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Architectural History and Sustainable Architectural Heritage Education: Digitalisation of Heritage in New Zealand

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Abstract: Over the last few decades, a significant amount of literature on the preservation and adaptive reuse of historical buildings has been published. More recently, the use of digital technologies in heritage projects and academic research has become increasingly topical worldwide. However, the topic of architectural education and the teaching of architectural history in relation to heritage is less discussed. This paper contributes to this relevant and necessary topic that has not received much attention in academia so far, and presents a case study—a real-life heritage project to teach architectural history in higher education. The methodology applied in this case study is based on the digital methods of heritage surveying. The paper explains the methodology process and illustrates the key tasks across three project phases of a Scan to BIM/Capture to CAD methodology: methods and activities developed with the students, from building survey, data processing, development of BIM models, etc. The aim of the paper is to analyse the positive contribution for the teaching curriculum and the benefits for community and industry. The paper is a reflective narrative piece and seeks to share useful tools and strategies to make educational use of a heritage building and its resources as one way of teaching architectural history and heritage today.

Keywords: architectural history; built heritage; heritage education; digital technology; sustainability

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1. Introduction

The ongoing discussions between architects, architectural historians and architecture students on the role of architectural history in architectural education, design and professional practice today fully aligns with the Sustainable Development Goals (SDGs) related to the sustainability of cities and communities (Goal 11) and Quality Education (Goal 4). Two concurrent and burning topics among professionals in the field are:

(A) Academic. Questions on the status of architectural history in higher education have been continuously raised at the 2017–2022 annual conferences of the Society of Architectural Historians [1] and the Society of Architectural Historians (SAH) Data Project [2].

(B) Professional. The present-day Royal Institute of British Architects (RIBA) [3] criteria for ranking of the top five skills necessary for future employment in the UK, based on an analysis by Bakshi and colleagues [4], are judgement and decision making, fluency of ideas, active learning, learning strategies and originality abilities [5]. The recent Architects Accreditation Council of Australia (AACA) Architectural Education and the Profession Report gives a local perspective that reports the need for similar outcomes [6].

These reflections on the demands, pressures and priorities of higher education and the architecture profession throughout the world today coincide with the fact that the use of digital technologies in heritage projects and academic research is becoming increasingly topical worldwide. This is confirmed in editions of the *Journal of the Society of Architectural Historians*, with articles that discuss the use of digital technologies to uncover new information in the study of historical buildings, and as questions such as: how have digital media altered what we consider evidence and the ways we employ it for scholarship? [7–10]. These will be discussed in the Literature Review, to follow. The SAH Data Project [2] research results have shown that heritage preservation is of increasing interest to students, likely due to the fact that it is increasingly associated with new design projects, and also its use of digital/immersive technologies. It is possible to imagine heritage as a concept embedded throughout the curriculum rather than a specialisation that only comes later.

This paper draws attention to the fact that it is possible and even necessary to develop applied research projects that include students and meet the requirements of the community and industry needs in schools of architecture as applied institutions of learning. With that in mind, this paper proposes:

(1) That the future of architectural history teaching and learning is connected with heritage and preservation, and engages students by responding to local current events and focusing on a specific building in a community.

(2) That the future of architectural history teaching and learning is connected with the measuring and drawing of buildings, which needs to include digital technology, digital skills and digital environments.

These two observations are presented through one case study—Building One—examined through the research project "Digitalisation of Heritage in New Zealand" and the associated elective course run in 2020, 2021 and 2022 at the Unitec School of Architecture, in Tāmaki Makaurau Auckland, Aotearoa New Zealand. This paper aims to offer useful tools and strategies to make educational use of a heritage building and its resources as one way of teaching architectural history and heritage today. It presents a teaching and learning proposal that uses active methodologies and impacts the use and exploitation of the resources of the educational heritage environment. The following Section 2 includes the state of the knowledge and identifies the gap that this case study aims to address. The more specific territory of the research and the scope of the case study are explained in Section 3, Background to the Case Study. The case study methodology process and phases are explained in Section 4, Materials and Methods.

2. Literature Review

There is a growing body of literature that recognises the importance of the incorporation of new technologies that make the processes of accurately documenting, assessing, interpreting and repairing our heritage sites increasingly accessible and impactful [11]. There is no doubt that the past decade has seen a steady increase in digital technologies used to document the historical built environment [12]. This literature review aims to examine the state of the art in teaching architectural history and heritage regarding current trends, usage and benefits of digital tools. The methodological procedure used for selecting studies in the literature review process included a broad and systematic literature search across several databases, including Ebsco (Art and Architecture Complete, Academic Search Premier), Informit and tailored Google searches, and within Mendeley for research that had been shared there. The *Journal of the Society of Architectural Historians*, as a leading English-language journal and a stable frame of reference on the history of the built environment that has been in frequent and regular publication over the 80 years, was carefully examined.

2.1. Architectural History and Evidence—Academic Value

A few recent editions of the *Journal of the Society of Architectural Historians* (*JSAH*, 2017–2022) examine these technological developments in the academic field of architectural history. The issue of the journal published in November 2017 [7] contains four Field Notes that appraise the status of evidence in architectural history. Evidence is presented from diverse positions and perspectives, one of which particularly considers the digital humanities. This cross-section of the ways the field has expanded into new areas, raising further questions about the premises of the discipline, marks the beginning of the debate about new methods—discussing their undoubted advantages, and some of the problems they might bring to architectural history. Architectural historians are literally invited to 'rejoice' because they are entering an age in which our discipline can be immeasurably assisted, enriched and sometimes transformed by the advent of accessible, low-cost and increasingly user-friendly technologies [13].

