MASTER OF APPLIED SCIENCE (RESEARCH)

BN71

Built Heritage Management Systems: The Framework of a Digital Tool for the Conservation of Brisbane City Hall

ADAM JACK

Bachelor of Design (Architectural Studies), Master of Architecture

Principle Supervisor: Dr Mirko Guaralda
Associate Supervisor: Professor Robin Drogemuller

School of Design

Faculty of Creative Industries

QUEENSLAND UNIVERSITY OF TECHNOLOGY

2014

Key Words

Architectural Heritage, Adaptive-Reuse, Building Pathology, Conservation, Restoration, Building Information Modeling, Digital Tools, Brisbane City Hall, Heritage Management.

Acronyms and Abbreviations

Adaptive-Reuse = AR

Architectural Heritage = AH

Brisbane City Council = BCC

Brisbane City Hall = BCH

Building Information Modeling = BIM

Fire Engineering Report = FER

Abstract

Brisbane City Hall (BCH) is arguably one of Brisbane's most notable and iconic buildings. Serving as the public's central civic and municipal building since 1930, the importance of this heritage listed building to cultural significance and identity is unquestionable. This attribute is reflected within the local government, with a simplified image of the halls main portico entrance supplying Brisbane City Council with its insignia and trademark signifier. Regardless of these qualities, this building has been neglected in a number of ways, primarily in the physical sense with built materials, but also, and just as importantly, through inaccurate and undocumented works. Numerous restoration and renovation works have been undertaken throughout BCH's lifetime, however the records of these amendments are far and few between. Between 2010 and 2013, BCH underwent major restoration works, the largest production project undertaken on the building since its initial construction. Just prior to this conservation process, the full extent of the buildings deterioration was identified, much of which there was little to no original documentation of. This has led to a number of issues pertaining to what investigators expected to find within the building, versus what was uncovered (the unexpected), which have resulted directly from this lack of data. This absence of record keeping is the key factor that has contributed to the decay and unknown deficiencies that had amassed within BCH. Accordingly, this raises a debate about the methods of record keeping, and the need for a more advanced process that is able to be integrated within architectural and engineering programs, whilst still maintaining the ability to act as a standalone database. The immediate objective of this research is to investigate the restoration process of BCH, with focus on the auditorium, to evaluate possible strategies to record and manage data connected to building pathology so that a framework can be developed for a digital heritage management system. The framework produced for this digital tool will enable dynamic uses of a centralised database and aims to reduce the significant data loss. Following an in-depth analysis of this framework, it can be concluded that the implementation of the suggested digital tool would directly benefit BCH, and could ultimately be incorporated into a number of heritage related built form.

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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature:
QUT Verified Signature

Date: 25/03/2014

Acknowledgements

I would like to thank Dr. Mirko Guaralda first and foremost. His guidance, motivation, and patience helped me more than I can express. As an academic mentor, I have felt privileged to have Dr. Guaralda as my supervisor, and without whom I would have never completed this research. Also, my Associate Supervisor, Professor Robin Drogemuller, who was instrumental to this research for anything digitally related. I would also like to thank my parents Ronald and Margaret Jack, and my partner Eleanor for their support and encouragement over the past year, and through the entire course of my academic exploration.

I would also like to acknowledge some experts in their field, who have provided access to their vast amount of knowledge on all aspects of this research. Jim Mavronicholas, who introduced me to the 2010 Restoration Project on Brisbane City Hall, and provided an insight into Brisbane City Hall from a Principal Project Manager's point of view. I must express my thanks to Marcus Richardson, a Senior Heritage Architect, and passionate conservationist who had already researched Brisbane City Hall thoroughly and is partly, if not entirely responsible for the restoration of a neglected cultural icon. Without the help from Marcus and his willingness to be involved, this research would not have been possible. I must also express my appreciation to Research Fellows Bianca Toth and Ruwan Fernando for their continual support and digital expertise.

Chapter 1: Introduction

1.1 Scope of Study

Brisbane City Hall (BCH), located in the heart of Brisbane, Australia, was built from 1920 to 1930 and officially opened on April 8, 1930. Throughout its lifetime, BCH has had a number of restoration and maintenance works carried out, with the major campaigns occurring in the 1980s, and most recently, conservation work began in January of 2010 and finished in April of 2013. This research will focus on these areas of restoration work, as well as including the original 1930 designs and intent. Due to the most recent conservation work, a number of research prospects have given rise on the building itself. Opposed to the cultural significance of the building and the structural composition (individual research projects carried out by fellow researchers), this research paper will solely focus of the buildings pathology and the breakdown of the issues that produced such a large scale and highly budgeted restoration project.

In January of 2010, BCH closed its doors to the public to undertake a major restoration and repair works. This ensuing project, which was drastically overdue (Baker, 1992), is the direct result produced from a solitary report that was presented to Brisbane City Council (BCC). As part of the planning for the future of the BCH, City Assets (an internal department within BCC) commissioned a master plan in 2006. Following that, the Queensland Fire and Rescue Services (QFRS) issued a Commissioner’s Requisition to Council to undertake a Fire Engineering Report (FER) to address fire safety issues at BCH. In response, a report was prepared and the final version signed off in February of 2007. Within this report, BCH was found to be well below the current building standards, particularly relating to evacuation times (including exit spacing and procedures), sprinkler systems, and smoke detection. The adoption of the FER under the provisions of the Queensland Fire and Rescue Service Act 1990, established it as the controlling statutory compliance document for the BCH which supplants the relevant provisions of the Building Code of Australia (Brisbane City Hall: Concept Master Plan Review Report 2007, City Design). Once this FER was presented, BCC, through its internal department City Design (that deals primarily with historic and heritage related built forms), developed a sequence of investigations, decisions and actions that conformed to the Burra Charter (The Australian ICOMOS Charter for Places of Cultural Significance) process to produce a report to comprise a comprehensive addendum to the conservation management plan that provided policy and direction on all aspects of the proposed fire safety upgrade and overall restoration works proposed for BCH (Brisbane City Hall: Schematic Design Report 2009, City Design). From this point in time, BCC chose to outsource the project, and the multitude of components that make up its built form, to various private practitioners and specialised firms and companies.

1.2 Objectives and Research Question

Throughout BCH's lifetime, the one continuing issue that has plagued the building is its lack of documentation and recorded data. Since Cultural Heritage sites are mostly documented with traditional drawings or original papers, this case study seems to suffer a noticeable lack of information, even in its traditional paper form. This building, like many others, historically has data in hard copies and in many cases interventions have not been fully documented. In order to understand the pathology of the building and the causes-effects that have generated the situation before the most recent 2010 - 2013 restoration, a strategy to effectively manage the accumulated data is advisable. From its origins in 1930, the plans that were originally produced by the building's architects differ from the actual built form. These inaccuracies in documentation have continued with amendments and restoration works for over 80 years, up to and including the latest of conservation projects in 2010 – 2013. The research presented here examines BCH, but more specifically its built pathology, in order to define the work that has been previously undertaken. This, as a result will identify the faults and residual complications that may exist. Additionally, this research offers a digital framework for a heritage management system that can essentially act as a facility manager for heritage related data. This supplementary element is designed specifically to categorise building pathology, which at present is a disjointed and segregated research element, and has yet to make the technological leap and integrated abilities that the rest of the architectural field has and is currently experiencing. Ultimately, this research aims to investigate *how the 2010 – 2013 restoration project of Brisbane City Hall can inform the implementation of a heritage management system,* whilst updating and *outlining the buildings history through its built pathology*.

1.3 Research Methods

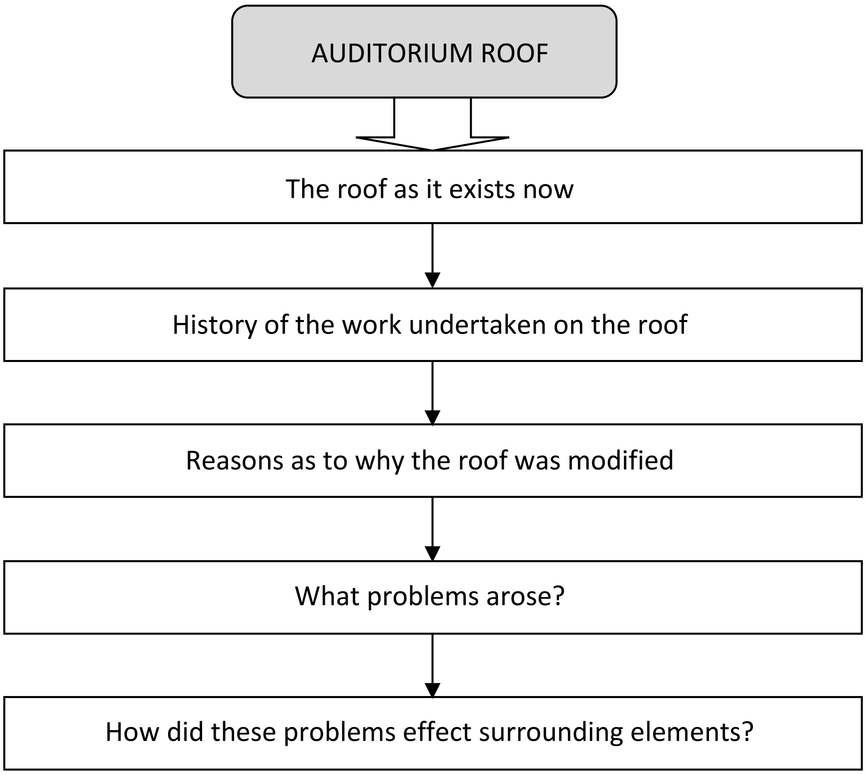
The data gathered to produce this research comprises of a number of research methods in order to obtain the necessary information to provide a comprehensive evaluation of the research question proposed. Data was composed by way of historic/heritage research at a number of depositories that contained any type of information relating to BCH, and additional qualitative data were collected through interviews with key members of the BCH restoration project. To enable an inclusive understanding of the digital tools used throughout the entire restoration process, the known media types and systematic programs that were utilised have been explored and examined. In doing so, this data set will provide the heritage management framework projected in the research question, and give the background information needed to quantify whether the restoration work at BCH can provide a resolved heritage management system to be utilised by industry professionals. Additionally, quantitative data can be extracted through the digital models that have been created in conjunction with restoration works (however, these exclude unknown additions to or subtractions from, and previous undocumented work) and evidence of building issues can be identified. The digital models used to obtain this information were built from the BCC's own data collection and original drawings. This data output was then reviewed against the heritage management principles (refer chapter 6) and results were edited to accommodate the proposed digital framework. The focus of this constituent will be the main element of BCH, the auditorium, which includes the highly distinguishable dome. The selection of such an area responds primarily to its iconic status and its position above all other built environments contained within BCH, as well as the overall costs that relate to restoring such a space.

Figure 1: *Brisbane City Hall's Auditorium pre 2010 – 2013 restoration project* (Brisbane City Council, 2012)

To be able to identify the issues that arose with the auditorium of BCH a large number of documents, pictures, records, and various building data (both hardcopy and digital) need to be collected and correlated from a wide spread area in order to develop a clear understanding of the building materials, techniques utilised, and overall grasp of the built pathology. This process is very time consuming, and, depending on the systems put in place to organise such a collection, this course of action could lead to errors, primarily the presentation of misinformation or the unavailability of records due to a number of circumstances that may occur. The current system of organising the multitude of information relating to any built work undertaken on BCH is technologically outdated, and extremely inefficient in terms of locating particular details. Not only does this system fail in a generalised search manner, but to obtain professional data, such as documented heritage works, the process is confusing, restrictive, and inadequate. To acquire the necessary information to gain an absolute awareness of the heritage conservation that had been undertaken on BCH in the past (pre 2010 work), the number of reference sites that would have to be visited leads to an information 'leaking' scenario. In order to obtain a small percentage of background data, four (4) locations needed to be visited. These locations were spread over a considerable distance, and consisted of the State Library of Queensland (SLQ), the Queensland State Archives, Brisbane City Council Archives, and Brisbane City Council offices at Green Square. It should be noted that of these four locations, three are publically accessible, while the fourth (Green Square) was made available by BCC for this research.

In response to these problems of data sourcing, further research has been undertaken on another major component relating to the digital elements, or tools, that have been utilised throughout the entire restoration of 2010 to 2013. Even though all the information has been collected from the buildings beginnings in 1930, the importance of the current work being conducted in BCH will be the main focus of the research, primarily due to the advancements of digital media and digital systems since BCH's last restoration period in the 1980's. This data set, including BIM (Building Information Modelling – it should be noted that in this context, BIM is defined as *the creation and use of computable information from design to construction (Baty, 2012, 34))*), 2D documentation, photos, and various other sources will be evaluated against the information blocks presented through the interviews and heritage guidelines, to form a project specified viable framework of the collaborative, systematically breaking the componentry down into uniformed sequences.

To provide a stable and logical database of this information, a heritage management system is envisioned to record the work that has been conducted in BCH. With a focus on the auditorium of BCH, the issues that have arisen throughout its history will be shown in a pathological sequence, with a cause and effect nature, highlighting what issues led to what problems, and how those problems are interconnected throughout the hall. It is important to be able to identify such problems and project these within an environment that will visually break down what has happened in the past, and how these have been dealt with according to Burra Charter guidelines, and the building codes of that particular time. This sequence is composed of a number of stages that provide different data sets, and the main string of information is comprised in the following order using the auditorium roof as an exemplar:



When applying this method of investigation, the buildings pathology is automatically broken down, and the information is presented in a readable and logical manner. Apply this within a digital environment, and these interconnections can be replicated, and more importantly, allowed to be updated, to explain the reasoning for conservation work, as well as highlighting the errors that may have been made in the past, which will enable a greater understanding and awareness of the building and its history.

For the current conservation work being completed at BCH, the digital data that is being produced makes way for a digital system to be not only produced as a by-product or afterthought, but to be integrated as a real time progressive database. Throughout the course of restoration, the use of digital tools, whether it be a documentation program, 3D model, digital photos from cameras, phones, tablet PC’s, have been the informative factors to which no previous BCH project had been privy to. However, this information has been captured by digital means, but the same problem has continued in that this data is distributed to specific people or certain groups, firms, or companies, opposed to being collected in a central, singular location. With this distribution of information, along with the data that is currently deposited at various locations in and around Brisbane, there is a great opportunity to evaluate how these digital tools can be utilised more effectively, and more efficiently, for not only this particular project, but as a resource to be used in future built heritage conservation ventures. Although a generalised approach to the configuration of a 'public' database would benefit the BCH restoration project immensely (such a system could be used to educate the public on why the work was done, and where their taxes were spent), this research will aim to provide a heritage management system that is more accustomed to the professional uses, particularly that of architects.

1.4 Outline of Thesis

Within this thesis, Chapter 2 will focus on BCH, but primarily centred on the iconic central dome and its underlying auditorium. This chapter will provide the history, cultural and historical significance, restoration, and accompanying Burra Charter and heritage conservation guidelines. Chapter 3 deals with the foremost authors and theorists relating to the corresponding themes of investigation: architectural heritage and adaptive reuse; building pathology of architectural heritage; and digital tools. These reviewed topics will provide concluding arguments that identify the course of action to which this research will adhere too. Chapter 4 will examine the methods and design of the research in order to answer *how the 2010 – 2013 restoration project of Brisbane City Hall can inform the implementation of a heritage management system that outlines the buildings history through its built pathology*. In asking this question, this research aims to investigate the restoration process of BCH to evaluate possible strategies to record and manage data connected to building pathology. Four main objectives need to be completed to do this, including: a full exploration into the restoration/rehabilitation of past and present projects relating to BCH; the examination of the conservation theories adhered to by all conservation work on BCH; an examination of the management systems of building related data that have been utilised, both presently, and in the past; and to provide a digital heritage management framework that is subject to the relevant factors that constrain this type of project, ultimately structured by the conservation theories that were employed, and incorporating Burra Charter guidelines and sequential information data sets (cause and effect categories/stages). Chapter 5 focuses of the results of the research, and discusses the outcomes presented, and Chapter 6 takes the next step by introducing a framework for a digital tool in the form of a heritage management system. Finally, Chapter 7 will provide the conclusions observed throughout this research project.

1.5 Contribution to knowledge

This research attempts to contribute to knowledge in the field of built historical analysis and its incorporation into conservation architectural projects. Utilising a method of digital integration, this study provides an avenue in which architects (and numerous others) can access all the building data of an historical building through a heritage management system in order to reduce the loss of information that is consistently related to historic and heritage classed buildings. Utilising Brisbane City Hall and its 2010 – 2013 conservation as a case study, a framework for the inclusion of such a management system within the BIM field is offered as a tool to negate the loss of information contributing to a buildings pathology.

Chapter 2: Brisbane City Hall

2.1 Introduction

Brisbane City Hall has been reviewed as a working case study through the relevant literature that the Brisbane City Council has accumulated for both the public and internal factions. This evaluation will provide background information on the building as an overall component, however, the main focus of the research will pertain to BCH's principal factor, the central Auditorium and Dome. Within this element of the review, Australia's textual reference for conserving places of cultural significance, the Burra Charter, will also be investigated. Case study conclusions will be made to finalise the chapter, and highlight the overarching issues with the building, and the reasons to which they occurred. This chapter aims to present an encompassing investigation into BCH and underline the principle findings.

