilation model by superimposing his design model on the church. What he is doing essentially with the eye tracking is actually enabling you to track people's attention has been drawn. Therefore, for example if we have a higher elevation that gets people attention as they enter the church to upwards for example because of the truss roofing at higher altitude. What he's doing then is actually positioning some of the key elements of its development because at slightly higher levels v Also that for example, some of the historic detail because they are of historic note and again get people's attention to be drawn to those so they're more likely to engage in this design activity in those particular locations.*

(RS) So that is very interesting. It kind of ties in a lot but I'm kind of looking at his and this leads me to the next section I suppose and you know we're always having this discussion at the moment about digital natives and digital immigrants and it's been largely debunked in terms of no one generation is more evolved than the next but, in your experience would you have found that support was there widespread now application really of digital technologies has it enhanced or hindered the level of engagement of the students.

(GO`S) *Oh most definitely in a positive sense. But I would say we are all the time looking for cutting edge technologies and different to inform essentially in a more defined sense going forward and yeah I have to say as a staff member I am very much on a learning curve and it's the students who are very much the drivers of this year. Particularly I wouldn't think so much for the architecture technology more the interior people. Yes, because they are dealing with existing buildings, they have the studio content buildings selected from the beginning and again because I noticed that they're looking for very sensitive and not invasive methods to try and investigate them but to inform the design development, as such, and technology of that nature, like thermographic cameras, like eye tracking… It's being driven pretty much by the student base and we are learning from them just as much.*

(RS) Oh absolutely, it is a two-way street. is this something that you see into the future, how both, I suppose heritage studies and the Landscape of digital technology, how they actually merge together? Do you think it is something that will continue to a large degree to stay as separate streams?

(GO`S) *No, this is looking at again in the context of the fourth year and part of the conclusions and recommendations to the research project. One of the things that you actually find in Cian Dalys in particular is. That there is not an inevitable awareness out there, that should b, particularity of an industry in the context of the potential of actually using conservation with the area of technology and such. So he is arguing at the the educational institutional level that there's more of a need again for this to be in terms of the design either specific and specialist modules and to be fused to the four year degree course. In terms of actually industry again is calling for this epertise For. design practitioners out there again to be more aware and produce essentially of the potential for the technology. So if anything I would say that it's some kind of cusp and going to increase into the future and very much so I would say as well from the point of view of the increasing point of view of multi culture reference . In a sense that what we have among student population here is very much of an increasing population and very much drawn back into their own culture reference points, and, they are very protective of the buildings and they're very much to protect them in the sense that they want as much technological base as possible that would be non-invasive and can actually inform developments going forward.*

(RS) Very interesting and can you see any negatives in terms of this going forward how one could overpower the other I suppose in the decision-making process.

(GO`S) *I would obviously and a key negative at the minute we are confronting in terms of accessing software, but we do have kind of limited access to them within the department. But obviously funding is something which is the key to unleashing the potential. The other barrier than that I suppose, and this came across in the fourth year recommendations that there tends to be an awareness, let's say, that is not referred out there in industry and today there is some understanding thast conservation practices are tried and tested and quiet historic. I think by their very nature that there doesn't appear to be as much of an openness or a willingness just to embrace the potentials as they are. So it certainly needs to be marketed more* regarding what it *can actually offer.*

(RS) Thanks a million for that a very insightful. Some great information there and I am not going to stop recording

Transcript of Interview – Mr. David Comiskey – UU – 16/05/2018

Robin Stubbs **(RS)** Hey Dave can you state your name, academic post academic institute and experience to date in teaching in the area of heritage-based modules please?

*David Comiskey **(DC) –** My names is David Comiskey I`m a senior lecturer in architectural technology at Ulster University. In terms of experience to teaching, first of all I teach year one level four of Architectural Technology and Management program really just looking at BIM fundamentals of basic Modeling as well as collaborative working. Similar in year two levels five of the program. I teach both the theory of the actual Modeling the final year of work an advanced BIM module which looks at collaborative work with a range of other programs. In addition to that we have a conversion or heritage type module in the final year for program also.*

Robin Stubbs **(RS)** Very good. How would you describe the approach to lecture and on the topic to date within Ulster University particular the architecture of technology program?