A number of articles present results of the application of these new technologies in different case studies. One is the case of Rome, where the authors examine how and why humans have formed and re-formed built environments by preserving, altering or destroying fabric over time. The article addresses whether we can make better sense of complex, historically rich built environments with the advent of digital, data-driven approaches and increasingly powerful mapping tools [8].

The question about digital technologies providing new evidence in architectural history today is further discussed in the article on the sixteenth-century Venetian church of San Geminiano, demolished in 1807. The authors demonstrate the historical reconstruction through methodological processes of 3D modelling and the interpretive value of the resulting models for studying architectural and urban histories. Moreover, it is acknowledged that their work on San Geminiano enables a re-evaluation of this historically significant and now lost structure and its relationship to the space of Piazza San Marco in Venice [9].

A study presenting and examining the 3D digital modelling of Santa Maria delle Carceri in Prato, one of the most representative and famous central-plan churches of Renaissance Italy, designed by Giuliano da Sangallo, confirms the importance of debate on how digital media have altered what we consider the evidence and the ways we employ it for scholarship. This study is based on the examination of an original drawing of the church by the architect Giuliano da Sangallo, as well as several recent technical surveys of the existing building. A specific methodology based on historical documents and three-dimensional digital models is introduced, and the authors reconstruct Sangallo's design methods by making use of a digital reconstruction of the building generated through a series of 3D models [10].

2.2. Digital Technologies and Architectural Professional Skills—Practical Value

Increasing numbers of academic institutions are acknowledging the academic, but also practical, value of these developments [7,13–17]. These new tools enable us to identify evidence that was not previously visible or accessible, synthesise and map geographically and chronologically referenced data points with precision, fuse databases to combine information from secondary sources that in turn generates a new type of data, and test hypotheses through 3D models and animations [13]. The ability to add layers of data beyond geometry contributes to enabling a deeper understanding of the building, accessible in a single location. The potential tools include the following: 3D laser scanning, which can be used to produce exact recordings of the dimensions and materials of monuments; photogrammetric 3D models of buildings, sites and objects, which can be generated with ordinary cameras (including those on portable devices); and HBIM (Historic Building Information Modelling) software, which can embed historical information within 3D scans and photogrammetric models [15].

A study titled "A Scan-to-BIM Methodology Applied to Heritage Buildings" confirms that a pragmatic and organised HBIM methodology is essential to obtain a consistent model that can bring benefits and integrate conservation and restoration work. This article specifically addresses the creation of an HBIM model of heritage assets using 3D laser scanning and photogrammetry. The findings are illustrated through the case study of Engine House Paços Reais in Lisbon, and the HBIM modelling phase is described based on point cloud data. The benefits of the 3D laser scanning and photogrammetry surveys—that they not only save time in the field but also prove to be extremely accurate at registering non-regular geometries of historical buildings—are clearly underlined. However, the efficient transformation of remote-sensing data into as-built parametric smart models is also acknowledged as currently an unsolved challenge [16].

This challenge, as well as a few others, has been discussed by other scholars, too. Some of the authors have included analysis of workflow for cultural heritage groups and the question of whether to use 3D or not. One example is the study that addresses the lack of information in contemporary academic discourse: it states that survey-based feature lists are seldom presented, nor a critical inspection of potential production pipelines; nor any direction and guidance for non-experts interested in learning, developing and sharing 3D content on a restricted budget. To address these issues, the authors studied a range of free and open-source software (FOSS) based on their offered features, workflow, 3D processing time and accuracy. The authors hope to help non-expert users understand photogrammetry and select the most suitable software for producing image-based 3D models at low cost for visualisation and presentation purposes [17].

Academics and professionals in the field also recognise the challenge of publishing the resulting 3D content research, which is not always accepted as scholarship and integrated into discipline-specific dialogue. An example is the article on Digital Karnak, in which the authors propose a reconceptualisation of computer modelling as a new means and form of knowledge production, offer a framework for peer review and publication of 3D content, and describe an experiment to develop an innovative publication with an interactive computer model at its core [18].

2.3. Emphasis on a Multidisciplinary Approach

Many studies that emphasise the use of a multidisciplinary approach for diagnostic study processes of historical buildings present a significant existing body of knowledge in the field. This multidisciplinary approach includes geometric documentation data acquired by 3D laser scanners and image-based photogrammetric techniques. An example is a study on the Catholicon of Kaisariani Monastery in Attica, considered one of Greece's most important Byzantine architectural complexes. The study concludes that these multidisciplinary tasks require collaboration among architects, surveyor engineers and materials scientists/engineers, which are also prerequisites for the planning and application of compatible and efficient conservation/restoration interventions for the ultimate goal of the sustainable protection of a monument [19]. Similarly, combined survey methodologies adopted for the geometric and architectural documentation of the site of the Castel of Scalea in Cosenza, Italy, demonstrate how the use of integrated methodologies allows for complete and detailed documentation, including information regarding architectural and geometrical features, but also archaeological and historical elements, building materials and decay evidence [20].

2.4. Heritage, Education and New Digital Technology

These previous studies provide valuable insight into new cross-disciplinary approaches that have been developed, which connect heritage buildings and sites with new digital technologies and tools. In all these previous studies, there seems to be no controversy about the relevance of the digital methods of heritage surveying and the use of digital technology. However, there are limited data and studies on the application of this topic within the existing educational system.