Figure 2: *Brisbane City Hall official opening 1930* (Official Opening of City Hall, Brisbane, Queensland, 1930)

2.2 History

Brisbane City Hall was designed in 1920 to 1921 by architectural firm T. R. Hall and G. G. Prentice Architects in response to Brisbane City Council's requirement of a City Hall and Municipal Building to be built on the site of 64 Adelaide Street, Brisbane City (Brisbane City Council, 2006). The structural elements of the building were designed by R. J. McWilliams who was a structural engineer employed by Hall and Prentice, and on the 29th of July, 1921, construction commenced following the laying of the foundation stone by HRH Prince of Wales Edward VIII. BCH was completed in 1930 and opened by the Governor of the day Sir John Goodwin. In 1992 the City Hall was officially listed in the Queensland Heritage Register under the Queensland Heritage Act 1992. Throughout its lifetime, BCH has had numerous restoration works carried out on it, and a number of cultural and economic factors have influenced its status and building identity. All these alterations to the building have produced inconsistencies with regards to the recorded information on BCH compared to its physical subsistence. Although the original drawings of Hall and Prentice are still in existence and held by BCC (Figure 3), it is an *'observable fact that some original built elements are not as shown on the plan'* (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009). A number of contributing factors could have caused this discrepancy, including budget cuts and the long time frame of the construction period, however, according to BCC (2009), there are no known 'as-built' sets of drawings of the completed 1930 building.

The original design by Hall and Prentice met the BCC's brief for a City Hall and Municipal Building by providing the former in a cylindrical domed form, and wrapping a hollowed square of the latter around the outside of that form (see figure 3, lower left image). Within the inside corners of the hollowed square Municipal Building are four light wells that give natural light to the internal spaces, and allow for natural ventilation via user operated windows. Circulation throughout the building is provided by the vestibules, lifts and stairs, which are located in the areas where the central City Hall cylinder touches the inner walls of the Municipal Building. Located towards BCH's eastern facade, facing King George Square, stands a 92 meter tall clock tower that provides Brisbane City with one of its most iconic and recognisable landmarks (Brisbane City Council, City Design, 2007).

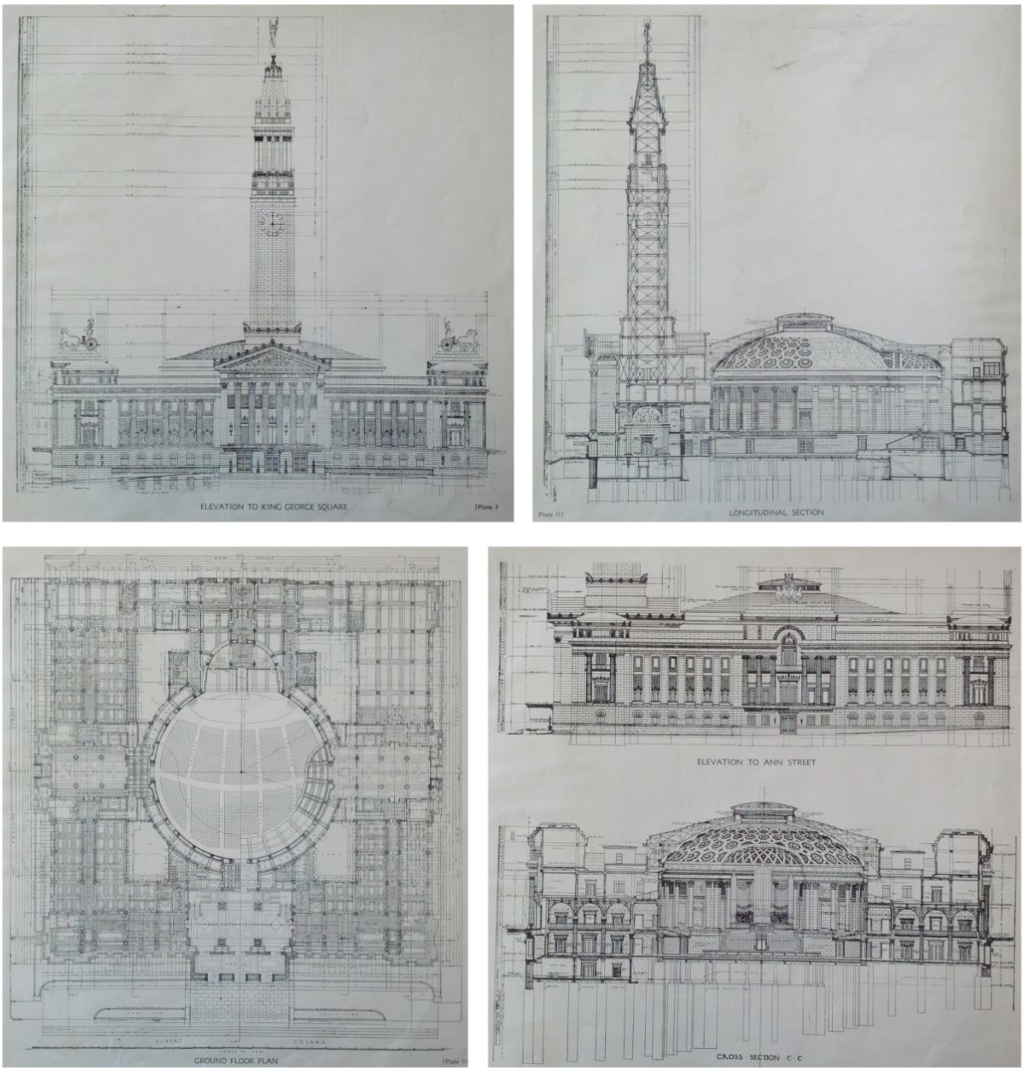


Figure 3: *Original architectural plans of Brisbane City Hall by Hall & Prentice* (Brisbane City Council, 1930)

2.3 Cultural and Historical Significance

Although City Hall has been altered over time, the original design intent is still imbedded within the building. The cultural significance of such a building has only increased with its 80 plus years since its construction, and a number of culturally significant facets can be identified. The following are only some of the significant factors that BCH provides, both culturally and historically (Brisbane City Council, 2006; Brisbane City Council, City Design, 2007; Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009; Brisbane City Council, City Design, 2009):

- BCH has become an icon evoking an image of the City of Brisbane, and used in the stylised logo on BCC literature, and can be identified throughout Brisbane on any Council related services

- BCH has continued as a focus point for a variety of community activities since 1930
- BCH has catered for the Council Chambers and City Governance since 1930
- Has become a city centre landmark and point of reference
- Is a fine example of a Classical Revival civic building
- It is the largest and most expensive of any Australian City Halls and one of the last civic buildings constructed in the Classic Revival style
- Is a building that has drawn on local materials and skills
- Incorporates quality art works that adorn the building, such as sculptured and leadlight work by local artists Daphne Mayo and William Bustard
- Its role in the second world war as a hub of Brisbane's wartime effort
- It is a demonstration of confidence in Brisbane city centre and municipal government.

While the cultural and historical significance of BCH can be identified, argued, or reviewed, what cannot be disputed was the state of disrepair and neglect that the building was in prior to the major restoration project of 2010. Until a complete building evaluation was undertaken that identified all the issues with the building, BCH was in considerable danger structurally, culturally, and economically (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009).

2.4 Restoration

BCC minutes and documentary records show that a process of change to BCH has been continuous since it was completed in 1930, with major periods of alterations occurring in the 1940s, 1960s, 1970s, 1980s, and the largest and most recent in 2010. These changes, excluding the latter, are generally '*incompletely documented and recorded, particularly those of the 1980s that were carried out by external agents*' (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009). Each major period of change was in response to its own set of imperatives, and each was distinctive in its scope and intent. In the 1940s BCC was concerned to increase its administrative accommodation, and as the need expanded, so did the inclusion of additional internal walls and false ceilings to separate and increase office/work space numbers. In the 1960s, major repairs were carried out to both structural and decorative elements. In the 1970s the use of the building shifted to a community focus after the BCC administrative staff moved out into the adjoining Brisbane Administrative Centre at 69 Ann Street. In the 1980s the focus was on improving the amenity of the civic offices and imparting a new aesthetic to the building through finishes and colour schemes. This push was warranted due to the years of neglect and fading state of the building, though the Lord Mayor at the time, Alderman Sally Atkinson, altered the building (especially in paint colour) from its original presentation to match the trends of the time. The latest restoration work that has been undertaken is the product of a thorough investigation that originated from a BCC Master Plan and a resulting Master Plan Review Report in 2006 (Brisbane City Council, City Design, 2007). This review was undertaken, in part, to the primary task of delivering an approach to meet fire safety regulations that currently exist to achieve Building Code of Australia compliance with the conservation of the cultural heritage significance of BCH. Consultants had completed a Fire Engineering Report and Services Upgrade Report that itemised the requirements for achieving these building codes, as well as a new overlay of efficient building services (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009). In order to assimilate the required work within a heritage listed building, City Design's Heritage Unit methodically examined the Burra Charter guidelines and proposed a system of conservation work that would achieve both sets of parameters. From the most recent restoration project, considerable costs have been allocated and raised in order to meet the requirements stated. A major component of this work has been invested into updating the central auditorium and dome roof, arguably the most identifiable feature of the building. Throughout the buildings life the auditorium and dome have had very little changes, with most of the restoration or updated work occurring within the outer Municipal Building. The modifications that have occurred mainly relate to the stage and balcony areas, with the needs of increasing seating numbers, and performance space. From these minor alterations however, significant issues have resulted. With the combination of those modifications, and the rest of the neglected components that make up the internal City Hall section of the building, the largest amount of work for the 2010 restoration project has been dedicated to this zone. Due to the increased construction and restoration volume of this space, the most important elements of heritage conservation and Burra Charter methodology guidelines are reflected within this section.

2.5 The Auditorium and Dome

Being the central focal point of the entire building, and standing three stories high, BCH's Auditorium (Figure 4) has provided Brisbane with a venue that has accommodated a wide array of uses, including music and dance concerts, citizenship ceremonies, lectures, and formal gatherings. Prior to its most recent restoration, '*the Auditorium required substantial rehabilitation'* (Brisbane City Council, City Design, 2008) mainly due to inconsistencies that arose from its original design. The main deficiency of the hall relate to acoustic issues that were apparent on its completion in 1930. A multitude of work has been carried out over the building lifetime to try to rectify the acoustic problems, which were the product of '*a sound-reflecting dome over hard surfaced walls and floor, compounded by a sound-focusing curved balcony form*' (Brisbane City Council, City Design, 2008). Of these rehabilitation works, the most significant effort to improve the acoustics occurred in 1976 when the original tiled ceiling was replaced by a mineral wool material. This however failed to comprehensively fix the acoustic concerns, and in addition, caused additional problems relating to the release of material particles due to complications with the ceiling (Brisbane City Council, City Design, 2008). When evaluating the Auditorium and Dome, BCC searched for various options to achieve the needs the hall required without adversely affecting its heritage values. This goal was managed through the aid of a conservation plan, produced in 1992, that incorporated heritage conservation guidelines, and provided a reference to any heritage restoration work that BCH would encompass.

Figure 4*: Auditorium with internal domed roof* (Brisbane City Council, 2012)

2.6 The Burra Charter and Heritage Conservation

The Australian Burra Charter is a localised adaption of the 1964 Venice Charter that was developed as a code of professional standards that gives an international framework for the preservation and restoration of historic, culturally significant, or heritage listed buildings, monuments, or sites (Australia ICOMOS Burra Charter, 1999). According to Australia

ICOMOS (1999), the Burra Charter '*sets a standard of practice for those who provide advice, make decisions about, or undertake works to places of cultural significance, including owners, managers and custodians*'. The Charter consists of numerous articles that relate to a certain subject, including Conservation Principles, Processes and Practices, as well as defining guidelines on Cultural Significance, Conservation Policies and Procedures. Since the Charters adoption in 1979, minor revisions were made in 1981 and 1988, with further, more substantial changes occurring after a five year review to produce the 1999 document and supersede the previous versions. A variety of accompanying reference sources have emerged to enable a greater understanding of the articles and guidelines, including the Burra Charter with additional explanatory notes, and illustrated editions that reference real world case studies and indicate the approaches and guidelines followed. An important element of the document should be noted in reference to the 'articles' the Charter provides. These are a source of definitions used throughout the guidelines, and particular attention on the word 'conservation' is focused on in Article 14., where '*conservation may, according to circumstance, include the processes of: retention or reintroduction of a use; retention of associations and meanings; maintenance, preservation, restoration, reconstruction, adaption and interpretation; and will commonly include a combination of more than one of these*' (Australia ICOMOS Burra Charter, 1999). Of the many codes presented in the Charter, a defining point of the document refers to the management of a culturally significant place, and the need for a management plan to be integrated initially, and continually.

The Burra Charter (1997) states that '*a Conservation Management Plan prepared by a qualified heritage practitioner in accordance with the Guidelines of the Burra Charter'* should be implemented on heritage listed sites. In September 1992, a City Hall Conservation Plan produced by Bruce Buchanan provided this requirement for BCH. Though this report was thorough and covered the guidelines of the Burra Charter extensively, it can be summarised by the recommendations that were produced relating directly to BCH:

- To remove the roof top structures as opportunities arise, particularly if there is a change in the use of the child care centre which is located on the third (top) level of the building
- To regularly inspect and maintain the external fabric
- To retain, and where possible, reinstate the original plan form, corridors and light wells, and to acknowledge the variation detail and finish between public and service areas
- To respect the cultural significance of the original fabric in foyers, auditorium and Council chamber

- To acknowledge the design intent and modulation of the various levels of the building according to their original uses
- To regularly inspect and maintain the art works in conjunction with expert conservators
- New work should be detailed to allow future removal without causing irreparable damage to the significant fabric
- New work should be identified by concealed date stamping or small exposed brass plates
- Explanatory signs should be mounted in areas where substantial adaptation work has occurred, to interpret the original use and why the changes occurred
- Microscopic colour analysis of previously painted surfaces should be undertaken before any redecoration
- New services should be integrated into the building with minimal interference with the original fabric
- A program of regular inspection and recording of elements subject to deterioration should be developed and maintained to reduce repair costs
- All work carried out on the building should be accurately recorded and stored
- An inventory or original or early loose furniture and fittings should be compiled with the assistance of an experienced conservator
- The existing fabric of the building should be recorded by a combination of photogrammetry, measured plans, and photography
- A report on the condition and conservation of the external stonework should be commissioned from an experienced stone conservator
- All proposed work on the building should be assessed by the Council Heritage Unit to determine its compliance with the findings of this study and to coordinate any necessary applications for State Government approvals
- Publication of sections of the Conservation Plan for public sale should be investigated

The main constraint to applying the Burra Charter guidelines to BCH was the need for the current Australian building codes to be met, whilst still abiding by the heritage considerations. Bruce Buchanan's Conservation Plan met this challenge at the time of production, however the level of degradation of BCH was not fully known at this point in time, and therefore some of the recommendations needed to be revised in order to accurately prescribe a course of action for the building as it existed in the current time (Brisbane City Council, City Design, 2007). Of the conclusions made in the City Hall Conservation Plan, almost all have been followed in the latest restoration project, and prior to the work being completed, the heritage conservation parameters outlined in the Burra Charter have been considered and implemented.

Compared to the pre-restoration ideology and theory of conservation that was investigated and incorporated in BCC's approach to BCH, the outcome of the 2010 project differs greatly. This is due to a number of factors, but mainly because of the introduction of external parties to complete the work that needed to be produced. Initially, BCC's own City Design department (which includes BCC Heritage specialists) formulated and developed the process of conservation which was split into various stages relating to the buildings area uses, and at the time it was predicted that the building, excluding these areas, would remain open (Brisbane City Council, City Design, 2009). Once external contractors were engaged for the project, this option was no longer considered as the building was evaluated to be in significantly worse shape than originally predicted. Core tests carrier out on structural concrete exposed the failing degree to which BCH was in. The processes of conservation and restoration management that were original conceived for BCH had to be drastically re-evaluated in light of the new data being uncovered. The option of completing restoration work in stages was discarded, and a complete closure of the building was necessary in order to address the critical structural aspects that were not identified in the preliminary analysis. It should also be noted that with relation to the policy area, the Burra Charter principles have been extended considerably since the 1990s and there are now comprehensive guidelines for a whole range of adaptive reuse, new work, as well as alterations. The entire heritage regulation process has been a turbulent ever-changing work in progress since 1990, responding to the constant changes in planning philosophy, intensity of development pressure, investment in public infrastructure, political support, and state and local government regulations.

2.7 Conclusions

From its very beginnings, BCH has been poorly documented, and the records about the building have not been organised or correlated in a sufficient manner that matches a building of its type and status. As-built documentation from 1930 is nonexistent, and the majority of the documented evidence of restoration work previously carried out was incomplete, the task of restoring BCH was a major undertaking by BCC. These factors, combined with the guidelines adduced by the Burra Charter, have led to the substantial restoration project that has closed BCH to the public for three years.