*David Comiskey **(DC) –** I suppose looking at the BIM based modules. First of all it's very much an applied approach to learning and the teaching and so it would be, certainly in year one, there would be a couple of large group sessions or a lot of architectural technology, construction management, quantity surveying students or a range of different disciplines would be working collaboratively. One of them would be our project of deliverables so they would start off each other in a large group to get them all together. The other would have broken down the principle of specific classes with the students they are expected to communicate with each other via a simulated common data environment like blackboard which is hosted in-house so they are expected to share their models communicate with each other and minutes of meetings etc. That's all very much cloud based in that scenario.*

Robin Stubbs **(RS)** Yes, that sort of pre-empts my next question I suppose in terms of how the development of digital technology has assisted your teaching but just in regards to your studio projects that involve retro-fit or maybe even historic buildings. Do you still apply the same BIM processes to these projects, or do you put them in a different capacity?

*David Comiskey **(DC) -** No. It's very much a different approach at this stage as I outlined that a lot of the BIM modules very much technology driven. The students will develop their BIM models and develop VR and even aspects of Mixed Reality in those modules. As outlined, we have a conversion ,maintenance type or heritage service module of delivery and that's I suppose quite different but more traditional at the minute where traditional Test Studieswill be looked at different styles, different types or different methods of conserving or adopting buildings but there's no real overlap ,certainly in Ulster at the moment, between the technology used and the other modules. The BIM based approach and the heritage approach, it's very much traditional, traditional teaching approaches I suppose at present.*

Robin Stubbs **(RS)** So what would you say then that and in your mainstream studio modules for architecture technology where you have adopted these digital technologies that the level of engagement of the students has either increased or decreased. Given the fact that you're using these I suppose very contemporary digital technologies in the BIM process?

David Comiskey ***(DC) –*** *Yes, its most definitely increased right through your first year to final year, certainly for the first year the BIM based approach using virtual reality gives up more of the virtual experience and really about early in the year helps them to engage a lot more and understand what it is they're actually modelling on things like basic construction principles. Right the way through to the final year group where some of them want to develop their skills in that area and have looked at Dissertations and research projects relating to BIM?VR/AR and that technological approach so its most definitely compliments the teaching and engagement overall.*

Robin Stubbs **(RS)** Cheers yes. I just will ask well that David in your opinion and how do you see the future for your heritage studies module, do you think that there is an overlap there or possibility that the skills you're acquiring in the mainstream BIM modules could be applied to the heritage based modules?

David Comiskey ***(DC) -*** *Absolutely , I think that has to be the next step or the next stage really, certainly in our own module we see a huge benefit for that digital technology even from a Test Study approach where you can't really understand or capture a building…you could use it for analysis purposes really looked at structures like I did with VR for the general population just to get that immersive experience. On a wider basis I suppose looking at the historic modules I see huge potential there and that's probably the next step on for a variety of legitimate universities probably the next logical step to merge those two, the technological approach with the Conversion Heritage aspect for deliver.*

Robin Stubbs **(RS)** Brilliant Dave thanks a million. I just have to formally let you know that I was recording this interview that it is going to be used as part of us as part of research for an ongoing PHC at Glasgow School of Art. And if you've any queries relating to the data protection of this interview and so on please feel free to contact me directly on the email address that I sent you or indeed my primary supervisor Stuart Jeffrey at the GSA we. Very much thanks for your time David. We talk to you soon.

Transcript of Interview – Dr Stuart Jeffrey – GSoA – 22/05/2018

Robin Stubbs **(RS)** I just want to make you formally aware that I'm recording these proceedings and hopefully some of the opinions that you express will be used as part of my qualitative analysis is part of the core element on my p HD in evaluating a new approach that I'm putting forward. So realistically what I would like to get is your opinion as a knowledge provider over the past few years…So for the record if you could start by just stating your name academic post Institute and so on?