One such study asserts that heritage-related curriculum design and content constitutes a key factor in the sustainable preservation of heritage, because only what is known and valued can be protected and preserved. This research analyses the way heritage is approached in the primary education curriculum in Spain [21]. It concludes that the curriculum itself becomes an important player—whether heritage education involves the inclusion of new materials in the curriculum, or the use of innovative approaches in handling heritage-related content that are already present in the several curricular areas in order to facilitate their teaching and promote heritage awareness.

Another study included university students of engineering and computer science, who traditionally do not address cultural or scientific heritage topics in their syllabus. The study focused on this theme and different courses, allying the learning of technical skills with the natural interest of younger people for 3D and animation for the profit of heritage. The goal was to raise awareness for the importance of maintaining heritage, in particular in a virtual way, both for documentation and for acknowledging their existence [22].

It is hard to find papers that address the combining of university courses with scientific research. One such paper questions whether, on completion of their courses, students' outputs can be used by scientists and conservationists in studies on material deterioration and research on historic monuments. The study addresses the existing gap between educational tradition and the needs of contemporary conservation [23].

One study points to the problem of the shortage of specialists in the architectural design and construction industry who have the skills to work in a new information environment. Integrating emerging technologies in architectural education is recognised as a possible solution to the lagging of universities' educational programmes behind the new demands of today [24]. The article assesses the level of penetration of emerging technologies into the educational process of architects at the Ural State University of Architecture and Art. Another paper showcases the academic implementation of BIM in university technical education centres. It aims to establish a methodology for shared and collaborative group work in a BIM environment through a Spanish industrial heritage case study dating to 1865. This study indicates a need to immerse the students in the BIM methodology [25].

This literature review reveals there are limited data and studies on the application of the use of digital technology within the existing educational system, in particular, the topic of architectural education in relation to heritage and digital technologies. We hope that with this paper, we can contribute to filling that gap. The paper provides the results of one case study as a possible resource for the educational and sustainable use of heritage buildings and sites.

3. Background to the Case Study

The case study is investigated through the Unitec research project "Digitalisation of Heritage in New Zealand", which aims to investigate the current state of knowledge of digitalisation and archiving of heritage buildings in Aotearoa New Zealand. This is an applied project, externally partnered, that aligns with Unitec's organisational priorities by including students directly, making a positive contribution to the teaching curriculum, and creating ongoing connections with the community and industry. This paper presents the work done as one part of the project as a case study, and as one possible avenue for teaching architectural history and heritage in higher education institutions today.

3.1. Case Study—Context: Community Needs and a Short History of the Building

The current events surrounding Building One, an acclaimed heritage building in the Tāmaki Makaurau Auckland suburb of Point Chevalier, are that it has been purchased from Unitec by the New Zealand Government, to become part of an intensive housing development that will comprise between 3000 and 4000 homes. This landmark building, which was a psychiatric asylum from 1865 to 1992, is a recognised Category 1 historic place [26]. Building One—formerly Oakley Hospital, then Carrington Hospital and originally known as a Lunatic Asylum of the 'Whau'—was built in 1865 under the supervision of James Wrigley, using plans purchased in England [27]. In 1857, the number of mentally ill compared to healthy New Zealanders was twice as high as in England, which explains the necessity of erecting what was the new colony's first mental hospital facility. As a major historic building in public ownership, it has always had great social significance. Its role in the institutional treatment of persons with mental illness gives it particular social importance. One of the largest public buildings in the country at the time of construction, it was gutted by fire in 1877 [28]. In 1881 Philip Herapath, working from original drawings, supervised the reconstruction. During its existence as a mental hospital, the building was extended and added to many times, until its closure as a hospital in 1992. It was then purchased by Carrington Polytechnic (soon to be renamed Unitec Institute of Technology), who refurbished the building for Unitec's School of Design and the newly formed School of Architecture and Construction. As a tertiary educational institution, this historic building, converted to house departments of architecture and design, had an important didactic function as an exemplar of the architectural and social values of the past [29].

The building is undoubtedly a notable example of late-nineteenth-century institutional architecture, and it still has intact elements from each of the periods of major building construction. The façade does not share the daunting appearance that many similar institutions in this country have, or have had [30]. It incorporates bricks produced on the site and at local brickyards, and distinguished polychromatic detailing. The use of local yellow brick has united the various periods of construction to give the whole ensemble remarkable unity. Corresponding use of bands of contrasting red brick turned over openings in arches of varying forms, further unites the whole—even though there is a wide variety in the form and detailing of the arched openings [29]. Particular social significance is held by the walls, which have patterns and lettering incised in brickwork by patients during exercise periods. Exterior elements, as well as numerous interior spaces, are considered as contributing directly to its architectural and historical significance and should be retained or conserved according to the Conservation Plan [29]. The original building is listed by Heritage New Zealand as a Category 1 heritage building. However, while there is recognition of its historical and cultural significance, the listing provides no guarantee of protection from demolition. Since January 2020, when it was vacated, the building has sat unused, in an abandoned state. Moreover, it is not earthquake proof. Therefore, despite the building's acknowledged importance and distinctive character, its future is uncertain.

Today, Ngā Mana Whenua o Tāmaki Makaurau and the Crown (through the Ministry of Housing and Urban Development) are partners in the residential development of the site, and intend to make decisions on the future adaptive reuse and preservation of Building One in due course. This is recognised as a stimulating opportunity to connect, regenerate and energise the surrounding diverse communities of Point Chevalier, Mount Albert, Waterview and Avondale, and the wider population of Tāmaki Makaurau. A community body, Point Chevalier Social Enterprise Trust, has prepared a feasibility study on Building One, for consideration by the Crown and Ngā Mana Whenua [31]. They have commenced public engagement with the community on their proposal.