Of the previous restoration works that have transpired (see Figure 5), the 1980's endeavour has proven to be one of BCH's main detrimental aspects in terms of record keeping and heritage values. Very little, if any, documentation of that period exists (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009), and little is known on the work that was produced. Until a recent inspection of BCH by Queensland Fire and Rescue Authority, and a culminating Fire Engineering Report by Beca in 2006, the state of the building was unidentified. Upon further inspection, and a thorough analysis of the building, structural issues were revealed, and BCC commissioned the latest restoration project from 2010-2013. Of the most recent conservation work, particular attention has been given to the Auditorium and Dome roof, as throughout its years it has been plagued with acoustic issues and usability concerns.

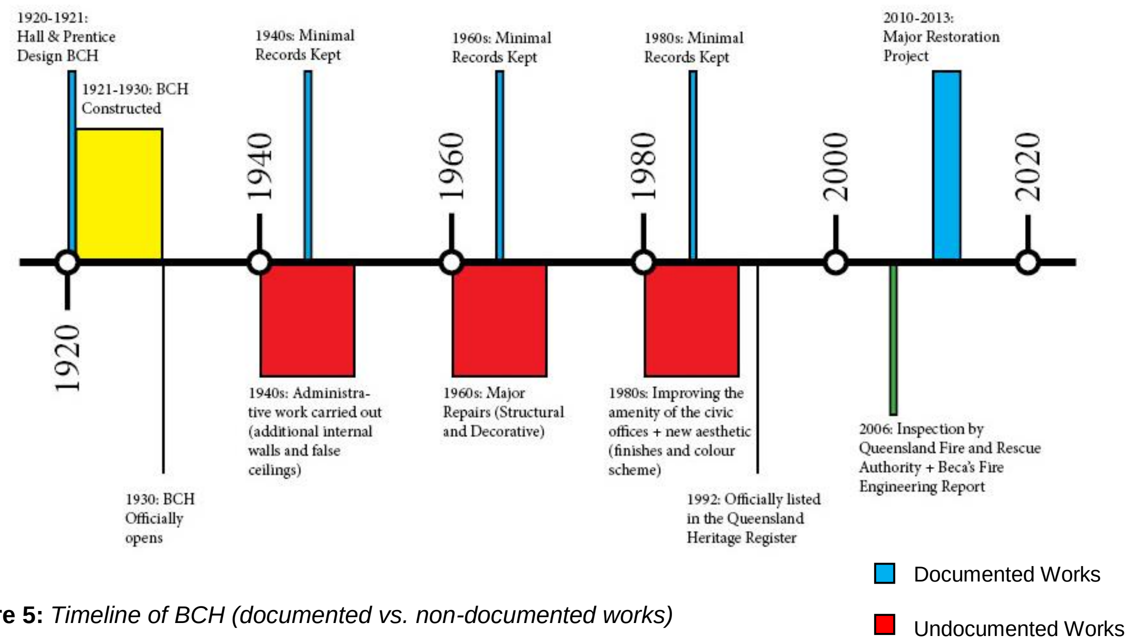


Figure 5: *Timeline of BCH (documented vs. non-documented works)*

The Burra Charter, produced by the Australian ICOMOS, provides the guidelines and procedures of dealing with the conservation of built heritage such as BCH. This document has been used by BCC's City Design department in formulating the approach to restoring BCH in its latest restoration undertaking. Prior to the actual 2010 restoration, City Design followed the heritage conservation parameters that are outlined in the Burra Charter, however the actual results of what has been completed within the building may no longer reflect the desired principles, processes, or practices due to changed circumstances, and the introduction of external private practitioners.

Chapter 3: Literature Review

3.1 Introduction

In order to enable a balanced and impartial dissection of the proposed research, a variety of literature obtained under three (3) separate headings aims to address the relevant and predominant works that currently exist and have existed in these respective fields. The purpose of the literature reviewed is to examine the individual elements that encompass the restoration project on BCH. An initial assessment of Architectural Heritage and Adaptive Reuse practices will provide the relevant background that is necessary to understand the contributing factors applied to BCH and the means and measures that currently exists to enable the rejuvenation and revitalization of these unused or neglected spaces. To address the underlying issues and identify the reasons that have led to the major restoration of BCH in 2010, an exploration into Built Pathology and the surrounding theories that apply to buildings of heritage status will provide a base of reasoning and accompanying strategies that are utilised as conservation/restoration approaches. As the 2010-2013 BCH Restoration Project is taking place in a digitally dominated era, an analysis of Digital Tools and the dominant programs/apps that are currently utilised within the building and heritage sectors will provide a digital overview of the technology used to aid the management building data, as well as identifying the restrictions of this technology in terms of relating directly to heritage implications.

3.2 Architectural Heritage and Adaptive Reuse

To provide a comprehensive analysis of Architectural Heritage (AH), a true definition must be acquired in order to understand the subject matter. The Oxford Dictionary defines heritage as ‘property that is or may be inherited’, and elaborates on its meaning with ‘valued objects and qualities such as historic buildings and cultural traditions that have been passed down from previous generations’ (Oxford Dictionaries, 2010). AH is also embedded in cultures and societies, and in most cases the defining quality of AH is its cultural significance. Places of cultural significance ‘*enrich people’s lives, often providing a deep and inspirational sense of connection to community and landscape, to the past and to lived experiences*’ (Australia ICOMOS Burra Charter, 1999). In order for heritage to be maintained within our built forms, certain preservation principles must be incorporated depending on the physical state of the building. Although arguments rage on about what methods to use for AH preservation, the subject of adaptive reuse (AR) has ignited interest mainly as a key sustainability factor, but also as a tool for heritage conservation (Bromley, Tallon, and Thomas, 2005; Stas, 2007).

One of the most important aspects in the conservation of AH is the way that heritage in static/built form is perceived. This concern is expressed by Burnham in comparing built to non-fixed heritage, who states that *"The treatment of moveable and immovable heritage is markedly different. While movable objects are highly valued and carefully protected, their immovable equivalents are often under the serious cloud of threat. This peril is the result of global mismanagement, failure of governments to provide adequate funds for their maintenance, and lack of recognition by the public that these disappearing resources are assets of major value"* (Burnham, 1998, p. 149). Locally, according to Bullen and Love (2010), there is growing acceptance within Australia both politically and publicly that conserving heritage buildings provide significant economic, cultural and social benefits. Furthermore, and in addition to Bullen and Love's previous findings, people feel a stronger sense of connection with their local surroundings through heritage. This is compared to the mentality associated with new building stock, in that it can be replicated anywhere, and therefore lends no specific connection to the local environment (Bullen and Love, 2011). Most of all, and in the more romantic ideals, an historic building is one that gives us a sense of wonder and makes us want to know more about the people and culture that produced it (Feilden, 2003), as well as the sense of place created both by the designers and the many people who have lived and worked in the building (Baxter, 2001).

Although it is generally agreed that conserving heritage buildings is a practice that provides many upsides, the question of who makes the decisions and how the work is managed, raises many issues. In Holtorf's (2007) article *What Does Not Move Any Hearts—Why Should It Be Saved?* he argues that heritage management policies can be politically variable, depending on the interests of the state and local councils. Dieter Hoffmann-Axthelm in his report to the German Parliament (2000) also argues this point. He believes that the private citizen should have the right, opposed to the state having the responsibility, in the decisions about what heritage should be preserved, and in what manner. Ultimately, this subject is widely debated, and the need for particular guidelines into this decision process has enabled key literature and procedures to emerge. Both internationally (The Venice Charter, 1964) and locally (The Burra Charter, 1979), certain principles have defined the processes in which AH is valued and appreciated. The broadly accepted values that exist in AH conservation tend to come under three major headings; emotional, cultural, and use (The Venice Charter, 1964; The Burra Charter (Rev. Ed.), 1997; Feilden, 2003; Jokilehto, 1999). *Emotional values* include wonder, identity, continuity, spiritual, and symbolic. *Cultural values* incorporate documentary, historic, archaeological, aesthetic and symbolic, architectural, townscape/landscape, and technological and scientific. *Use values* cover functional, economic, social, educational, political and ethnic (The Venice Charter, 1964; The Burra Charter, 1979; Feilden, 2003; Jokilehto, 1999). Although these values are regarded as the mainstream view, there are still arguments towards the criteria. Recently, there is pressure on these selective standards, with suggestions that the core criteria for determining whether a heritage place should be conserved should to be "*a site's ability to move people aesthetically and emotionally*" (Holtorf, 2007, p. 2). This point of view has previously been expressed by the prominent architectural critic and author Hoffmann-Axthelm (2000) who argued that aesthetic appeal is the most important criterion for determining whether a building should be preserved above all other possible values.

3.2.1 Adaptive Reuse of Heritage Buildings

The most common definition of AR involves converting a building to undertake a change of use required by new or existing owners (Latham, 2000; Wilkinson et al., 2009). When AR is applied to heritage buildings, it not only retains the building but conserves the effort, skill and dedication of the original builders (Bullen and Love, 2009). Bromley et al. (2005) have even advocated that AR is essentially a form of heritage conservation due to the buildings extended use and reinvigorated interest. However, many concerns arise with AR being applied specifically to heritage buildings. Bullen and Love explored these issues thoroughly in their article *Adaptive Reuse of Heritage Buildings* (2011) and isolated the main problems as being cost related, specifically the inability to estimate economic viability, and whether heritage buildings are icons that should be conserved or whether they are in fact eyesores and unviable for AR. It is also paramount to understand that many of the materials and components used in heritage buildings are no longer readily available and may have to be manufactured to special order. This alone addresses why an archiving system is so important. The idea to have an encompassed and immersive database in which materials can be stored by their meaning of architectural value and physical behaviours eliminates this shortcoming. Subsequent layering within such a system could identify these materials with the knowledge of the craftsmen who used them. As it currently stands, even if the materials are obtained there is no guarantee that suitably qualified craftsmen will be available locally or even nationally to work with them. These problems will impact on the economic viability of carrying out an AR project and may prove totally impractical for developers as an investment (Bullen and Love, 2011). A complex knowledge management system could lead to cheaper and more obtainable fabrications of elements as replicas of damaged ones. In complete contrast to these negative aspects, positive outcomes have been found through significant financial savings and returns, as well as the ability to transform heritage buildings into accessible and usable places that provide the added benefit of regenerating a particular area (Bullen and Love, 2011). Stas (2007) also agrees with this, claiming that there is no doubt that AR is one of the most effective ways to promote new urbanism and resist urban sprawl. Old buildings to a great extent contribute to the significance and identity of the urban fabric, and maintaining these buildings enhances the values of history, continuity, and identity (Stas, 2007). AR also conserves the architectural, social, cultural and historical values that are embedded in heritage buildings (Latham, 2000).

Although AR is a viable option when considering heritage buildings, the function of the adapted space needs to be taken into account. In Ahn's *Adaptive Reuse of Abandoned Historic Churches: Building Type and Public Perception* (2007), a study of issues in AR reveals that the transformation of a building for a different function is a major concern. Function is one of the critical elements that define the architectural integrity of a historic building. Therefore, an AR project is more difficult than any other preservation strategy (Ahn, 2007). Regardless of this, many buildings of cultural and historical significance are being adapted and reused rather than being subjected to demolition (Ball, 1999; DEH, 2004; Wilkinson and Reed, 2008; Wilkinson et al, 2009), with the most successful projects being those that "*respect and retain a building's heritage significance as well as add a contemporary layer that provides value for the future*" (Bullen and Love, 2011).

3.3 Building Pathology of Architectural Heritage

To conserve built heritage there are underlying theories that enable the process to be undertaken. Of the various hypotheses that exist around the world, three main approaches have emerged as leaders in the field. Before these are discussed, there must be a definitive definition of the term 'building pathology'. An extensive description is given by the Association d'Experts Europeens du Batiment et de la Construction (AEEBC, 1994), who draw attention to three separate, though interrelated, areas of concern:

(1) Identification, investigation and diagnosis of defects in existing buildings;

(2) Prognosis of defects diagnosed, and recommendations for the most appropriate course of action having regard to the building, its future and resources available; and

(3) Design, specification, implementation and supervision of appropriate programmes of remedial works, and monitoring and evaluation of remedial works in terms of their functional, technical and economic performance in use.

Building pathology can be described more simply as identifying faults/defects in buildings (Shelbourn, Aouad, Hoxley, & Stokes, 2000). This method of diagnosis is generally utilised, but not limited to, historic buildings, as the age of these structures have deteriorated due to various decay over time. With this being said, it is also critical to examine modern architectures also, making building pathology a recurrent theme. According to Feilden (2003), there are three main causes of decay in historic buildings;

- gravity;
- the actions of man (probably the greatest damage today); and
- diverse climatic and environmental effects (botanical, biological, chemical, and entomological).

Feilden's main causes failed to specifically identify the most destructive of them all; water (which would come under diverse climatic and environmental effects) (Watt, 1999; Harris, 2001). Air pollution, particularly in Europe, is also another main contributor to building decay (Watt, 1999). Ultimately, when dissecting a building to investigate its pathology, the information presented better helps to understand past ways of life and heritage significance (Lush, 2008).

Three main approaches have dominated the world of building pathology and its integration into building conservation. These have been described by Edward Augustus Freeman (as cited in Skarmeas, 1983, p. 40), who believed that within the subject of building restoration three systems were applicable; the Destructive; Conservative; and Eclectic Systems of Restoration. The Destructive System of Restoration disregarded all built form, essentially rendering the building obsolete, to be either demolished or built over. The Conservative System of Restoration aim to preserve a building from the moment the restorer finds it, including the preservation of all that has happened in that building up until that time. Finally, The Eclectic System of Restoration was a mixture of the two other systems, it would restore and remodel. Emerging from Freeman's ideologies are the schools of theory that govern the conservation movement.

3.3.1 Schools of Theory

To provide an outlook on the practices utilized by AH conservationists today, one must examine the approaches that have been formalized by three main schools of thought. John Ruskin and William Morris represent the English school of conservation theory, and this approach on building restoration dealt primarily with preservation, with the belief that preservation should be the only means of architectural conservation, and that restoration shouldn't and wouldn't be required. A multitude of conservation theorists, including Freeman, publicly criticised this approach, for the continued use of the artefact was the justification of any type of restoration (Freeman, as cited in Skarmeas, 1983) and most dilapidated buildings would certainly be lost if restoration was absent (Jokilehto, 1999). At the same time as the English method, the French school of conservation theory emerged, dominated by Eugene Emmanuel Viollet-le-Duc. Viollet-le-Duc's approach to restoration as written in the *Dictionnaire Raisonne de l'Architecture Francaise de XIe and XVIe siecle* (1866) is composed of two parts; theoretical and practical. The theoretical component analyses qualities that are necessary for a restoration architect to act upon, and the practical component applies those qualities to a series of techniques and operational procedures that are necessary for a successful restoration project. Viollet-le-Duc argued that restoration, both the term and the practice itself, should be considered as modern. To restore architecture is not to preserve, repair, or rebuild a building; it is to complete the building, reinstate the original design in a condition of completeness that could never have occurred without today's technology and intervention (Violette-le-Duc, as cited in Viollet-le-Duc and Hearn, 1990). This is further observed by Baxter (2001), who advocated that we should not hesitate in using technology to rebuild or upgrade a building, and that people should celebrate primarily the abstract intellectual achievements of buildings opposed to the tangibles, and replace materials with better-detailed products when and where they are needed.

The major difference between the English and French schools of thought is one (English) wanted the building to be completely original, with the belief that the building stood complete, whilst the other (French) believed that buildings could be improved or completed with modern day technologies and/or techniques (Jokilehto, 1999). Lying somewhere in the middle of these theories exists the Italian school of thought, which championed by Camillo Boito, tries to reconcile the conflicting views of his contemporaries to provide a somewhat 'hybrid' theory. Today, these schools of thought helped to produce the Venice Charter (1964), and for Australia, as discussed previously, a slightly adapted version called the Burra Charter (1979, with the reviewed 1999 edition being the primary reference) provides the guidelines to work off for heritage conservation.

Although these theories exist in well publicised documents, and building pathology can be identified through studies of heritage architecture, the one factor that remains is that these systems have been in place for a long time, and have yet to be adapted, updated and integrated within a digital realm. The importance of being able to provide such theories within a digital environment pertains to the evolution and continuation of such strategies. These theories can be discussed continuously, but unless they have a platform that can be integrated and constructed from their ideals, then they remain subject to segregation. There are many digital tools that can currently provide these options, including facility management systems, Building Information Models, and digital databases.