Stuart Jeffrey ***(SJ) -*** *My name is Dr Stuart Jeffrey and I teach in the School of Simulation and Visualization at the Glasgow School of Art.*

Robin Stubbs **(RS)** Excellent Stuart. What I am particularly interested in is your expertise in teaching Heritage visualization that you've been lecturing on heading up there for quite some time. So first off could you describe your approach to lecturing this topic up to this point?

Stuart Jeffrey ***(SJ) -*** *On heritage BIM specifically?*

Robin Stubbs **(RS)** No on heritage more so, don't necessarily worry about BIM or anything like that it's, just on the heritage-based modules.

Stuart Jeffrey ***(SJ) -*** *OK well my approach is….well, essentially we get Masters students our master's degree which is really the only students I teach apart from the PhD students We only do graduate masters level get cohorts or somewhere in the region of the 9-15 per year from a mixed cultural heritage background which means that. I've got to meet challenges at the start of the course, one of which is making sure people understand what heritage is. The political and theoretical aspects of heritage so the underpinnings of heritage.*

So nobody's coming into the idea that heritage is a kind of neutral technical activity they understand that how it is build up in people's identity formation and speaking politics and so forth. And that's really important for students who come in. So, for example we get students who 3D model at undergraduate degrees but really haven't been exposed to heritage or other topical history or some of these theoretical heritage programs at undergraduate level.

Robin Stubbs **(RS)** OK. Would you describe your approach to teaching as more traditional or is more innovative?

Stuart Jeffrey ***(SJ) -*** *Well I think it's quite traditional. Yeah OK. So that is essentially lectures followed by discussion seminars.*

Robin Stubbs **(RS)** OK so you're talking about the theory of let's say heritage-based modules in that it's more lecture based and then obviously there is assessment and follow on and so on. How, in your opinion, has the development of digital technology assisted your teaching in any way. (Repeat)….Sure yet how has the development of digital technologies assisted your teaching in any way.

Stuart Jeffrey ***(SJ) -*** *In essence what we are teaching is digital technologies. So for the other side of the coin this one's be more of an underpinning or an understanding of their heritage context landscape and we talk about deploying digital technologies in that landscapes.*

So we almost, you know, necessarily that these technologies are teaching practice. So on one end its creating VLE`s, virtual reality learning environments. On the other hand it's being out in the field practically deploying data acquisitions. So there's a whole range there, and also as new technologies come through for example the recent changes in 360 Capture you know we have to stay current. So basically we have to stay on top of all this technology as it changes and comes through so we can deliver for the students by the end. A lot of the underlying questions don't change however, regardless of the technology

Robin Stubbs **(RS)** OK. I'd just say obviously you've been doing this for a period of time so as well. So has the deployment of these digital technologies enhanced or hindered the level of engagement to the student in your opinion?

*Stuart Jeffrey **(SJ) -** Well again this course of a kind of special case because, If the question you just outlined there, is one of the key questions basically the master's program try's to answer.*

There's a kind of underlying assumption that yes there is better engagement and it is better for dissemination and solving the underlying assumption very often but basically it gets expanded into a short discussion as I just did, I think control technologies will do that. Well. I think they dobut I think the circumstances and consequences as well as the oneself investigating this is really what we're about. So not just saying. Oh yeah sure the technologies are great, it's a great for engagement with the community, it is great, for, you know, the students. Students are great at engaging academics because it's not the technology. It's how that technology's is implemented. How the content is introduced and worked up.

Robin Stubbs **(RS)** Very good, and what we do you see this evolving going forward you know the merging the constant battle of the conflict in some ways because you started talking there about your traditional approach to teaching ,say conservation and heritage theory, yet then we're talking about deploying a kind of cutting edge digital technologies and so on. Are they happy bedfellows or are they something that there's a constant, if you like, conflict as a as we evolve in the teaching of that subject ?