The Unitec Research Project "Digitalisation of Heritage in New Zealand" responds to these current events by creating, with Unitec School of Architecture students, a digital archive of Building One that informs the feasibility study, and the Crown and Ngā Mana Whenua's decision on its future use, preservation and protection. The main goal is to reduce the risk of losing Building One, to retain cultural heritage in digital form and ensure its legibility, interoperability, availability and authenticity over a long period of time. Thus, the current events and what the community wants for this heritage building—Building One—were taken as a starting point for an elective course in the Bachelor of Architectural Studies programme.

3.2. Case Study—The Need for Digital Recording

Almost everything that is known today about the history of Building One derives from very few paragraphs in the published literature on New Zealand architecture [27,28,30,32,33] and an extensive report—the Conservation Plan prepared by Salmond Architects in 1994 [29]. Overall, information about Building One is represented as a collection of individual documents, reports, drawings, computer-aided design (2D) files, and various data provided by different professionals, each of whom has worked with their own tools and standards. Information about Building One is dispersed across a number of locations (physical archives) and in various formats. The status and quality of individual pieces of information are unknown (superseded, uncoordinated or incomplete). There is no single source of reliable and consistent information about Building One. Thus, generally speaking, the lack of systematic, detailed and publicly available information and surveys of the building presents, at this moment, a major deficiency that needs to be addressed.

The measuring and drawing of buildings—the discipline of surveying and analysing historical architecture in order to learn from it—has been systematically developed by architects since the Renaissance. Surveying (with more precise tools) remains one approach and part of the architectural history discipline today. For every conservation plan or large-scale repair and maintenance heritage project today, it is becoming standard practice for experts to strongly recommend a digital survey is undertaken as the first stage of any project. This includes a laser measure survey (preferably with control and geo-referenced), a drone survey and photography to produce an accurate and concise record of the property [34,35].

For that reason, the 2020–22 survey of Building One aimed to use the accurate survey not only to provide archive material, but also to attempt to understand the design choices made by its architects, and changes over time to the function of spaces. The intriguing past of the building—first as a psychiatric hospital, then as an educational institution—and the wide variety of spaces, circulation areas, and many rooms of considerable architectural quality, hold secrets of the many destinies of former inhabitants. This means that the use of HBIM and digital technologies for this heritage building can be clearly seen as an effective strategy for the management of historical information, as it will allow for the structured integration of both geometric and non-geometric information (including tangible and intangible values) and external documents into a single model, which will become a central hub for all information relating to Building One.

Thus, the employment of digital technology and the teaching of students, combined in this heritage project and associated academic research, may provide new evidence about our architectural history. As discussed in the Section 2, this is confirmed by the fact that more and more academic institutions are acknowledging the academic and practical value of these developments. The Literature Review has discussed more fully a significant number of research articles with new findings about this that have recently been published.

4. Materials and Methods

Chart 1 captures three phases of the methodology process and illustrates the key tasks across three project phases of a scan to BIM/capture to CAD methodology. The educational components of the case study presented were designed around and to fit into the framework of this process. The sections below detail the additional activities developed and conducted with the students in the corresponding project phases, from preparation of the whole workflow, building survey, data processing, development of digital assets, etc., with the main emphasis based on the digital methods of heritage surveying and modelling:

Phase 1. Preparation
Phase 2. On-Site Process: Educational Workshops and Point Cloud Creation
Phase 3. Asset Development: Scan to BIM/Capture to CAD

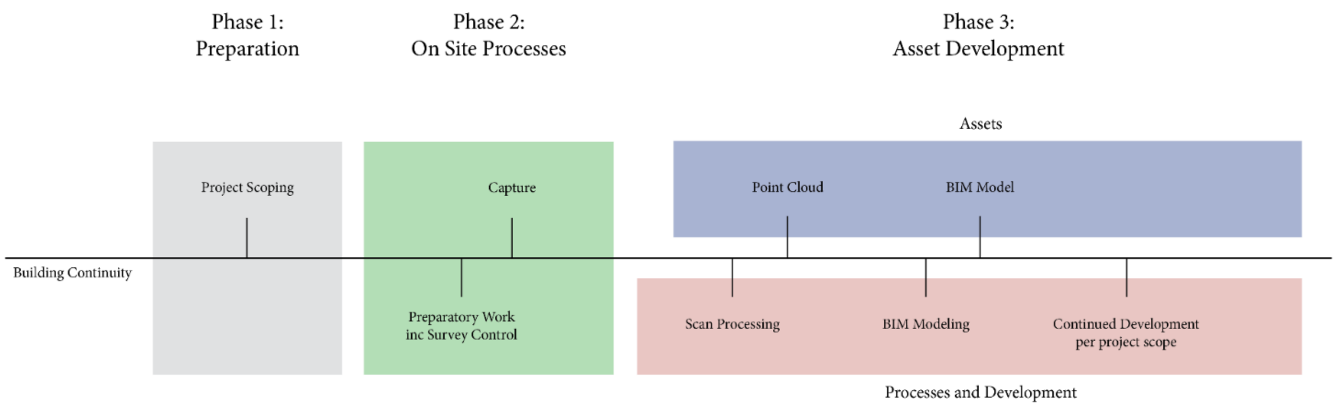

Chart 1. Three project phases: Methodology process.