3.4 Digital Tools

There are a number of digital tools that are currently available which all relate to the gathering of information resources that allow for tasks to be streamlined, and an overall ability to enable quicker and easier workloads. To narrow the focus on these digital components, only relevant tools will be discussed, relating only to the field of architectural reference. These tools mainly consist of databases, Computer Aided Learning (CAL) systems, and BIM. There have been thorough and consistent documentation of built heritage that have helped to improve the understanding of historic structures, however, full exploitation of these resources have been impeded by their static, non-interactive nature as printed documents (Morrish, and Laefer, 2010). Adding to this analysis, and specifically relating to architectural conservation, Forster and Kayan (2009) state in *Maintenance for Historic Buildings: A Current Perspective* that to date, very few national heritage organisations have an integrated database for management systems. In Morrish and Laefer's (2010) *Web Enabling of Architectural Heritage Inventories* it is argued that the state of access to AH records severely limit their potential contribution to being used in the planning and permitting process. However, immediate downsides to digitised formats can be seen, as Charlton (2010) suggests that digital data is essentially meaningless unless it is contextualised. It is proposed that for digital archives, this contextualisation should be mediated by our initial method of creating, organising, accessing and navigating content. This has been studied in depth by Murphy, McGovern, and Pavia (2009) in *Historic Building information modelling (HBIM)* where a reverse engineering process is undertaken using multiple raw data sets produced by surveys and terrestrial laser scanning to produce full 2D and 3D models including methods of construction and material makeup. This study proves the importance of contextualised data due to the sheer amount of information that was initially produced and the resulting framework produced.

When exploring digital integration for heritage conservation, the primary tools to be optimised are databases. Context and technological progression are the key factors in dealing with database design. With reference to Borges' *The Library of Babel*, Chalton (2010) argues that the vast amount of information that can be accessed within an endless library, either physical or digital, is unattainable without the use of context. To minimise the torrent of jumbled data, context must be introduced within a digital system to enable the retrieval of specific information. Nevertheless, even with appropriate context, one must concede that the idea of an ultimate archival solution is undeniably impossible, due to the forever changing nature of human interactions with organization and technological advancements (Chalton, 2010). This implies that only present day options should be provided for disseminating heritage related content, with the facts of out-dated technology always evident. One could build a system to be integrated into future technology, but as that is unknown, only the information can be provided first hand, then ultimately adapted or integrated at a later time. In relation to this proposal there are numerous Base-Knowledge Models (BKM) theories that argue that it is not a matter of technology, but how knowledge is formalised and organised to meet the ever updating technology instead (Gero, and Maher, 1993).

Currently web-based systems exist that contain an array of heritage data. According to Morrish and Laefer (2010), an English Heritage web-based interface has both revolutionized access to collective historic and heritage resources and has enabled system administrators, registered surveyors, and all project contributors to make corrections and insert new material. However, this system is currently a standalone mapping interface, independent of each other, singularly tasked, with no cross referencing, and ultimately *“devoid of advanced inquiry or decision support capabilities”* (Morrish and Laefer, 2010, p. 17). Another option that is available which can rectify the flaws produced by the web-based system is case-based-reasoning (CBR) that is incorporated with artificial intelligence (AI) programs. This database can be specifically applied to heritage projects. Working off case studies, the CBR database utilises a cyclical process of the four “R”s:

- Retrieve the most similar case
- Reuse the case(s) to attempt to solve the problem
- Revise the proposed solution if necessary
- Retain the new solution as part of a new case

Shelbourn, Aouad, Hoxley, and Stokes (2000) researched this particular system and found that building faults are matched against the cases stored within the case base, to which a solution is suggested by the matching cases. Although more adaptive, the cycle rarely occurs without human intervention, and ultimately the process lacks dynamic and automated functions.

One of the major digital tools that must be examined with relation to any type of architectural project is BIM. It should be noted that opposed to the term ‘tool’, BIM is a ‘process’, with the tool component residing in the software (BIM software) that is used. In the article *The Rise of BIM* Baty (2012, 34) gives this definition of BIM as *“BIM is the creation and use of computable information from design to construction. BIM is not an ‘on-off’ switch, while the ultimate use of BIM is a digital file of as-built conditions for the owner, many are using BIM at a smaller scale to detect collisions or just model the project. The key to success with BIM is understanding that it is an information rich digital representation of a project”.* Charles Eastman, a pioneer of BIM and creator of one of the first building databases (Building

Description System) adds to Baty's definition by including two more important ideas that failed to be mentioned; coherence and coordination (2008). The definition of BIM is further developed by Spencer (2010) where he states that BIM has four key elements in terms of virtual construction, these are: three-dimensional design; 4D scheduling capabilities; 5D cost estimating; and emergent 6D lifecycle management, which uses the model to perform activities related to post-construction management of a facility. BIM's key elements can be considered as different stages of the building process, especially referring to new constructions. One could describe the endless features of what BIM programs are able to produce, but to determine the significance of BIM in regards to AH, the main concepts and digital outputs need to be identified. *BIM is the word* (2011) highlights one such advantage of BIM as being the clash detection of services within a building, where an integrated model can expose conflicts and clashes that traditional two dimensional working might miss. The current popular media for most architectural information are 2D images, drawings and photos. These are inadequate in representing 3D components, their complex joints and their relations, and it is often almost impossible to understand correctly the whole construction process. In such cases a common approach is to build a physical model (a traditional model) to examine the spatial layout, construction rules and other aspects, and hence to understand the building and the design concept (Cao, 2005). BIM takes the next step over traditional models of the past by creating a truly interactive model that can accurately plot the building down to the minutest detail. This is further endorsed and built upon by Horwitz-Bennett (2012, 35) who believes that BIM's benefits over conventional, two dimensional CAD drawings are well established, be it with optimized designs, shortened construction schedules or reduced change orders, as well as its capabilities to detect clashes through its visualization tools. He also suggests that an additional feature of BIM is the ability of these 3D visualization tools, where *"owners can easily toggle through a number of aesthetic design options to choose the most appealing look (*Horwitz-Bennett, 2012, 35). Goedert & Meadati (2008) also believe that BIM could eventually become the sole source of information on any building, including its facilities management and design planning.

One of the most challenging factors of BIM however is the compatibility and interoperability issues that have risen with the popularity and expanded use of BIM systems. Anderson (2008) argues the compatibility issues when using different programs to create a BIM model, where unfortunately, a model generated by an architect in one format will not be readily useable by a contractor who works with a different program. This can lead to further issues down the track, where a conversion of models between different software types can yield questions of whether all of the data is reliably transferred, or corrupted. This idea is further reinforced by Daley (2009, 33) as he states that *"There is a need for all parties to be working* *from the same platform in order for BIM to succeed. In a world where proprietary software architecture remains a widespread strategy, that's not easy to achieve. Everyone wants to set their own standard."* This is a paramount aspect. Dealing with multidisciplinary fields and actors, BIM needs to retain a 'knowledge translation attitude' all over the process. In October of 2012 the Smart Parameters Platform introduced the paper *SoftBIM – An open-ended building information model in design practice* at the 32nd Annual Conference of the Association for Computer Aided Design in Architecture where an interoperability strategy was put forth in direct response to 'hard BIM' (developed using proprietary software frameworks only). Although aimed to address interoperability issues, the study produced both pros and cons for each method of BIM (soft and hard).

Another big issue that BIM modeling raises is identifying responsibility for the maintenance of the model. When the architect, contractor, and subcontractors all have access to the one model, a protocol has to be developed and agreed upon from the beginning on how changes are going to be made to the model (Anderson, 2008).

According to Gerrard, Zuo, Zillante, and Skitmore (2010), there are a number of key concerns that BIM raises, delaying its use in the professional field. These have been examined and identified in order of importance as:

1. Lack of BIM knowledge and expertise
2. Complete lack of awareness of BIM
3. Resistance to change
4. Inadequate technology and interoperability issues

Interoperability is a word that has been repeatedly linked to BIM from a wide range of sources. It is believed that due to the absence of a single model from day one, the field of BIM is somewhat disjointed as software vendors aspiring to gain commercial advantage forged ahead with different competing BIM implementations (Howell and Batcheler, 2005). Subdivisions in the field arise whereby a unified industry is the desired outcome, and for BIM to achieve its full potential, it requires a collaborative environment (Plume and Mitchell, 2007). Possible solutions have been examined in the research of Cheng, Yen, Chen, and Yang (2010), who have created websites that are specifically set up for hosting architectural digital data. From these digital repositories, tools are becoming available for anyone on the Internet to be able to access and explore digital models without having to buy expensive BIM software to interact with the model. However, this information is normally imbedded, and the user is unable to edit or modify its contents.

With BIM being of a database typology in its own right, the exploration of incorporating external database information is a natural progression. Currently, these external reference types are mostly limited to statistical information, and BIM specific data. With direct relation to BIM, digital databases, and heritage related building data, Jantz (2007) explores how developing trusted digital repositories will be crucial in the storage of future digital information. Jantz (2007), in parallel to Anderson's (2008) argument, also asks if it is possible to store digital models for up to one hundred years, and in one hundred years how can the viewer of the information be confident that they are viewing the original digital content? This correlates with Tost and Champion's (2007) paper, titled *A Critical Examination of Presence Applied to Cultural Heritage,* where they argue the importance of preserving heritage architecture, and how capturing historic architecture with digital tools preserves the architecture forever so that future generations can explore and interact with the buildings long after they are gone.

Further exploration into digital database systems includes industry specific tools that rectify previous database issues highlighted by Morrish and Laefer. These tools have provided a direct relationship between BIM internal database systems (built into the program) and external, updateable records. BIMserver is a Building Information Modelserver that essential turns a computer/server into a 'BIMserver', and enables one to centralize the information of a construction (or other building related) project by permitting multiple users (architects, structural engineers, mechanical engineers, and all types of industry professionals) to work on their individual components, and the complete model is continually updated (BIMserver, 2012). The core of the BIMserver software is based on the open standard Industry Foundation Classes (IFC), which is used to facilitate interoperability in the architecture, engineering and construction (AEC) industry, and therefore knows how to handle IFC data. The BIMserver is not a fileserver, but uses the Model-driven architecture approach, which is essential a set of guidelines for the structuring of specifications that are expressed as models (Frankel, 2003). This means that IFC data are interpreted by a core-object and stored in an underlying database. The main advantage of this approach is the possibility to query, merge and filter the BIM-model and generate IFC files on the fly (BIMserver, 2012). This resource provides an effective solution to the management of a BIM file, and is a free open sourced tool that can support and manage multiple users. Amongst the most prominent of these freely available 'servers' is the TNO developed BIMserver, however, there are also much more advanced servers that provide a more specialized output that relate to specific disciplines and materials, which include the readily available Tekla (building, construction and infrastructure management BIM tool) and Jotne's more advanced EDMserver and additional accompanying programs.

3.5 Literature Review Conclusions

Of the literature reviewed, the following conclusions can be made with reference to the particular category of study. The general perception of the authors who investigated AH reflect on the subject in a positive way, arguing that AH provides a country, nation, city, suburb, street and place with an identity and a link to its past (Burnham, 1998; Bullen and Love, 2011; Feilden, 2003; Baxter, 2001). There are however debates as to who decides, or considers, a building to be of heritage nature, and the political versus public interests (Holtorf, 2007). Consensus between the key heritage authors and organisations indicate that AH is valued and decided by three theorised categories; Emotional, Cultural, and Use (The Venice Charter, 1964; The Burra Charter (Rev. Ed.), 1997; Feilden, 2003; Jokilehto, 1999). Adaptive Reuse of AH not only conserves the effort, skill and dedication of the original builders (Bullen and Love, 2009), but it has also been suggested as a form of conservation itself (Bromley et al., 2005). Opinions differ between key researchers as to whether AR of AH is a viable option economically, but most agree that that AR can restore cultural, social, and historic values embedded in the heritage architecture. There are some researchers that oppose AR of heritage buildings when a change of its original function is proposed (Ahn, 2007), however, this option is not always available due to economic and viability issues, with the only other alternative being demolition (Ball, 1999; DEH, 2004; Wilkinson and Reed, 2008; Wilkinson et al, 2009).

To examine the Building Pathology of AH is to investigate and diagnose the faults and defects that exist or have occurred within such a building type. Gravity, manmade events and environmental factors have been identified as the main categories of causes to building decay (Feilden, 2003; Watt, 1999; Harris, 2001), and the study of these contributing factors provides a greater understanding to how a building was constructed and/or developed, and which methods and techniques were used (Shelbourn, Aouad, Hoxley, & Stokes, 2000; Lush, 2008). Three main approaches of building pathology were investigated by Edward Augustus Freeman, which subsequently evolved into the three main schools of theory on the subject. These 'school of theory' provide different opinions on what should be deemed as 'conservation', with the English supposition being that a heritage building should be left as it is, completely original, whilst the French belief was the building could be improved using modern technologies and materials. The Italian theory resided somewhere in the middle of these two ideologies, acting as a compromise to both points of view. These various schools of thought helped to produce the Venice Charter (1964) and the local Burra Charter (1979) and propelled the evolution of conservation theories and guidelines.

Digital Tools that relate directly to architectural parameters, such as digitised databases, CAL, CAD and BIM are continually developing to accommodate the additional needs placed on them. The lack of evolution within the AH field to assimilate and integrate with these systems has led to a significant weakness in heritage management. Charlton (2010) examined the need to accommodate this type of digital data, however, an overarching emphasis must be put on the contextualisation of said data. A number of database systems are currently available that have the capabilities to process AH data including CBR and AI incorporated platforms, and are accustomed to storing architectural data (Shelbourn, Aouad, Hoxley, & Stokes, 2000). Although these databases are updateable, they are currently void of automated functions, with manual allocations required to input the data in the correct context. The use and benefits of BIM as a conservation and record management tool for AH has been highlighted, with Goedert & Meadati (2008) indicating that this technology could be the sole source of information for any building, which includes any relating record, document, or data, as well as an overall facility manager. Interoperability and compatibility issues are currently plaguing this medium however (Anderson, 2008; Daley, 2009), as well as the responsibility issues of who will be maintaining and updating the files when needed.

The next progressive step that has emerged from the BIM platforms is the incorporation of external databases to integrate with BIM's own database setup. These external databases are currently limited to static numerical typologies, however, Jantz's argues in *Digital Preservation: Architecture and Technology for Trusted Digital Repositories* (2007) that developing external digital repositories for the use of heritage building data could change this format in the future. A number of online server products specifically dedicated to BIM management are currently bridging the gap between isolated models (files restricted to internal databases) and shared models (external, accessible to multiple user databases), although the input of data into such programs still remain strictly BIM related data types (Frankel, 2003; BIMserver, 2012).

Chapter 4: Research Design and Methods

4.1 Overview

Of the literature that was reviewed pertaining to the case study of BCH, a number of issues were highlighted that are reflected in the additional subject matters of AH, Building Pathology, and Digital tools. With respect to BCH, incomplete or inaccurate documentation has plagued the building since its construction. The conservation work that was carried out in the 1980's is a focal point of the examined documentation, as the BCC specifically note that documentation of any type is currently minimal or unobtainable (Brisbane City Hall Restoration Project - Schematic Design Report, City Design, 2009). Heritage conservation guidelines, adhering to the Burra Charter, were followed and implemented within BCC's own preliminary studies and recommendations, however the likelihood of this approach having actually taken place for the 2010-2013 restoration project is in dispute due to the inclusion of external contractors taking over the project, and the known and unknown circumstances that have occurred during rehabilitation works.

Expanding on the previous chapter and the literature reviewed, the current chapter defines the methodology of this research and specifies the research questions as well as its aims and objectives. Drawing on the firsthand experience of participating in the historical collection of data that relates directly to the case study introduced in chapter 2, a further insight into the history of the building, and the conservation methods previous employed is a foreseeable goal. With a focus on the restoration project of 2010-2013, and the focal point of the Auditorium and Dome, an investigation of the current digital tools utilised on the project, and the examination of the management of heritage data will be used to illustrate the current practices used, and the conservation theories adhered to. This chapter will then conclude by examining a conceptual framework produced with the aid of building pathology breakdowns and historical information sequencing, and the management of this data by the development of digital tools.

4.2 Research Question

Upon evaluating BCH and the accompanying literature that revolves around heritage, adaptive reuse, building pathology, and digital tools which are currently associated with architectural practices and built heritage, a clear line of research has emerged that incorporates all these factors and directly relates to the case study selected; *How the 2010 – 2013 restoration project of Brisbane City Hall can inform the implementation of a heritage* *management system that outlines the buildings history through its built pathology?* In order to approach this research question, a number of systematic steps need to be taken to procure the information that is available not only on the building itself, but the means by which the building has been documented, evaluated, preserved, and restored.

4.3 Research Aim and Objective

The aim of this research is to investigate the restoration process of BCH to evaluate possible strategies to record and manage data connected to building pathology. Certain objectives must be met in order for this to occur to be able to decipher whether BCH can be used as an adequate example. These objectives include:

- A full exploration into the restoration/rehabilitation of past and present projects relating to BCH;
- The examination of the conservation theories adhered to by all conservation work on BCH, incorporating cause and affect analysis with heritage conservation intentions paralleled to ‘as built’ outcomes;
- An examination of the management systems of building related data that have been utilised, both presently, and in the past;
- And to provide a digital heritage management framework that is subject to the relevant factors that constrain this type of project, ultimately structured by the conservation theories that were employed, and incorporating Burra Charter guidelines and sequential information data sets (cause and effect categories/stages).