*Stuart Jeffrey **(SJ) -** OK, the massive underpinning….ok, the elephant in the room is that changes in technology teaching environment aren't necessarily driven by what's best for the student….they are more often driven by the model of higher education institutions as profit making organizations or maybe not profit making in a corporate sense, but as financial institutions they have to generate income, they have to generate funds. So quite often people turn to digital technologies in delivering courses or, you know, increasing use of VLE`s or an immersive learning environment subject that people turn to these not because they're proven to work but are currently better or they answer some specific problems….they'll turn to these because they think that there may be an opportunity to do that or teaching more efficiently to a bigger audience and we reep the financial awards of that.*

Robin Stubbs **(RS)** But is that not very cynical now?

*Stuart Jeffrey **(SJ) -** Yes….laughs*

Robin Stubbs **(RS)** Put the cynicism to one side and I do understand your point, and obviously it's a very …I won't say cynical act. It's actually it's…. it's a truism really isn't it! What I suppose the point I'm trying to get at is that….. at the moment we nearly have two distinct areas, okay, and I accept that your experience with in Glasgow is different to most other programs and so on, but from speaking to other practitioners in the area we really do seem to have the traditional approach to kind of heritage conservation studies and then we have the more enlightened, shall we say, approach by the likes of the SSV and Glasgow and so on.

What I`m asking is, as this evolves and as the two spheres hopefully come together, is there some ….utopian solution…. that we get the best of both worlds. Do you have an opinion on that?

*Stuart Jeffrey **(SJ)** **-** I have to say that's exactly right this is what you would aim for is a balance between the two. See if you dispensed with traditional methods altogether…what you dispense with is something that is actually quiet important for the student…in terms of human contact, socialisation a feeling of being part of a learning community because one of the potential downsides of a lot of digital technologies is that information is consumed alone, it Is essentially an isolating technology.*

That doesn't mean it's a bad thing in its own right but what it does mean is that we must be very clear that we don't throw the baby out with the bathwater…,… people come to higher education institutions and end up going away dissatisfied with their experience.I suspect the reason they're going with such a dissatisfied experience is that they expected to be trained and it is challenging and collegiate and working together where you can speak to your lecturers in intellectually stimulating conversations. I'm not being cynical here.

Robin Stubbs **(RS)** No, no, no,…..You have been very accurate.

*Stuart Jeffrey **(SJ) -** So saying that for most people, not everybody, but that's what most people enjoy are… social animals.*

So drifting to far towards a kind of highly technologically developed kind of open university position where everyone is working away on their with this business of having not much contact with research academics then I think you may gain something but also lose something by not connecting with expert knowledge. The Utopian position is actually is ….balance.

Robin Stubbs **(RS)** Excellent. OK Stuart thank you very much for your time.

I have to formally inform you that if you have any issues or if you wish to receive a copy of this recording please feel free to contact me directly or if you wish to complain or…. if you wish to complain… you can contact my primary supervisor.

Transcript of Interview – Dr David Heesom – Uni Wolverhampton – 21/06/2018

Robin Stubbs **(RS)** Hi Dave. Thanks for agreeing to this interview. Before we start, a bit of housekeeping to let you know that this interview is being recorded. It's going to be used as part of my PhD at Glasgow School of Art. All the information will remain anonymous. However, if you wish to receive a transcript at any point in time, feel free to contact myself or Stuart Jeffrey my supervisor in the Glasgow School of Art. Are you happy to proceed on that basis?

*David Heesom **(DH) -** Yes. Great.*

Robin Stubbs **(RS)** - So if you could start by stating your name, qualifications, and experience to date in teaching heritage-based modules.