4.1. Phase 1. Preparation

The Preparation phase for digital recording of Building One started in July 2020 with the elective course "Digitalisation of Heritage". To understand the context of Building One and its history as the Carrington Psychiatric Hospital, Unitec School of Architecture students were introduced to guest speakers who shared their knowledge and experiences of the building. This included Bertie Plaatsman, the writer and director of the documentary *Building One*, selected for the 2015 DocEdge International Documentary Film Festival [33]; and Sue Thomson, who worked in the hospital as a nurse. The subsequent discussions focused on the stories and experiences of former staff and patients that occupied the hospital, and importantly shed insight on how the building was used. The students were also introduced to the Point Chevalier Social Enterprise Trust, who had organised an adaptive reuse feasibility study, which investigated the potential use of Building One as a vibrant community space [31,36,37]. Results of the feasibility study indicate strong community support for an adaptive reuse of Building One that facilitates public access to affordable art and creative studio spaces, residencies, workshops, lecture theatres, and community rooms for youth and adult education programmes [31]. Provided with historical context and a future-use case for Building One, the students were given the task of indicating the historical and architecturally significant spaces that would need to be captured in the scanning process, and researching methods of digitalisation to carry it out.

The research into digital capture techniques involved industry leaders in Aotearoa New Zealand, Mari McKee (Salmond Reed Architects), Malcolm Archbold (Survis Ltd.) and Freddie Nodalo (asBuilt Digital). Through a series of seminars, each leader provided insight into the technology, capture methodology and practical applications, contributing to the students' overall understanding of the field.

Overall, the Preparation phase included:

- Active learning about the historical context of Building One.
- Active learning about possibilities for future use of Building One and an adaptive reuse feasibility study preparation with Point Chevalier Social Community Trust.
- Active learning into digital capture techniques through a series of seminars that involved industry leaders in Aotearoa New Zealand.

4.2. Phase 2. On-Site Processes: Educational Workshops and Point Cloud Creation

The scanning of Building One was conducted through a series of onsite educational workshops with equipment provided and demonstrated by industry partners. The first of these was led by Malcolm Archbold, who demonstrated an aerial drone photogrammetry capture of Building One using a drone and also, collaboratively with Unitec School of Engineering and Applied Technology, demonstrated survey control and targeting techniques using established LINZ survey markers, a Leica TS series total station and GNSS (GPS). The subsequent assets created, including the aerial point cloud and survey control, were shared and used to geo-reference the project. The second workshop was run by asBuilt Digital, who demonstrated terrestrial scanning methodology over two days, using two Leica RTC360s (Figure 1) linked to iPads (Figure 2) running Cyclone to process the live point cloud data. The students were heavily involved in the scanning workshops, and received hands-on experience with the equipment and methodology of capture. The terrestrial scanning only covered areas scoped by asBuilt, including the front façade and exterior, the interior of the central wing and basement, as well as portions on the west wing interior. During the scanning, 360-degree photos, using an insta360 provided by asBuilt, were taken of the scoped area to be used as reference imagery for students while modelling. asBuilt would also go on to complete the post-processing registration and geo-referencing of the scans using Leica Cyclone, delivering a functional and intelligent point cloud asset for the students to use.

Figure 1. Leica RTC360 during scanning of Building One.

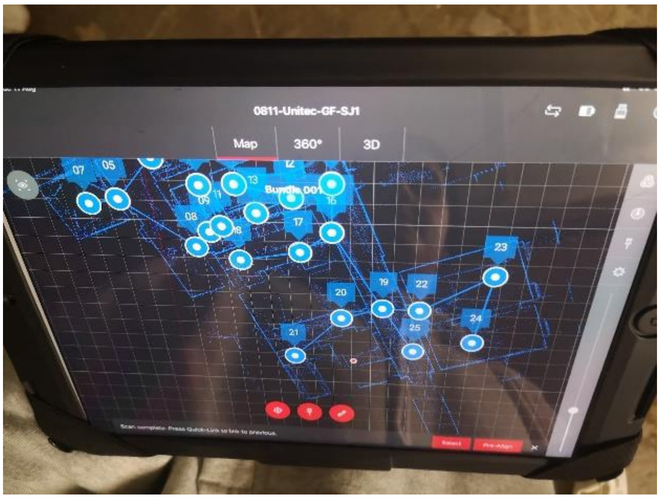

Figure 2. Linking scans on Leica Cyclone on iPad during scanning of Building One.

4.3. Phase 3. Asset Development: Scan to BIM/Capture to CAD

To capture Building One in CAD format, the point cloud was first divided into fourteen zones using Autodesk Recap. This was done to spread the workload between the fourteen students in the programme, who were each assigned one of the zones (Figure 3). Exporting each zone as an individual geo-referenced point cloud allowed the students to focus on their zones in a manageable capacity, and made for efficient localised co-ordination when dealing with adjacent zones (Figure 4). For modelling, Autodesk Revit 2020 was used with a standardised template enabling a shared co-ordinate system across all authors. Using the shared co-ordinate system to position point cloud files, we were able to ensure that all individual Revit files would be modelled spatially in relation to one another (Figure 5). This would be crucial, particularly at the junctions between zones, as students would eventually insert each other's models into their files to co-ordinate building elements. This was stressed as a significant aspect of the grading system to ensure a high standard of work from the students in these areas, as it would greatly affect the overall model quality. With this set-up, students would be able to interpret the point cloud files within Revit, and essentially trace the point cloud with 3D geometry. They would also have oversight of their peers' work and adjacent point clouds, using the shared co-ordinate system to accurately position these models.

Figure 3. Building One—Students' assigned zones in plan.