The building pathology and resulting cause and effect, along with the initial design intent compared to the actual design outcome, need to be evaluated to provide a comprehensive heritage analysis of the building. This action will be utilised as the encompassing factor which will ultimately guide the framework of the proposed framework for the digital management tool.

4.4 Research Design

This research has been undertaken as part of Brisbane City Council’s Brisbane City Hall Restoration Project of 2010-2013 for the purpose of exploring the buildings pathology and its implication for the history of the building, and the alterations that have been made to the building fabric throughout its lifetime. In doing so, it establishes a medium between academia and industry, between theoretical discourse and the constraints of real world projects to foster the development of new and innovative knowledge (Maher, Nelson, & Burry, 2006). This research has collected built pathology data on BCH whilst examining the theories and the processes in which the construction adhered too, ultimately exploring how these theories were addressed within the conservation processes.

The research presented here has been conducted as part of a broader program. Due to the complexity of the BCH project, a number of research opportunities were presented that each related to a specified field of study. In order to thoroughly examine BCH and its history, a team of researchers are investigating individual aspects that focus on the Buildings Pathology, Structural Engineering, and its Architectural and Cultural Significance.

The ‘Schools of Theory’ on heritage conservation that was adopted for the BCH project will also be examined. This will be evaluated as a categorizing element when approaching the heritage management system in a digital setting, as depending on the theory utilised, the order and layout of the information presented will be arranged differently. Again, these theories will alter and change accordingly between the original restoration designs and the resulting built works. This evaluation will shed light on the heritage process to inform the user of the proposed management system of the systematic development and procedural stages of a heritage listed restoration project. As a result, the underlying theory will act as the foundation for the proposed database, and all the data presented will be categorized by the individual theory used.

A major component of this research encompasses the initial ‘intention’ for the restoration work, and the resulting ‘outcome’ that was produced. This factor can be contributed to the various schools of theory introduced as part of the literature review, along with the evolution of building pathology and the defining of issues/reasons that produce architectural conservation outcomes. Although all avenues of heritage approaches were originally evaluated by the BCC City Design department, and the Burra Charter guidelines followed and maintained, the resulting work that has actually been constructed may vary significantly compared to the ‘on paper’ proposed work. All the initial conservation design content of BCH will be reviewed and compared against the actual built outcome. This data, combined with the information obtained from site visits, and along with the various archives investigated, will work to provide a comparative that will highlight the need for an updatable database system that can accurately represent the building as it physically exists, opposed to the intended built form. This will aim to eliminate the errors from drawn plans verses the built product. The process of this clarification will also illuminate the reasons as to why plans were changed or altered, and provide a further level of investigation as to why these adjustments occurred.

Qualitative data have been collected through archive research and interviews that were conducted in order to acquire firsthand knowledge on the building and the processes in which the BCC collect and organise building data, with particular interest in the heritage guidelines used for heritage listed buildings, and the ‘school of thought’ processes followed in their conservation practices. Qualitative data have also been gathered through the digital models created for the restoration work on BCH (mainly BIM) to identify the elements of the buildings pathology that need to be focused on in order to produce the most logical framework for heritage management. This will consist of how and where to include data point sets within a BIM model, and how one building element effects a variety of others (i.e. roof leaking water effects joining walls, etc.). A pivotal element of this research relates to the intended conservations plans and the actual built outcome produced. This component of the restoration project will be examined from the origins of the concept, through the development made by the BCC, to the external parties involved with final mark-ups and alterations, and finally to the finished built product. Finally, in order to grasp the digital tools aspect of this research, an exploration of the digital media that was, and has been used for the most recent restoration work of BCH, from preliminary investigations by BCC and specialised firms, initial heritage design conservation strategies, and concept developments, to working documents and the multiple types of recorded data captured. This will provide the knowledge needed to assess the methods currently employed in storing this data.

A further exploration into the digital programs that have been used to aid and inform the restoration projects, particularly focussing on the 2010 works, as this rehabilitation project has taken place during the digital age of information processing, will expose the digital tools prominent within the industries involved with heritage conservation. Through this examination, a framework of the research can be presented via an objective – method – and data table:

OBJECTIVES	METHODS	DATA
Explore the restoration/rehabilitation of past and present projects relating to BCH	Participant-Observation Approach (data collection, site visits, archive research, interviews)	Comprehensive restoration records and data
Examine the conservation theories adhered to by all conservation work on BCH	Observation (site visits, archive research, interviews)	Conservation and Building Pathology theories to be used as digital base/structure
Examine the management systems of building related data that have been utilised, both presently, and in the past	Participant-Observation Approach (data collection, site visits, archive research, interviews)	Data systems and the integration of architectural/engineer programs
Provide a digital heritage management framework that is subject to the relevant factors that constrain this type of project, ultimately structured by the conservation theories that were employed, and incorporating Burra Charter guidelines and sequential information data sets (cause and effect categories/stages)	Participant-Observation Approach (data collection, site visits, archive research, interviews) + Digital Experimentation	Heritage Management System (Framework)

4.5 The Participant-Observation Approach

The method adopted for this research is one of participant observation. This primarily qualitative method of research, although quantitative dimensions are also present within this approach (Kothari, 2004), seeks to source knowledge within a practical setting whilst recognising the tacit element of theory and hypotheses that inherently exist. The relevance of participant observation to this particular research is evidenced not only by the fact that literature on this approach states its applicability to the investigation of tacit knowledge, but also by theorists of practice advocating its use to unlock the implicit practical knowledge possessed by individuals (Bourdieu, 1990, 1993; Zahle, 2012). The data collection generated by this approach serves to address the research aim by immersing the researcher in historical inquiry and data management processes that relate to the specified case study, and the observation of the conservation work, practices, and outcomes currently being produced on said case study. At the research outset, observation must take place first to allow the researcher to establish their bearings within the environment by learning the history, development, political implications and necessary background information (Fetterman, 2003) that is associated with the selected case study or organisation. What makes this a legitimate research activity *"is ultimately the social contribution it makes: the accountability and transparency of the theorizing method; the communicability of the theory to others; and its ability to transfer meanings and transform practice"* (Fook, 2002, p.93).

To realising the aim of this research, a comprehensive and detailed working knowledge of practices pertaining to information retrieval, record management, and building modelling is required. BCH (introduced in Chapter 2) will serve to provide a case study of heritage significance in order to gain an insight into how these practices are carried out within a local context. A comprehensive investigation of the case study will be accomplished through a thorough historical analysis, and with the aid of in-depth unstructured interviews.

4.6 Observation: Brisbane City Hall Restoration Project 2010-2013

This component of the research involved the outward-focused investigation of the most current conservation work being completed on BCH. An initial site visit was conducted in December of 2011 that involved a brief overview of the conservation work that had already been completed. Following this initial site visit, three more formal visits were organised in a guided tour setting. Unrestricted access was then granted to visit the site unsupervised, allowing for multiple visits throughout all of the year of 2012, and providing the means to evaluate the effectiveness of the tools and methods currently employed for heritage conservation. This process also allowed for the examination of the building pathology, as initially construction focuses could be identified, and the relating issues that consequently developed that affected its surrounding elements. Considering that the restoration project of 2010-2013 was of considerable scope, the focus shifted from the entirety of the project to an emphasis on the Auditorium and Dome, primarily due to its hierarchy within BCH, as well as the volume of work that was undertaken on it.

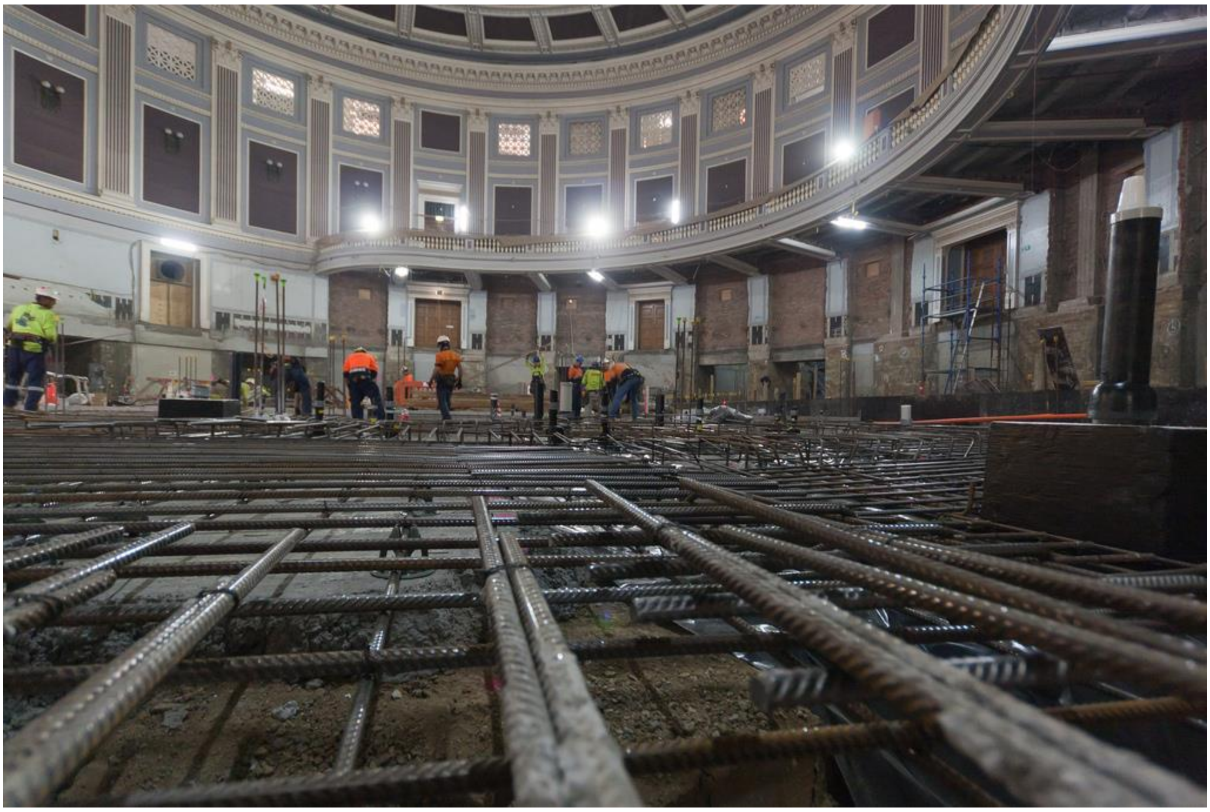


Figure 6: *Restoration work being undertaken in the Auditorium of Brisbane City Hall on the basement slab in October of 2011* (Brisbane City Council, 2012)

Figure 7: *Finalising work in the Auditorium in November of 2012* (Brisbane City Council, 2012)

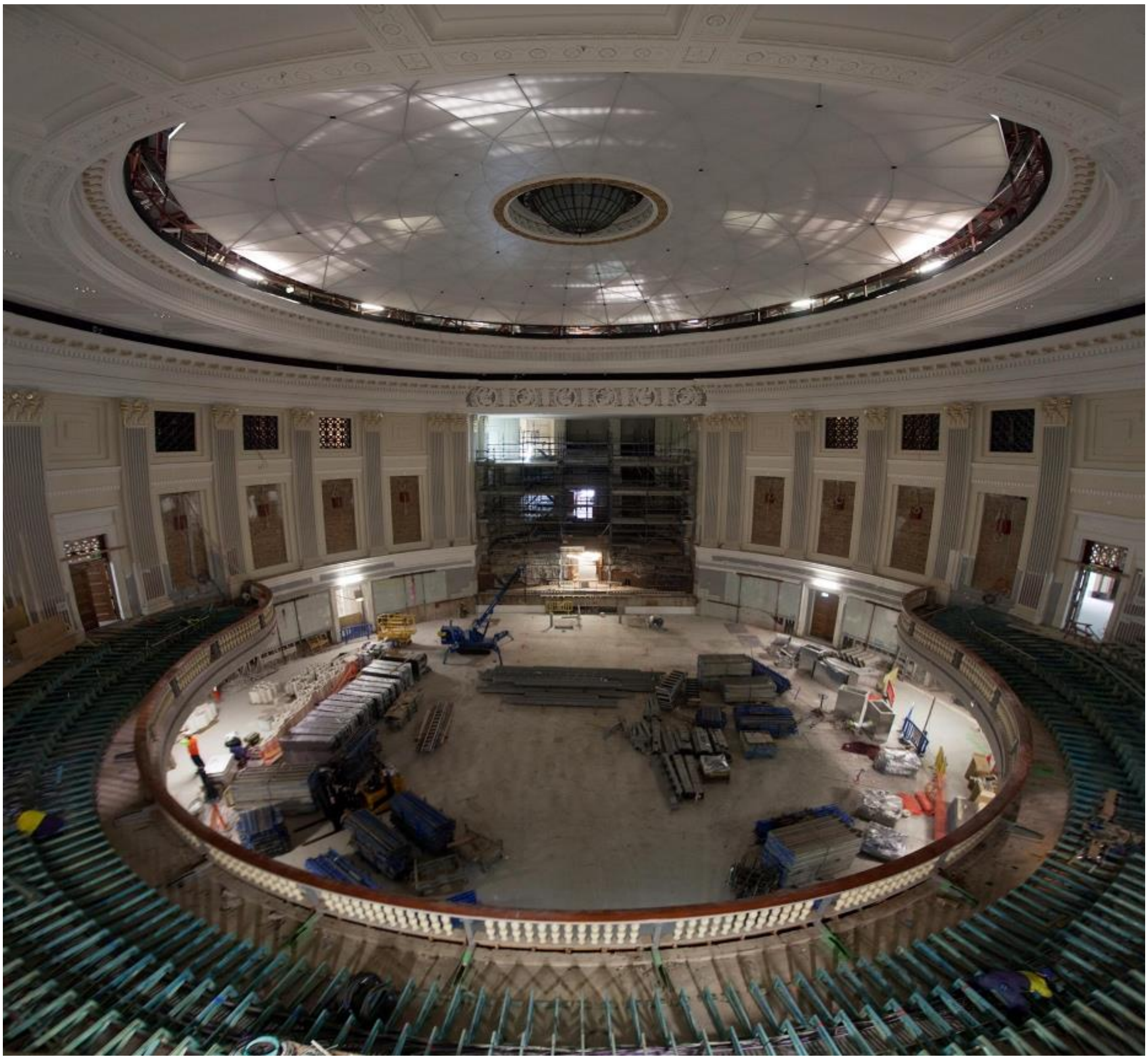


Figure 8: *Work completed in the auditorium prior to stage restoration and balcony seating in August of 2012* (Brisbane City Council, 2012)

In addition to site visits, the underpinning processes of managing the project were observed through BCC's City Projects Office, as well as the practices employed by BCC's City Design with the exploration of the project during its initial stage of development. Following directive from City Design, the BCH Restoration Project of 2010-2013 was to incorporate the use of 3D digital models produced on a BIM platform (design and FM output using BIM-enabled modelling software) in order to succinctly organise the building data in a form that is now required for City Design projects. The table on the following page indicates the locations of the observations, and what was observed in more detail:

Location	Year	Observations
Brisbane City Hall	2011 – 2012	Construction methods used to conserve the building The conservation work that was physically produced
Brisbane City Hall – Auditorium	2012	Original construction methods and the new construction employed to overcome raised issues Undocumented work that was built prior to 2010 Heritage principals and methods included or excluded from actual construction
Brisbane City Council Offices (relocated to 171 George St.)	2012	Project management of the conservation project
Brisbane City Council – City Design (Green Square)	2012	Original heritage advisement on conservation procedures Initial project involvement responding to heritage implications

4.6.1 Observation Limitations

Although access to BCH was obtained, the analysis of the building pathology was severely restricted as the project was already in the mid-construction phase. This information needed to be sourced elsewhere, and therefore the observation analysis applies only to the as built restoration work from December 2011 to December 2012. Data retrieval in the form of photographs was also limited, as photography was restricted on the site. It is unknown if any thorough photographic documentation was accomplished for the project. If it was, access to these images was not achievable through any BCC liaison or external party. Project data and building information produced and obtained by external contractors were controlled by those parties, and only limited information was sort by BCC. This source of updated information was unobtainable, equating to a significant absence of data. This process reflects the loss of records that have plagued the building in the past. Within this unobtainable information were the most recent digital models, although the documentation that has been produced reflects a 2D CAD format. This 2D output is more than likely produced from BIM software, although this could not be verified.

4.7 Participation: Brisbane City Hall Historical Data Collection

This second phase of the case study is an inward-focused data collection investigation exploring the management of heritage/historical information and the processes in which these records are procured. It adopts an active participant role on the BCH Restoration Project to be able to construct a conceptual framework for a digitised heritage management facility. Although the data of the building, or the records that actually exist, have been gathered previously, the whereabouts of these are not always known. There are multiple locations at which the information on BCH is kept. To be able to provide an accurate progression of building pathology, these various repositories must be examined in order to obtain a historically true representation. The practical benefits of engaging in this historical analysis enable first hand consolidation of data, as well as the inclusion of new and unrecorded information.