*David Heesom **(DH) -** So I'm a Reader in building information model at the University of Wolverhampton based in the school of architecture & built environment which is in the Faculty of Science and Engineering. I have been an academic at the university for just over 18 years...researcher in the field of BIM for around 18 years as well…. PhD was in the field of BIM, before it was BIM… which developed from 4D model and took me back to 2004…..Interest in terms of the Heritage side interest in the heritage side...Let's go back probably around three to four years from a university. Prior to that we've been engaged in lasers scanning projects through KTP`s But we started to get involved and look at the potential heritage BIM around 4 to 5 years ago.*

Robin Stubbs **(RS)** OK, so how would you describe your approach in those three to four or five years and how you're actually teaching at postgraduate level.

*David Heesom **(DH) -** Mostly it's predominately a postgraduate level, however we have also done some work at undergraduate level with the architectural technology students and probably one of the first times that we took it into the classroom. My approach is somewhat blended. I firmly believe that the traditional techniques still have great merit in that the students needs to visit and experience the building or site…..in saying that…you cant ignore the role digital technologies now play. Our approach, as a course board is that we involve the community…eh, and industry as much as possible and base all our projects within that context. The heritage modules are no different.*

For instance, we have had the opportunity to get the students involved on the Springfield project…its basically a retrofit of an old building here in town that we are converting into the new school of Architecture. It has given a great vehicle to demonstrate all out technologies in terms of data capture utilising laser scanners, drones and the like….we do a comparative study with the earlier years we ask them to look it traditionally, then the following semester we will use the technology.

Robin Stubbs **(RS)** So would it be accurate to say that you guys at Wolverhampton are fully implemented the latest technology, if so how has it assisted your teaching?

Is that accurate…eh, I would say yes to a large degree …We have been fortunate, through research funding to have state of the art computer lab and hubs where the students can avail of extremely sophisticated hardware and software… but the underpinning theory is still there...if you know what I mean. In terms of teaching, I would say yes, it really helps to get the students engaged. Take for example the Springfield project…..not only can the students go and physically visit the site *but they are effectively design new studios that they may end day use….therefore they cant wait to model it in Revit, using their laser scan as a base, bring it into VR and walk around it….they are excited about the project because it has a direct effect on them.*

On a more broader level the use of VLE`s…is that your angling at?...well, they have proved great with overseas students and part-time students. We use Canvas and I find it very user friendly…we conduct online classes, use it as a common data environment…use if for forums and so n….its basically the future…not necessarily Canvas but the idea of co-existing in a cloud with easy access to information.

Robin Stubbs **(RS)** So, and given your last answer this is probably a bit obvious, but can ou elaborate how such technologies has increased your students level of engagement with the content of the course…particularly in relation to heritage based modules?

*David Heesom **(DH) –** An yes, I would say without doubt…maybe e have been fortunate with the Springfield project it being so accessible and relevant and when the time comes and that is complete maybe we will see the enthusiasm subside a small bit but till then…as for heritage modules…that is something I am very much interested in. My specialist area of research is HBIM and I have been looking at intangible heritage as well…don't worry, i`m not trampling on your toes…(laughs) but it is something we have begun to develop…I am more interest in classification of intangible heritage and how to embed that with a BIM…..therefore, back to your question (laugh's) yes we have trialled aspects of this with the masters students and I have to admit it has varied in success. I find with heritage that unless the programme is a heritage programme than the students tend to be interest…or not…its that binary sometimes. So, the on that like older buildings grasp it and love the idea of VR and old churches whilst the guys interested in modern architecture normally just fulfil the module requirements and move…*

Robin Stubbs **(RS)** Thanks Dave, great answer and very insightful…something o have noticed myself in WIT re interest levels….that said, how do you see the future of heritage studies and digital technologies evolving?

*David Heesom **(DH) –** definitely going the route of digitisation…in the context of capturing, authoring and dissemination…it just has to given the resources and opportunities that are now available….don't get me wrong, the theory is still the theory and that will say but how we deliver the programmes will definitely need to keep pace with mainstream architecture/construction programmes*

Robin Stubbs **(RS)** Thank you Dave, that was great. If you wish to receive a copy of this recording or a transcript please feel to contact me and I can arrange that. Thanks again and take care.