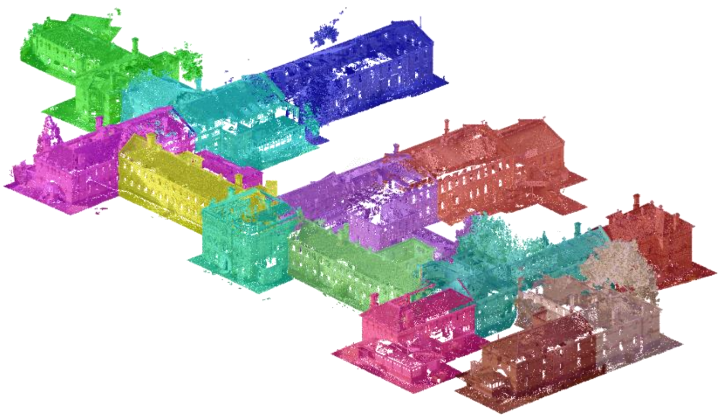

Figure 4. Building One—Students' assigned zones in 3D Point Cloud.

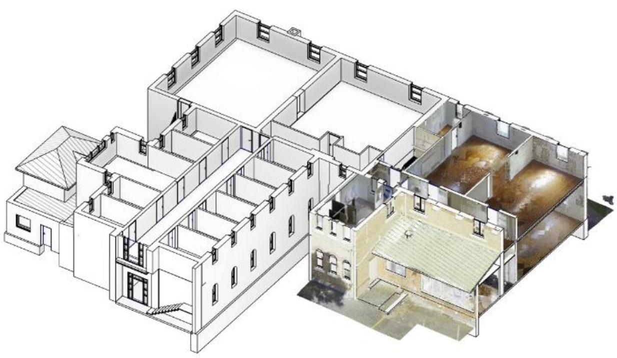

Figure 5. Scan to BIM/Capture to CAD work in progress.

The entire modelling process spanned the course of eight weeks, including weekly model sharing, and workshops that focused on different aspects of the software and modelling building elements, as well as milestone deliveries for quality assurance. Discord, a web-based chat and call platform, was used to host the workshops and discussions regarding technical and modelling inquiries from the students.

Using the same technique used by the students to view each other's models, a dedicated file was created to link all the zones in a process called federation. This file gives a complete picture of the work carried out (Figure 6), is useful for analysing the entire building and comparing zones, and has been the basis for graphical outputs following the project.

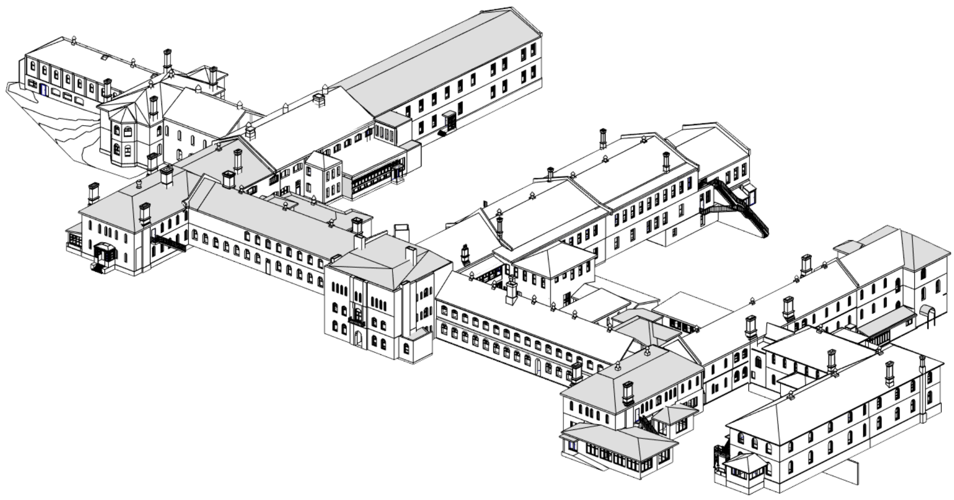

Figure 6. Building One. Federated Revit model.

The Scan to BIM/Capture to CAD methodology and workflow from Point Cloud–Zones–CAD–Federation is schematically presented in Chart 2.