To participate in the collection of data, various locations were sourced that stored information pertaining to BCH. These sites incorporated both public and private institutions, and all are located in the greater Brisbane area, although the distance between each establishment was considerable. The following establishments were included in the participation element of historical research:

The John Oxley Library at the State Library of Queensland in South Brisbane houses unique resources ranging from diaries to newspapers that cover a wide range of content relating to the history and shaping of Queensland. As a public domain, this resource provides more cultural information opposed to specific building data. A digitised database is used here, however the majority of the information remains in hardcopy original format, and the database only serves to locate the information requested. A digital index of images does exist however.

Queensland State Archives is located in Runcorn and is the custodian of the largest documentary heritage collection in Queensland, to which it manages, preserves and facilitates public access to the state's permanent archival public records. A digitised index locates the hardcopy material, although in relation to BCH, the information sourced is very limited and refers only to Hall and Prentice material.

Council Archives are located in Moorooka and is associated with the BCC Libraries. Here the council stores public information mainly associated with annual records, and in-house record keeping. Information retrieval is limited for BCH, again only accommodating general enquiries, on par with the Queensland State Archives.

City Design is an internal department of the BCC located at Green Square in Fortitude Valley. This department incorporates the councils Heritage Unit, as well as associated works with the Council's Project Services. As the primary division involved with BCH, the amount of building data that was produced is substantial. As an internal sector of BCC, public accessibility is not allowed, however permission was granted for this research to be undertaken, and all records were made available.

Although there are a lot of records pertaining to BCH, this information has been distributed to numerous locations, with no centralised data bank. To obtain a specific piece of information, one must travel to the location that holds it. The majority of information that these repositories contain are of a generalised nature, with minimal building data in terms of architectural or engineer specifications. City Design held such documents and records, however much of that information was only gathered due to the studies that department produced as part of their initial assessment of BCH for the precincts master plan.

4.7.1 Participation Limitations

While every attempt was made to gather the maximum amount of data relating to BCH as possible, it is known that not all the information could be gathered, especially with regards to the collection of updated information on the restoration project of 2010. This is owing to the inability to access information held by external (to the BCC) contracting parties. It is also known that not all the documents in the possession of BCC were willingly divulged, due to these records either being lost in the councils system, or because it was part of a closed statutory process. As the majority of the data on BCH had previously been collected, the inclusion of a participatory approach shifted from a traditional view of data collection, to an accumulative outlook, gathering the pathological information on BCH and collating this information from a number of different sources and locations.

4.8 In-depth Unstructured Interviews

This method of research entails enquiry by way of open-ended questions or simple prompts that allow interviewees considerable interpretive latitude in responding. The type of unstructured interview adopted primarily in this research is best described as 'active', where negotiated interactions between the researcher and an individual who shares their interests are undertaken in and influenced by the research context (Fontana, 2003). Objective and subjective views were taken with relation to how the information gathered was filtered and summarised. Only subjective consideration were utilised within the 'participant' approach as a means to defining the logical and relevant data. Adopting a conversational tone, the active unstructured interview unfolds in a natural manner that encourages serendipitous exchange (Pohland, 1972). This offers a flexibility that affords the researcher opportunity to pursue relevant lines of enquiry as they emerge, delving into the subject matter in greater depth and with greater focus (Bogdan, 1973).

In this research, the unstructured interviews are referred to as in-depth unstructured interviews, as these have taken place and have been continually conducted over the entire course of this research (18 months). These interviews have been used to gather detailed information concerning BCH's history, planning, management, and documentation. This has occurred largely through conversations held with practitioners on site visits and at their offices while they worked. A range of observations were included in this process, from personal opinions, project experiences, and initial interpretations of the BCH project. This type of unstructured interaction was found to both support the case study approach and further complement the information gathered from these cases with an in-depth working knowledge of the BCH Restoration Project of 2010 – 2013, the buildings history, and newly uncovered aspects.

The interviews that were conducted comprised of a number of individual meetings with each of the participants. The first introduction of BCH was provided by Interviewee One, a project manager of the BCH Restoration Project for the BCC. This prologue of continued briefings examined the work that was underway within the building in the form of a walk through tour. Throughout this exploration a large amount of information was described by Interviewee One that covered a wide range of highly relevant topics, including the buildings pathology, the focus of this study. A number of interviews (both informal and formal) continued throughout the time this research thesis was developed, which led to another contact with more of a specialised discipline that corresponded with the heritage management system framework intended to be developed. Interviewee Two, a Heritage Architect and Design Manager who works for City Design, an internal department of BCC, was one of the primary figures that moulded the restoration project from conception to schematic design before the work was outsourced to external parties. Although Interviewee Two is arguably the leading expert when it comes to the heritage breakdown of the BCH, he was primarily interviewed for his knowledge of the heritage strategy that the BCC follow, including the Burra Charter guidelines, and the process of evaluating what building elements were considered historically or culturally significant. These processes decided the outcome of whether certain built components were to be kept, conserved, restored, or demolished. Both of the interviewees were asked similar questions pertaining to BCH, however, due to their specialties, the commonalities of discussion grew further apart the later into the interview period, as Interviewee One was the primary source of later works, and Interviewee Two for the earlier phase. This collective of information obtained directly from two of the original members relating to the 2010 restoration works aims to provide the basis of a preliminary framework for the management of the vast amount of data that is, at its present state, distributed amongst many places, people, government departments, and private practices. Although questions were asked relating primarily to the interviewees speciality, a number of common questions/themes were incorporated for a base to provide common outputs relating to both participants:

Question / Theme	**Time and Place**
What was your role with the Brisbane City Hall restoration project?	Interviewee 1 – Brisbane City Hall, December 2011 Interviewee 2 – Brisbane City Council Offices, January 2012
What do you think of the conservation methods employed?	Interviewee 1 – Brisbane City Hall, January 2012 Interviewee 2 – Brisbane City Council Offices, January 2012
What was your experience with conservation projects?	Interviewee 1 – Brisbane City Hall, January 2012 Interviewee 2 – Brisbane City Council Offices, January 2012
Which digital tools were utilised for the 2010 – 2013 conservation project, and how or why were they chosen?	Interviewee 1 – Brisbane City Council Offices, March 2012 Interviewee 2 – Brisbane City Council Offices, April 2012
The building data that relates to this project is minimal, considering its status within Brisbane. Why do you think that is, and what are your thoughts on this issue?	Interviewee 1 – Brisbane City Council Offices, April 2012 Interviewee 2 – Brisbane City Council Offices, April 2012

4.9 Digital Experimentation

Utilising the results gathered from the research methods employed, and the exploration of digital technologies that were exploited throughout the BCH Restoration Project, vital experimentation into digital tools and their attributes to heritage management will project a sychronised heritage management system that conforms to building pathology and architectural heritage ideologies and constraints. The output of such experimentations will be presented in the form of a theoretical framework of a digital management system, and combine its use as a standalone database with modern digital tools incorporated within the architectural and construction industries. The processes initially explored as methods of investigation will be adapted to supply a need for an integrated heritage management system that employs all the concluding factors resulting from the literature review and the case study analysis. This framework will be used as a concluding resource developed by the limitations of the current management systems incorporated for BCH, and the necessary data result sequencing prescribed by building pathology breakdown analysis which strictly conform to heritage guidelines and principles.

Chapter 5: Results and Discussion

5.1 Introduction

A number of factors relating to the BCH restoration project (2012) have exposed defining characteristics that make it an ideal choice as a case study for a heritage management system. The most crucial of these points include:

1. The large number of internal and external reference locations obtaining to the current and past restoration work;
2. The lack of an updatable system that is confined to a single source;
3. A large amount of information on built work undertaken on BCH that was either inaccessible (even to BCC) or completely misplaced or undocumented in the first place;
4. A summary of the building pathology and the cause and effect issues that existed.

Ultimately, all these points came down to one main issue, which was the inability to easily access any type of information that related to the building. This not only occurs as a problem for the general public, but also for the professionals who have to work on the building, and even BCC staff. Being a BCC project, and a major one at that, the latter of these groups having access problems highlights just how inferior the current system is.

Even though the restoration project of BCH is of significant value both historically and culturally, it appears to lack considerable information pertaining to the built work undertaken on it. Through the interviews that were conducted, it was clearly apparent from the start of this research that a large amount of BCH's background information was either lost or unobtainable. The initial site visit/tour held by Interviewee One included systematic analyses of water leakage through the roof that was obtained only by Interviewee One' personal research. He claims that conservation work that had previously been completed on BCH included the use of European practices of tarring the top of the roof (outside) to essentially seal the building from the elements. However, because the European climate does not match the sub-tropical climate of Brisbane, the tar continually melted causing major issues relating primarily to water penetration. To exacerbate the issue further, ash was used as a filler agent in the tar (produced by the local Brisbane Powerhouse of the time), which, when the tar melted, was exposed to the elements. Once exposed, the ash would swell due to water saturation and absorption, and in doing so would expand the tar once it set again, leaving cracks and gaps that riddled the rooftop. As the tar would be continually melting then setting, and the ash would swell and shrink recurrently, considerable water leakage was produced through the roof, which in turn affected internal concrete stability, internal wall components, and a variety of finishes used, including paint work, decorative plaster settings and plaster boards. Although all this information has been described by Interviewee One, there is no tangible evidence of what has been said. All this knowledge has been gathered by speaking with people who once completed work on BCH, and these series of event were explained by these sources. Very little evidence, and in most cases no evidence is found in any documentation of these conservation works. The work described was produced in a non-formal process, where a project manager, site foreman or overseer saw a problem that needed to be addressed and told someone to complete it without any form of citation to reference that particular change or adjustment. As this apparently happened on a regular basis, the amount of conservation work accomplished (particularly in the 1980s), whether it is minor or major, remains relatively unknown as the building stands. These types of undocumented works have caused these key issues with respect to producing accurate plans and models of BCH prior to the 2010 restoration project. To prevent this type of data loss, a range of media devices were utilised within the most recent conservation plan to capture all types of building interventions, regardless of how seemingly insignificant the changes or additions were.

With the ability to easily record this data, a highly accurate portrayal of BCH could be represented digitally at the conclusion of restoration work in 2013. However, prominent issues still exist, as this data exists only in sporadic form, and no ordered categorisation has been produced to file and store this information. Although the new restoration project is producing the evidence of built changes, the same issues that arose previously are being produced again. Once the data has been sent from the BCH building site to the necessary people, including private contractors that work outside the BCC, then this information can be held by that particular contractor, and once again exist only in the minds of the people who worked on the job at that time. Without a centralised digital database that all the work produced by this most recent conservation project can be sent to, continued data loss on BCH is inevitable.

5.2 Collected Data

During the data collection process that included research on any type of building records that were relating to BCH (from 1930 to the present), a number of separate locations were investigated to source the required information. Of these available repositories, the output of information was limited, disjointed, and unordered. The structure in which the information was stored was non-existent, and there was a considerable gap in the data relating to any work carried out in the 1980's. The process of finding any relevant information was highly inefficient. It is understandable that public access to such information can be limited (particularly searching non specialised repositories like the SLQ, State Archives, and BCC Archives), however the access to such information within the BCC should be easily obtained, especially as the BCH is of immense importance both architecturally and culturally. This however was not the case, as the location of the building data was either unknown, or unobtainable. This is the outcome of BCC being so departmentalised that no one knows who holds the information, or how to get it.

Of the information that was acquired through the repositories, almost all was in its original form, that being the hardcopy product. Although this information was categorised within a digital system, the resulting outcome would more than likely produce a location for the hardcopy material. Some of the results would lead to a digital copy, but this was more applicable to the minority, opposed to the majority of non-digital search results. There exists however a rather comprehensive database of photographs of BCH, mainly acquired at SLQ, but also available online. Although this database of imagery is detailed, the sorting of them is lacking. A digital search can produce a variety of images that contain incorrect descriptions, or fail to indicate the date the image was taken.

The digital models that have been created for BCH have provided significant data of what the building consisted of, prior to the 2010 restoration work. While considerable data was produced via this morphological data model, the accuracy of it is questionable. The only 3D file produced by BCC was in the form of an Autodesk Revit output, and this file consisted of minimal detail, not only in the form of the building elements that were modelled, but in the subsequent building data associated with the file. False ceilings and walls were excluded from this model, and previous work (1950s and 1980s) that was done on the building was left out. This led to the exclusion of the BCC Revit model by the outsourced architectural firm, as it was an unreliable source of information. A new digital file has been created for the latest restoration work on BCH, however, this file was supposed to be produced in a BIM format, but instead, the output was created in a 2D program. To be able to produce and integrate a digital heritage management system within a BIM format for direct use by industry professionals, a BIM file will need to be created from the latest building schematics. In order to be able to produce and integrate a digital heritage management system within a BIM format, that BIM file will need to be created from the latest building schematics. This raises a crucial element that must be addressed as there is no guarantee that these schematics are entirely accurate. A number of errors could have been produced through the surveys depending on whether the more accurate range based equipment was used, or if other not so reliable measures were taken. It also must be noted that the BIM operators themselves could add to the file errors either by mistake or through subjective interpretations.

This BIM model generation phase is paramount and specific methods of modelling the required elements need to be incorporated. The most thorough survey undertaken on the site should be attached as a survey link within the BIM model and double checked as to the scale and dimension of the imported file to the project parameters of the BIM file. Through the Autodesk Revit software this is easily achieved, and the linked file will predominantly be in the Autodesk AutoCAD format. In addition to this, the process should be coordinated with the surveyor team itself to eliminate any doubt or confusion within the file. By incorporating this method of data integration within the BIM process, it allows for direct referencing to the survey file and control over the layers that are included within it. As this research is dealing only with the theoretical framework for such a system, the actual file will not have to be produced. This however highlights the same issue that has plagued the collection of data for the BCH project. Because this data is not easily accessible, the management of these building records is a definitive problem. Without the existence of an updatable digital database that sources all the building data on BCH, the issues of locating the correct, and more importantly, the accurate information, will continue.

Figure 9: *BCH Auditorium after 2010 – 2013 restoration project - May 2013* (Brisbane City Council, 2013)

Of the building data that was collected, focussing on the auditorium and dome, the buildings pathology can be presented. However, the information that was obtained is presented only as a summarised breakdown, as the pathology in its entirety cannot be guaranteed due to the loss of information throughout the buildings lifetime. What can be assured however is what physically existed prior to the 2010 restoration work (as the building was), and what work has been done since (as the building now is – figure 9). To distinguish the various ‘causes’ and ‘effects’ the auditorium has been divided into five (5) major components. Presented in a progressive breakdown of the buildings pathology, these categories consist of the dome/roof, walls, balcony, stage, and the floor/basement. The analysis of each element is as follows (pages 58 – 62):

5.2.1 DOME / ROOF

DOME / ROOF

Documented Works (prior to 2010)	Issues that arose	Action taken to Rectify Issue	Issues emerging after rectification	Action taken to amend (2010-2013)
Tiled ceiling up till 1976	Leaking	N/A	Continued leaking	New ceiling will not copy the historic fabric but will clearly be seen as contemporary
Mineral wool material was sprayed into metal lath that was fixed to the underside of the ceilings framework (post 1976)	Ceiling damaged in several areas and was deteriorating, releasing fine rain of particles caused by leaking dome damage pre copper replacement	Copper Roof Replaced	Mineral wool continued to deteriorate and rain fine particles into the hall	New acoustic ceiling (removable) installed, also able to be lowered Existing waterproof sheeting on the top surface of the ceiling structure has been extended and perimeter gutter installed
N/A	Sound and Accoustic issues	2 loud speakers were added	Acoustic problems remained and centered sound only to central areas	Third centralised loud speaker added to existing speaker arrays to improve acoustic performance
N/A	N/A	N/A	Substantial maintenance costs for auditorium lighting	All high wattage lights to be replaced with low energy LED arrays to provide controllable lighting with very low maintenance requirements
N/A	Timber walkways located within the dome space are structurally suspect	N/A	Timber walkways located within the dome space are structurally suspect	Wide metal walkways replaced the older timber ones (resulted from consultation with QLD Fire & Rescue Service
N/A	No sprinklers or fire protection	Sprinklers installed	Existing sprinklers only provided in the dome section (not the auditorium space) and sampled test indicate pipe wall thickness as low as 1mm No drainage if sprinklers were to activate	Fire Systems: new automatic sprinkler system; new dome sprinkler water discharge system; new automatic smoke detection and removable system

5.2.2 WALLS

WALLS

Documented Works (prior to 2010)	Issues that arose	Action taken to Rectify Issue	Issues emerging after rectification	Action taken to amend (2010-2013)
N/A	N/A	N/A	Substantial maintenance costs for auditorium lighting	All high wattage lights to be replaced with low energy LED arrays to provide controllable lighting with very low maintenance requirements
N/A	Accoustics in the auditorium have been a major issue since construction	New accoustic panels installed	Accoustics remained poor and failed fire inspection for Updated building codes	Replace existing outdated and low performing acoustic panels with new high performance panels with backing panels of Calcium Silicate to comply with 120/120 fire rating
N/A	N/A	N/A	Failed to meet building code standards when investigated in 2006	Structural walls to first floor level and the balcony structure have been upgraded to achieve a 120/120/120 FRL

5.2.3 BALCONY

BALCONY

Documented Works (prior to 2010)	Issues that arose	Action taken to Rectify Issue	Issues emerging after rectification	Action taken to amend (2010-2013)
N/A	N/A	N/A	Failed to meet the current BCA requirements pertaining to access, user volume, and fire evacuation controls	BCA requirements carried out to meet today's standards Passageway entrance to balcony widened to improve circulation and facilitate quick evacuations
N/A	Balcony shape focuses sound into the central area of the floor significantly diminishing audience enjoyment	N/A	Balcony shape focuses sound into the central area of the floor significantly diminishing audience enjoyment	Original shape reconstructed Acoustic treatment of balcony facades with reversible acoustic panels
N/A	N/A	Track lighting	Highly visable and blocked some view points	New lighting is concealed behind acoustic panels
N/A	Not enough balcony space	Seating added to increase the compacity of the balcony and the hall	Overcrowded seating space and dangerous space due to fire evacualtion strategies	Reduced seating
N/A	Not enough balcony space	Seating added to increase the compacity of the balcony and the hall	Overloaded weight due to addition of timber to build up the height of the seat levels	Reduced dead load, avoiding significant structural intervention into the original reinforced concrete fabric
N/A	N/A	N/A	Substantial maintenance costs for auditorium lighting	All high wattage lights to be replaced with low energy LED arrays to provide controllable lighting with very low maintenance requirements
N/A	Audio control station was required to keep up with the current technologies	Audio box added to balcony	Current audio box location raised issues with sound quality as it was located in a zone that receievd poor feedback	Relocation of audio box to the centre of the balcony to optimise audio control location
N/A	N/A		Balaustrade height is too low and failed to comply with standards	BCA compliant balustrade height
N/A	N/A	Seating added	Non-complient with any disability standards or BCA codes	Removable seating at exit doorways to accommodate people with disabilities

5.2.4 STAGE

STAGE

Documented Works (prior to 2010)	Issues that arose	Action taken to Rectify Issue	Issues emerging after rectification	Action taken to amend (2010-2013)
N/A	No AIR handling unit	AIR Handling Unit (AHU) mounted behind the organ	Discharged air through 2 intrusive 1980s wall vents between pilasters	New AHU unit to existing roof plant with new ducting to ceiling above the stage Intrusive wall ducts removed and wall repaired to original appearance
N/A	Deteriorated paint	Painted to revitalise and match trends of the time (1980s)	Lost building character and neglected original intent	New paint and new finishes
N/A	N/A	N/A	Substantial maintenance costs for auditorium lighting	All high wattage lights to be replaced with low energy LED arrays to provide controllable lighting with very low maintenance requirements Reversible lighting bars added to provide further lighting uses
N/A	N/A	N/A	Fire safety (no inlet air)	New air vents in the non-significant front face of the stage to assist with inlet air for smoke and fire safety
N/A	Stage was not big enough for prescribed use	Extention of stage	Fire safety - effected evacuation procedures Changed outlay of original design intent	Stage was restored to original intent and updated to integrate modern technologies (removable)

5.2.5 FLOOR / BASEMENT

FLOOR / BASEMENT

Documented Works (prior to 2010)	Issues that arose	Action taken to Rectify Issue	Issues emerging after rectification	Action taken to amend (2010-2013)
N/A	Poor Acoustics	N/A	Poor Acoustics	Acoustic treatment of ground floor back wall
N/A	N/A	N/A	Substantial maintenance costs for auditorium lighting	All high wattage lights to be replaced with low energy LED arrays to provide controllable lighting with very low maintenance requirements
N/A	N/A	N/A	During the 2010-2013 restoration, archaeological artefacts were uncovered beneath the auditorium	A full investigation of the underground site was undertaken, recorded, and recovered

Although minimal data is available on the auditoriums floor/basement, the most recent restoration works completed in 2010 – 2013 have provided substantial and previously unknown building history. The last time that any significant work was carried out in this area was when BCH was first constructed in 1921 - 1930. Upon excavation work on the auditorium floor in 2010, an important archaeological discovery was uncovered which pre-dated the building. Three (3) meters below the auditorium floor the first artefact was uncovered; a cobblestone drain (Brisbane City Council, 2010). The uncovered drain, and additional paving that were also found have been dated back to the late 1880s (figures 10 – 11). These discoveries are believed to be remnant from when the site was converted from swamp land into Council yards. During this time, some of the features on the site (including the cobblestone drain) were incorporated into access paths and driveways that allowed movement of stock, tools and equipment onto the site. The site was also used to store various tools and equipment for the construction and maintenance of the city's infrastructure, including the storage of paving stones and kerbing used for Brisbane's early streets (Brisbane City Council, 2010).

Figure 10: *Excavation work under the auditorium floor* (Brisbane City Council, 2013)

Figure 11: *Cobblestone drain, pipes and paving* (Brisbane City Council, 2013)

To document the archaeological findings of the site, PHAB architects, as part of a consultant team (including surveyors and heritage specialists), were commissioned to produce accurate records in a number of media. A 3D digital model (non-BIM based) of the existing auditorium (timber floor, stage, walls, ceiling, dome, organ, balcony, etc.) was produced using scanning technology. This model was a progression on previous work produced in 2005, where Ai3D developed a digital model of the existing auditorium during the conservation design phase. The archaeological dig, undertaken by Bennett and Bennett Surveyors and Planners, utilised conventional survey techniques and equipment to pinpoint the edges of concrete slabs, timber pieces, pipes etc. with both a 2D and 3D AutoCAD file output. To measure each element on site, tape, a laser measurer and pen and paper were used, and these were documented in 2D AutoCAD. Extensive photographical documentation was also undertaken. PHAB Architects were first involved with the documentation of the archaeological findings in March of 2011 for the first stage of excavation and then re-engaged in June when further findings were uncovered. This involvement lasted till November 2011. Additional work was carried out to produce a digital (non-BIM) output along with a physical model, ultimately envisaged as an educational tool. With the collaboration between PHAB Architects, Model Consultants International, Ai3D and the Queensland University of Technology (QUT) School of Design, AutoCAD DWG files were produced along with both digital and physical models (see figures 12 - 14). In terms of data produced by this exercise, there is no doubt that substantial documentation has been taken, however these sources are of a static nature, and cannot be integrated into an overarching BIM platform. Although these works have been comprehensively documented, there still exists the loss of such important data as these external sources will be subjected to an inferior database system that is currently utilised by BCC, to which data has previously been lost or misplaced.

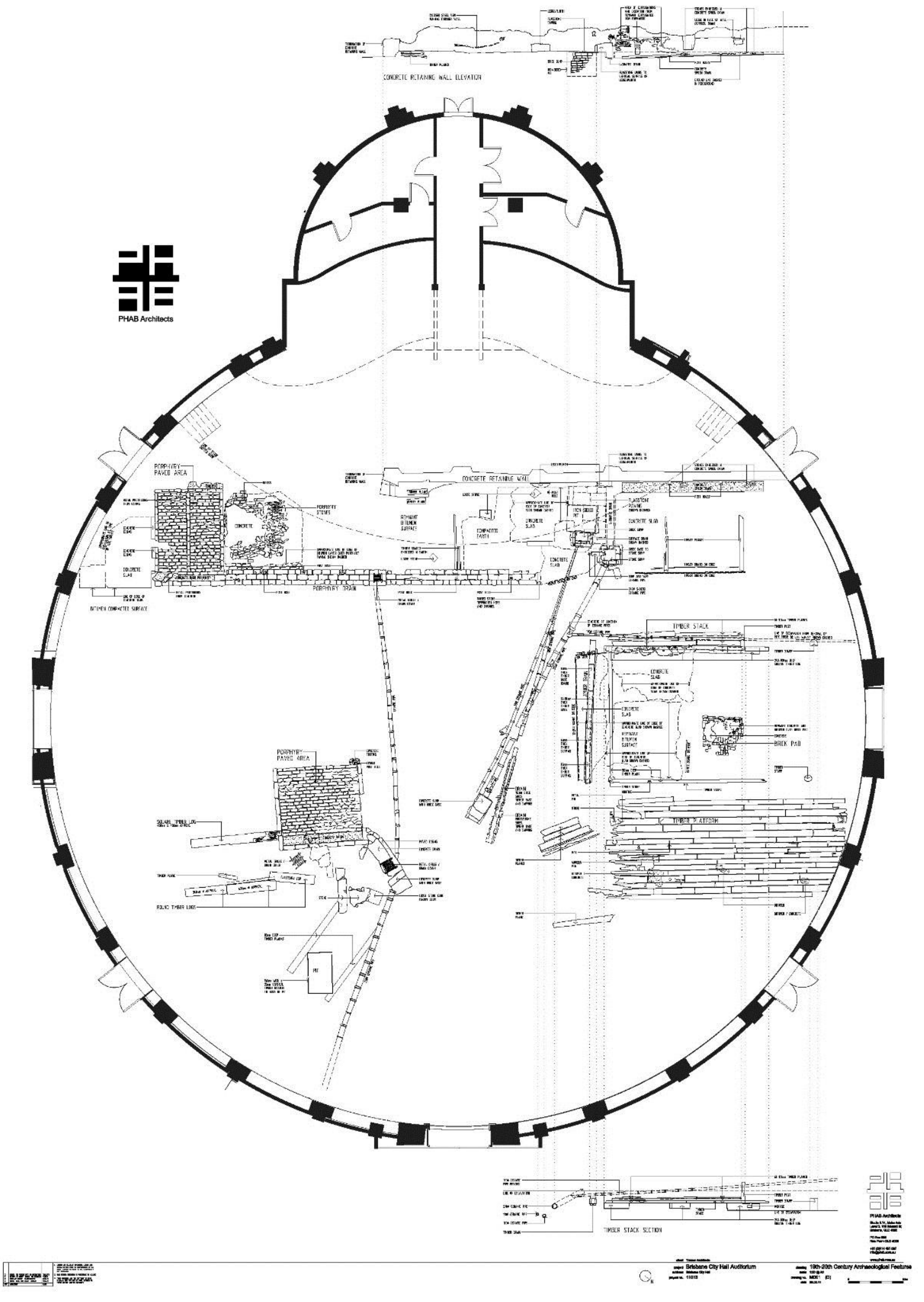


Figure 12: *Architectural documentation of archaeological excavation of BCH auditorium* (PHAB Architects, 2013)

Figure 13: *3D model of archaeological finds* (PHAB, 2013)

Figure 14: *3D model of archaeological findings with contour analysis* (PHAB, 2013)

5.3 Interview Results

Of the interviews carried out, the primary data collected can be categorised under two main titles, defined by the interviewee's position in the BCH restoration project of 2010 – 2013. The first of these would be background and processing analyses, mainly dealing with the BCC guidelines and development schedules for undertaking heritage listed projects such as BCH. The second consists of building pathology and the methods of documentation and data storage. Throughout the course of this research project, a multitude of informal interviews were conducted with each of the participating interviewees. The collected data presented throughout this research was partly obtained through leads provided by the interviews held.

As these interviews were conducted as unstructured and informal, the data obtained has been integrated throughout the collected data and results. However, the number one issue that was described and continually alluded to throughout the various meeting with each interviewee was the lack of a singular reference point of BCH related data, be it in the digital format, or even hard copy productions or reproductions. This became a more prominent issue with the proposal of the 2010 major restoration project, as the information relating to BCH was difficult to acquire due to the inadequate or nonexistent means of record keeping. This matter was only exacerbated with the introduction of digital documentation. A once outdated method of managing built data was now even more so with the new technologies being utilised on the 2010 – 2013 restoration project. This set the parameters of not only providing a heritage management system as an independent entity, but to allow this database to integrate with the BIM programs that have been used for the BCH restoration, as well as for the BIM programs utilised by BCC's City Design Heritage Unit.

5.4. Primary and Secondary Goals

Within the initial proposal presented by the heritage department of BCC, it is also stated 'that all new work must be date stamped to provide a clear identification of new work that has been done' (Brisbane City Council, City Design. 2007). This will help with easier recognition with what, and at what date, the work has been carried out. At the start of the 2010 restoration work, it was very difficult to identify if work was original, and if not, when these alteration/additions were made. The above results clearly clarify the initial aspects of why the restoration project of BCH was undertaken, as well as identifying additional facets that would 'enable' the building. The following table indicates these primary and secondary goals:

PRIMARY	SECONDARY
Fire Engineering Report compliance – statutory requirement for all work done after 8 February 2007	Associated works – economic or practical considerations
Building Code compliance	Enhancement works – solely to enhance the functionality of the building

In comparison, these goals can be broken down into necessities and recommendations. The building aspects that were required, and were necessary for the building to remain open to the public, was to meet and comply to the current Building Codes of Australia which stemmed from the unsatisfactory evaluation regarding fire and safety. From these primary goals, the decision to accommodate the secondary facets of improving the buildings functionality, and therefore providing greater economic and practical benefits, was the next logical step, considering the major work that would be required in the first place to address the primary objectives.

5.5 Discussion

With respect to the observations made within the case study investigation in chapter 2 and the subsequent conclusions that resulted from that historical analysis, as well as the results that were obtained in the previous chapter relating specifically to the 2010 – 2013 BCH Restoration Project, it is clear that there is a fundamental breakdown in the way heritage related information has been, and is currently being managed and maintained. Of all the factors that led to the major conservation work of BCH in 2010, the single underlying contribution remains that of poor record keeping and documentation. BCC's City Design initially proposed restoration works in stages, which would allow BCH to remain open to the public, if only partially, however due to the unforseen complications that arose from a more thorough investigation, the building was forced to be closed for an extended period of time, and preliminary conservation costs were drastically increased.

The major construction that has been undertaken on BCH occurred due to the unknown factors that were essentially concealed within the building. According to BCC reports produced years prior to the 2010 conservation work, certain building alterations were expected based on information about the building that the BCC possessed, however after more detailed inspections, it was evident that the documentation procured by BCC did not contain all the necessary information needed to provide an 'as stands' reflection of BCH.

Once a more thorough inspection of the building was completed, unexpected building modifications and construction elements were exposed, which in turn significantly altered the conservation projects outlook. Focussing on the results produced relating to the 2010 – 2013 Restoration Project of BCH within this chapter, a prime example of the resulting factors of undocumented or unknown works exists within the central auditorium. Continual upgrades that were performed within this space have spawned residual effects, the most prominent of which is the relationship between the stage and the balcony. As the stage area was increased to adapt to the productions and performances that were carried out on it, this resulted in the loss of seating spaces on the main floor. To make up for this loss of seating capacity, the balcony increased its seats by adding additional levels. This led to overcrowding of the balcony area, subjecting this space to inadequate emergency evacuation requirements, and overloading structural implications.

Another indicator of this 'cause and effect' relationship is evident with the exterior dome and the interior roofing components. Resulting from a leak in the domed roof, the interior ceiling began to cause air pollution issues relating to the fine particles of acoustic material being dispersed from the ceiling. Potential catastrophe could have also been produced within this space due entirely to the lack of fire protection. Even after the introduction of a sprinkler system during a previous building upgrade, the rest of the space was left unchanged, and therefore no drainage system was introduced within the roof or the floor. This 'cause and effect' relationship is reflected in the data tables produced previously in this chapter, however this evolves into an 'intentions and outcomes' comparison. What is initially 'intended' in respect to conservation/restoration works that are carried out are not always echoed as its overall 'outcome'. A number of deciding factors are indicative of this, primarily time, as well as technologies that exist in the era of when the alterations were made.

What was made abundantly clear during the collection of the built pathology data is evidenced by the tables that outline pre-restoration 2012 and post-restoration 2012. When comparing what is known to have occurred pre-restoration, and what is intended to take place post-restoration, the absence of verified information in the pre-restoration column proves that the adopted means of recording that data is fundamentally flawed. Although this is a key finding within the research, it is not the only fault to be presented, and these failings are not restricted to past processes. The data presented in the post-restoration are offered solely as 'intended' outcomes. Due to BCC's decision to outsource the conservation work to external firms and companies, the actual work produced within BCH is somewhat unknown until each element is once again studied and documented.

These issues that continuously and constantly arise within BCH, both in the past and during the latest major restoration, could ultimately have been addressed, or at least have been known about, if a system was put into place that accounted for the heritage data that has been accumulated over the buildings life. The conservation work that is currently being completed provides an opportunity to incorporate an adapted facilities management system that specifically addresses heritage information and values. As all this old information about BCH is exposed and new adaptations are taking place, a new heritage management system must be implemented to avoid the same loss of heritage information that has plagued BCH since its construction.

Chapter 6: Framework of a Digital Tool

6.1 Introduction

Of these results that have been gathered and organised (Chapter 5), a digital database can be proposed that incorporates these set values on the basis of a pathological breakdown of BCH's built elements. Again, this series of data will specifically focus on BCH's main feature, the central auditorium. Of the data collected, using multiple methods of research, it is obvious that the BCH project lacks a central database for its collection of information. Not only is the course of finding information restrictive for the general public, it is also limiting the known information to the professions who require such data. The errors in data storage that have challenged the retrieval of information on BCH in the past is almost certain to continue with the latest restoration works, especially with the absence of a centralised database system that can be incorporated into the building software utilised today.