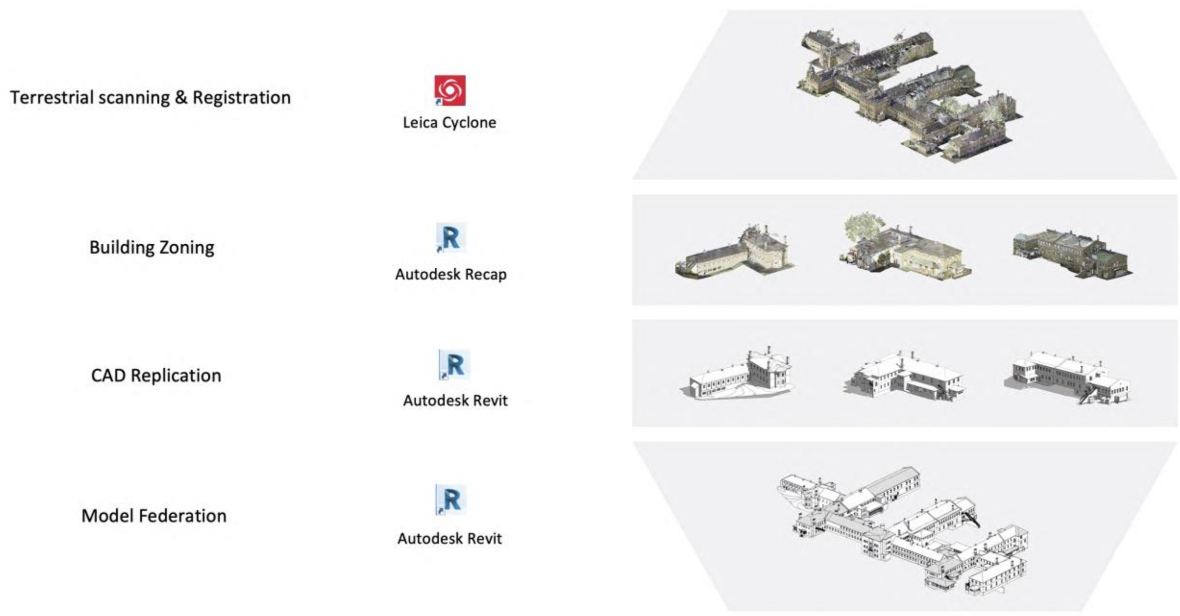

Chart 2. Scan to BIM/Capture to CAD methodology and workflow from Point Cloud–Zones–CAD–Federation.

5. Key Benefits of Case Study: Results

The initial observations—about the future of architectural history teaching and its connection with heritage buildings and local current events; measuring and drawing of buildings; and engagement with the digital world—that this paper proposes have all been applied in this research project and case study. Moreover, the results have shown that the case study follow Unitec's institutional priorities—to "grow a productive, diverse, student integrated, engaged and sustainable research workforce with the necessary resourcing and infrastructure". It aligns with the Unitec Research Strategy 2020–2024 [38] by concentrating on opportunities and problems identified by industry and community partners; undertaking impactful research to provide economic, social, cultural and environmental benefits and having transformative outcomes for the communities we serve; creating ongoing connections and partnerships with industry, community and the research community; including students' engagement directly; exploiting and developing synergies with their associated teaching programmes.

There is no doubt that digital surveying is highly relevant and can be practically translated for use by the industry (the architecture profession as well as the wider construction and engineering industries) and others. It is now a standard, which is one reason why the industry is interested in taking part in this research project. Working with heritage buildings and sites is a developing field in Aotearoa New Zealand, and the industry wants graduates that can work with it. The industry is also interested in helping to educate graduates and help them engage in what is real-world best practice. Furthermore, the impact of outcomes from this case study is in the possibility of influencing modifications of the existing legislation related to heritage buildings in Aotearoa New Zealand. The case study coincides with current national policy changes in the Resource Management space [39], and the development of ICOMOS NZ Charter Practice Notes [40], and addresses current lack of synchronisation and direction between the many different organisations that manage heritage in New Zealand [41,42]. Thus, this work is gathering national momentum and is in an area of high value to Aotearoa New Zealand's heritage. The practice of dealing with heritage buildings and sites in this country can, and should, be enhanced using modern digital technologies. The members of this project team advocate for this by taking an active part in the Resource Management Act Reform Working Group review [43], as well as contributing to the ICOMOS New Zealand Charter Practice Notes and Best Practice Guidelines Scoping Report [40]—in both instances sharing the experience, approach and integrated methodology developed for digital scanning of this case-study heritage building.

The case study also values the conservation and teaching of historical and cultural heritage and strongly aligns with the Sustainable Development Goals (SDGs), mainly related to the sustainability of cities and communities (Goal 11) and Quality Education (Goal 4). Based on the work developed so far, the recognised and acknowledged critical benefits for specific groups are:

(1) Community benefits [21–25,31,44,45]:
  - Having a 'digital heritage' made up of computer-based materials of enduring value, recorded for and accessible to future generations.
  - An active preservation approach is developed so that the continuity of the heritage building is maintained.
  - A digital library of information is created which could be used to remediate the building in the case of natural or other disasters.
  - A new generation of architects learn about the importance of heritage protection and preservation, and how to work collaboratively with local communities and agencies towards a common goal.
  - Digital data enables the creation of digital models and virtual tours, which allows remote access to inaccessible or dangerous areas from specialists nationally and across the world through virtual reality.
  - The precision of measured survey for assisting future seismic and fit-out design.

- ○ Interactive CAD and online-based material can be shared globally. This minimizes the need for site visits and even eliminates the need for specialist contractors to fly over to sites, reducing the contractor's carbon footprint.

(2) Four core benefits for industry partners [35,46,47]:

- ○ Priority access to graduate and postgraduate students.
- ○ Positive publicity: the public is informed of their support (public-relations efforts in the form of the Unitec Research Blog, industry blogs [46], press releases highlighting the work our students are doing, etc.).
- ○ Digital archive of all surveyed buildings—an opportunity to be innovative.
- ○ Potential for future external grant applications.

(3) Key benefits and 'learning curve' for students [3–7,12–20,35,38,47,48]:

- ○ Learning about digital tools and equipment, and setting up survey controls.
- ○ Learning how to use software (point cloud processing) and setting up a central model, which is now the industry standard.
- ○ Developing digital modelling skills—modelling from point cloud, choice and application of LODs [48], HBIM, federated model co-ordination.
- ○ Learning architectural history and heritage from the existing as-built building (and not only through historical sources).
- ○ Learning architectural history and heritage 'by doing' and through personal engagement with local current events.
- ○ Working experience in real-life projects, with industry partners.
- ○ Internship opportunities and full-time positions after graduation.

The first three points of group (3) expose students to practice—to develop specific technical skills. The last two points explicitly expose students to practice overall. This creates an environment for students to develop further communication, collaboration, judgement and decision-making, and time-management skills—all recognised as necessary for their future employment and as priorities of higher education and the architect's profession today [3–6]. We were able to identify the impact on students' learning of architectural history and heritage as recorded in the students' reports as well. Examples of this learning are evidenced in their specific reflections about: learning through process; mutual coordination and linking of work; learning by doing.

Students reported the benefits of learning the digital tools with professional equipment in a real-world situation, being taught by practitioners who were able to give them tips on refining their use of the technologies in response to the specific tasks of the study. The importance of the learning from numerous sections and 3D views of the recorded data was shared by most students; and they learned to overcome the challenges of the use of the 3D material in this context by frequently reviewing and cross-referencing their data in order to achieve an accurate modelling result.

Many students referred to the challenges they faced in understanding the architecture of the building. What seemed a straightforward task to begin with was revealed as increasingly complex due to the variations in wall thicknesses and angles as a result of layers of modifications over time. Students gained a deeper understanding of the constraints of the technology when faced with measuring and mapping inconsistent walls that were not parallel or perpendicular, and learned how to use the point cloud to ensure accuracy in this context. Students also shared their discoveries of spaces that do not exist in previously published material [27–30,32,33]. In one case, a student discovered a small room under a staircase by cutting the building using 3D sections. They noted that the room would have been easy to overlook while physically walking around the building.

One student commented on the scope of the learning opportunity provided by the course, citing the range of experts guiding students in the use of the technology, underpinned by a trio of tutors who could provide both technical and academic backup and support. The latter is an important factor in the success of such a class; industry experts will not always be on hand for students who need extra help or clarification, so the presence and involvement of academic staff members with a range of strengths and expertise is vital.

6. Discussion and Concluding Remarks

Although BIM has been applied widely for many years in new-build construction, and with numerous relevant publications and online content, BIM for heritage assets (HBIM) is a relatively new field of academic research and with currently low engagement by heritage professionals [34]. However, heritage projects typically rely on multidisciplinary collaboration: a number of experts and specialists contribute, exchange and interpret complex information and data about a heritage asset to inform the understanding of its value and significance. This understanding is crucial for decisions on future interventions, conservation and management, so the quality of information for this multidisciplinary knowledge base is vital for heritage projects. Layering of data is an important aspect of maximising the potential of a BIM, or HBIM, model so that information beyond the visual is captured to develop a deeper understanding of a building.

The case study presented in this paper and used in the elective course "Digitalisation of Heritage" represents a multidisciplinary collaboration. A number of experts and specialists have contributed, exchanged and interpreted complex information and data about Building One to inform an understanding of its value and significance. This understanding is crucial to inform decisions on future interventions, conservation and management. Overall, the project has both academic and practical value in advancing knowledge about heritage in the country, and in teaching students aspects of architectural history and heritage. It also provides a means for advancing Aotearoa New Zealand's current state of knowledge in the practice of archiving heritage buildings. The final outcome—the digital model of the building—is useful for the end user. A digital library is established to archive building information, which in turn can be used alongside applications for the remediation of sites after natural or other disasters. Overall, it can aid in learning about the built environment.

The question of whether digital surveying can be relevant and practicably translated to industry or users and other institutions can be answered with the fact that it is a standard now. That is one of the reasons why the industry is interested in taking part in this project. The project team includes senior staff and colleagues not only from Unitec's School of Architecture but also from the School of Engineering and Applied Technology. This research collaboration between the School of Architecture and the School of Engineering and Applied Technology was envisioned to allow for sharing knowledge and expertise, to encourage future collaborative opportunities in teaching and research, and to provide interdisciplinary student supervision.

By teaching students through this project, better use of HBIM and modern digital technologies in local conservation practice should be enabled. HBIM encourages protection of architectural heritage through the procedures of its digitalisation and documentation. The use of modern digital technologies not only facilitates and improves conservation practices and processes, but also enables the creation of a digital database. However, it is not applied as much as it might be, internationally and in Aotearoa New Zealand. Some of the reasons for this are lack of education and a negligible number of professional or academic papers in local journals, but also the fact that it is not yet recognised as an important element in the protection of architectural heritage in local practice [45], nor in the circles of heritology theorists. We believe that schools of architecture in this country, as educational institutions, can and should play a role in helping this to happen. Projects such as this demonstrate the value of producing an HBIM asset that includes not only physical data but historical and cultural value to aid in the assessment of a building. We are aware, however, that the costs of producing such 'assets' are high, and universal software standards and models of ownership are still developing.

This case study shows that carefully designed academic courses that include students' engagement in real-life and current heritage projects, direct collaboration with industry partners and ongoing connections with the community are one possible avenue for contributing to the teaching of architectural history and heritage in higher education institutions today. It also highlights the importance of systematically creating opportunities for architecture students to develop skills necessary for future employment by working with industry partners on problems and local current events identified by the community. Further, this case study results represent a useful starting point for other architecture schools to plan future research projects in the field. Other communities locally and internationally can utilise the learnings of this research project for adaptation to their own heritage preservation contexts.

The broader research project, "Digitalisation of Heritage in New Zealand", is developing to be truly beneficial for Aotearoa New Zealand, and to enable change. Results aim to influence modifications of the existing legislation and an apparent anomaly and lack of synchronisation and direction between different organisations that manage heritage in this country [40–43]. Based on progress made in 2021 through communication with architects and engineers from the sector, district councils, and government organisations, quantitative aspects of the research have been developed in 2022, and a more robust three-stage methodology includes surveys, focus groups and interviews. Finally, the project's future development includes establishing a new research centre at Unitec that deals with heritage in Aotearoa New Zealand, and offers a possibility to record, protect and preserve numerous heritage buildings and sites—engaging architectural history and heritage with local current events while teaching architecture students.

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