The results presented have exposed a number of issues that relate to four distinctive subjects.

1. Brisbane City Hall – the case study itself, and the multitude of restoration and conservation work that has been carried out on it;
2. Data – the information gathered using quantitative and qualitative data through interviews and digital models that is not easily accessible, or even available, to the industry professionals that require it;
3. Original design intent versus the actual outcome produced in parallel to the Burra Charter – the original 'school of theory' presented by the BCC compared to the built outcome, which ultimately comes down to the one theory, that of the French school of conservation, as a theoretical approach was used (the BCC) as well as a practical one (outside contractors that made the necessary decisions for a successful restoration project);
4. Digital tools – the use of digital tools used throughout the 2010-2013 BCH restoration project and the lack of a centralised information network.

All of these subjects are considered, to a certain extent, as individual elements, and have yet to be fully integrated within one another. This is mainly due to the absence of a digital system core, as prior to the latest restoration, digital interfaces were nonexistent. At present, the number of internal and external reference locations obtaining to the current and past restoration work is widespread, which has led to inefficient, ineffective, and a highly confusing process of information gathering. These issues should not be occurring with the technological means that are now available and prevalent in the building industry. The conservation work that is currently underway has such resources to produce an overall digital system, or more specifically, a digital heritage management system, to correlate the collective data within a core database. However, such an opportunity has been neglected due to lack of research and knowledge on the issue. To produce such a system a number of priorities must be addressed first. In order to integrate the data sets that have been produced within the results section, an overarching heritage management system must be defined by a logical and practical framework in order to deliver the necessary information in an accurate and clear manner.

6.2 A Heritage Management System

To represent the most logical order of information in a heritage management system, and to evaluate that data, a pathological approach to the database output must be adopted. When assuming such a system, the information needs to be categorised into its relevant fields, and cross referenced where and when applicable. As the information is already in existence, there are only a few steps that need to be taken initially to provide a basis for the framework of a usable database that is interwoven into the design software that is used today. These steps include

1. The selection of a BIM interface – in this case Autodesk Revit was used earlier in the project, so the file can be updated to reflect the work that has been done.
2. The information that needs to be presented – what people need to know about the auditorium space? A digital heritage documentation system should comply with the definition of 'model view' used in BIM approach as a sort of filter aimed to discretise knowledge offered to different users interested in specific topics and contents fruition.

The last of these steps can be investigated by exploring different elements of the room. For example, if the material of concrete was selected, then the sequence of information would need to state what is currently there, then the issues that occurred, the tests that were carried out, and finally how it was fixed.

The initial sequence of the systematic breakdown of built pathology that was indicated within the methodology can work at this crucial stage of framing a centralised database, however, this overall sequence will need to be altered slightly. Before this framework is realised, the background information of Autodesk Revit's external database plug-in feature should be addressed. Although this will not be presented in detail, for the heritage management database framework is the focus of this study, the programs, and the order of these programs (see figure 15), need to be understood in order for the heritage management system to be implemented into a professional setting. As described in the earlier literature review, the prominent BIM programs utilise a feature that can incorporate external databases within their systems. Autodesk Revit DB Link, which is a tool that Autodesk users can subscribe to, allows you to maintain a relationship between a Revit project and a Microsoft Access, Microsoft Excel, or Open Database Connectivity (ODBC) database. You can use Autodesk Revit DB Link to export Revit project data to the database, make changes to the data, and import it back into the project. The database displays Revit project information in a table view that you can edit before import (Autodesk, 2012). Essentially, this BIM program permits the use of external databases, primarily to change building data, such as wall lengths, widths, and heights. To utilise an external database provides a range of benefits with the key one being the standalone nature of an independent database. Currently, that option of complete independence of a database system to a BIM program is lacking, as the BIM tool parents the other programs (Microsoft's Access and Excel) in the case that these external programs can control the BIM data, however, this data has been produced and exported from the BIM program itself, and without these external programs plugged into a BIM system, the data is only identified by numbers, and is presented rigidly in the absence of a linked digital model.

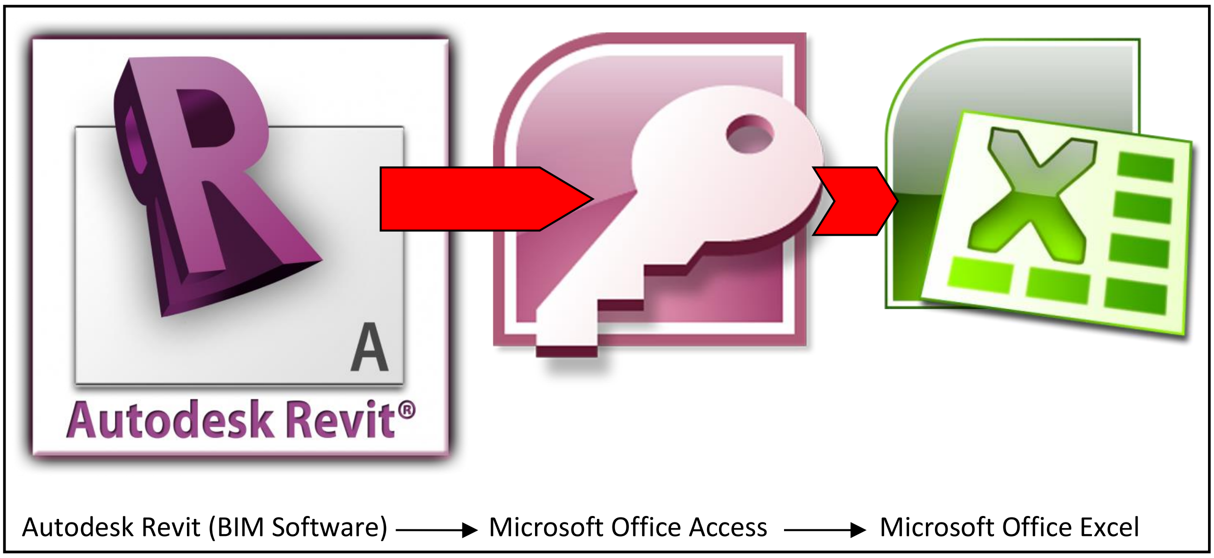


Figure 15: *Current order of programs for incorporation of external databases*

With this being the case, there is a great opportunity of incorporating a standalone database that is comprised of all the heritage data that is attainable. This database could allow for not only statistical and strictly raw number data, but also include images, videos, documents, and all types of records which are currently excluded from such BIM linked databases. In figure 16, the sequence of program plug-ins remains the same as the order of Revit's DB Link tool, however an additional database needs to be added that directly links to Microsoft's

Excel program. As an Excel spreadsheet is parented by the Access program, and in turn Access is parented by the BIM program, there needs to be an integration of the Heritage Management database into Excel.

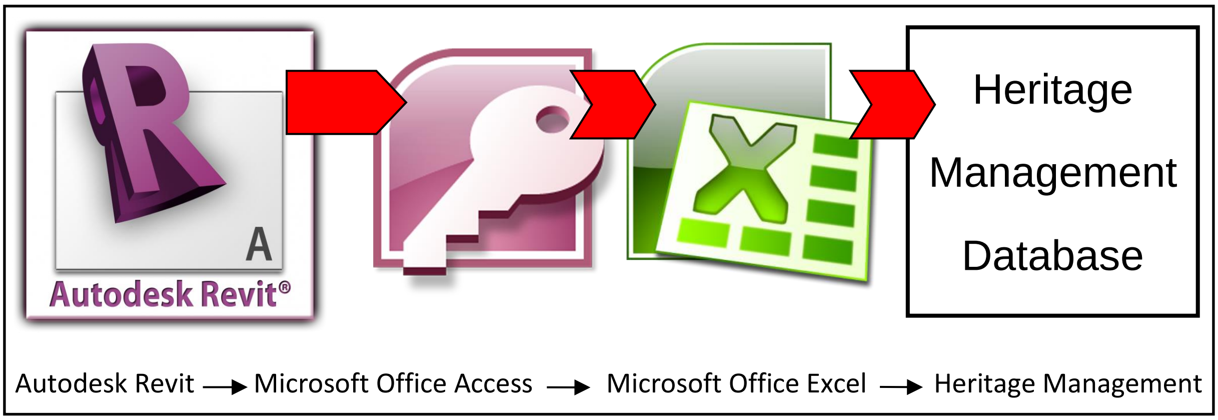


Figure 16: *Order of programs for incorporation of external databases including proposed Heritage Management Database*

With regards to BCH, the first task of producing a Heritage Management System would be producing a number of digital models that represent the building at various times through its lifetime, focussing on the different stages of restoration or conservation work that has been undertaken on it. To be more specific and relevant to the case study, it would be suggested that these 3D models would be created from original drawings produced by Prentice and Hall, then of the actual built building in 1930. Also included would be the 1980's restoration work, and the latest results produced by the major 2010 – 2013 works. Ideally, all these BIM models should be produced under the one file, and reflected in the one 3D model with the various stages of the buildings life modelled under different construction stages that can be turned on or off within the central model. Another option would be to model separated stages within their own file, and link these to a central model. This option allows for the same control over what is visually representing by simple visualization/graphic options or link options. . To accurately provide an all-encompassing heritage database, all new and old building components must be identified and given an individual label that relates to its function. In producing this system, it would also be beneficial to divide the building into its various 'components' to easily identify Item ID's. This would be best produced by utilising the 'smart object' feature embedded in BIM software. A smart object is an element, hierarchically defined and identified by an ID code, which is 'conscious' of its relationship capabilities with other objects, for example a wall knows to be related to windows or doors, and stairs know they can be related to railings. For example, a column in the auditorium could be labelled as follows (figure 17):

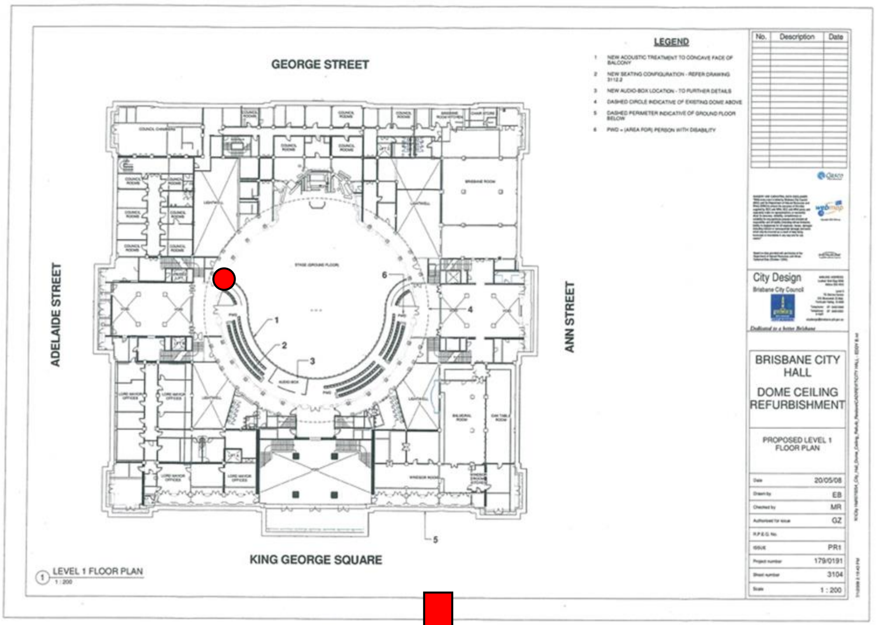
MODEL	
COMPONENT	Column # 0001 - Auditorium
COMPONENT LABEL	C0001-A

Figure 17: *Conversion of building components to digital identity codes*

Once the individual building components have been given their digital ID's then all the information (historical, heritage, and building information) that relates to that specific item can be categorised and arranged under that ID's heading. As per the proposal by Brisbane City Council (City Design, 2007) that all new work must be date stamped (physically) to provide a clear identification of new work that has been done, this research proposes that not only should all new work be date stamped, but that all past work should be digitally time stamped within a 3D model. Utilising the case study of BCH, once all the information has been associated with a particular Item ID, then it can be categorised into the Heritage Management Database according to its registered time stamp. This type of registration of building components will enable a simplified method of automatically updating the Heritage Management System, and when queried on the status of the item as being of current, previous, or original work.

Another key function that a standalone Heritage Management Database provides is interoperability. With the Heritage Management Database acting as an external product, opposed to being incorporated into a BIM specified database, then the previous issues raised by Howell and Batcheler (2005), and Plume and Mitchell (2007), on interoperability are deemed non-existent because of its external, not internal, status. It also eliminates the compatibility element as any BIM software that enables the option to incorporate external databases can utilise such a system. As this system can act independently from the BIM program, then Item ID's can be manufactured in this database then updated later via a BIM model.

6.3 A Theoretical Framework

To clarify a theoretical framework that not only provides the entire collected historical records (of any media) of a heritage listed building, or any building for that matter, as well as any updated modern or current data, then a logical format of deliverable information needs to be formulated and produced. Considering the previous literature review of building pathology that applies to heritage architecture, Association d'Experts Europeens du Batiment et de la Construction (AEEBC, 1994) concluded that the process analysing built pathology should be ordered as such;

> (1) Identification, investigation and diagnosis of defects in existing buildings;
>
> (2) Prognosis of defects diagnosed, and recommendations for the most appropriate course of action having regard to the building, its future and resources available; and
>
> (3) Design, specification, implementation and supervision of appropriate programmes of remedial works, and monitoring and evaluation of remedial works in terms of their functional, technical and economic performance in use.

As this outline was supported by the majority of the relating literature (Shelbourn, Aouad, Hoxley, & Stokes, 2000), this process has been adopted and adapted to suit a digital output. To begin with, a digital heritage management system must identify the order of programs to which a heritage management database follows and branches from. The order of programs to reach this independent storage of records has previously been discussed. Once an item identification has been given to a built element, then the framework for the delivery of information can be theorised. With large civic buildings, such as the case study of BCH, as previously stated, a breakdown of building components should occur to minimise information sourced, and focus on specific areas and zones. Once a 'component' has been identified by the user, an investigation of all the elements within that component will be accessible, and the various ID's and time related documentation of that particular zone will result. A diagnosis stage of defects will follow that includes what building elements were causing issues and the reasons why. Prognosis and recommendations provide a prediction of the probable course and outcome of the identified building element, and allows for recommendations to be made in rectifying the diagnosed issue. The next and final stages of dissecting a buildings pathology relate to designing, specifying and implementing the recommendations offered and calculated in the previous step, then monitoring and evaluated those changes/adjustments that were made. The following diagram (figure 18), adapted from the Association d'Experts Europeens du Batiment et de la Construction (AEEBC, 1994) process of analysing built pathology, shows the breakdown of these individual steps:

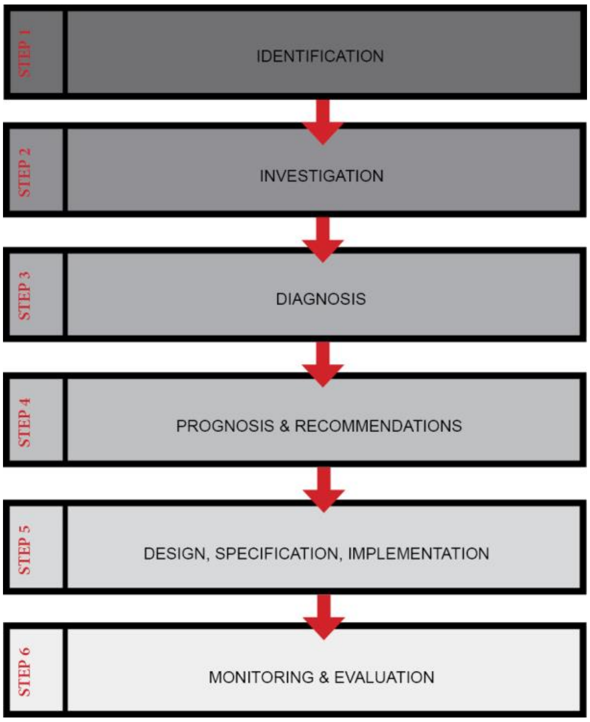


Figure 18: *Process of Building Pathology breakdown adapted from Association d'Experts Europeens du Batiment et de la Construction (AEEBC, 1994)*

This pathological breakdown of building components provides the basis of the heritage management system proposed. In order for this system to achieve the necessary requirements of a heritage management database, the layout can be adjusted slightly to produce an output that is more compatible with BIM databases, and the external programs that manage them. The same principles are followed, however the order is adjusted to some extent. This is only done so that the information about a particular built element is presented in a consistent manner, and because this system is adapting to a building that has already had a multitude of work carried out on it, with many search results leading to little or no outcomes due to lack of record keeping. Therefore, the following framework outlines the order to which this information should be delivered within built pathology guidelines:

<u>Heritage Management Database – Theoretical Framework</u>

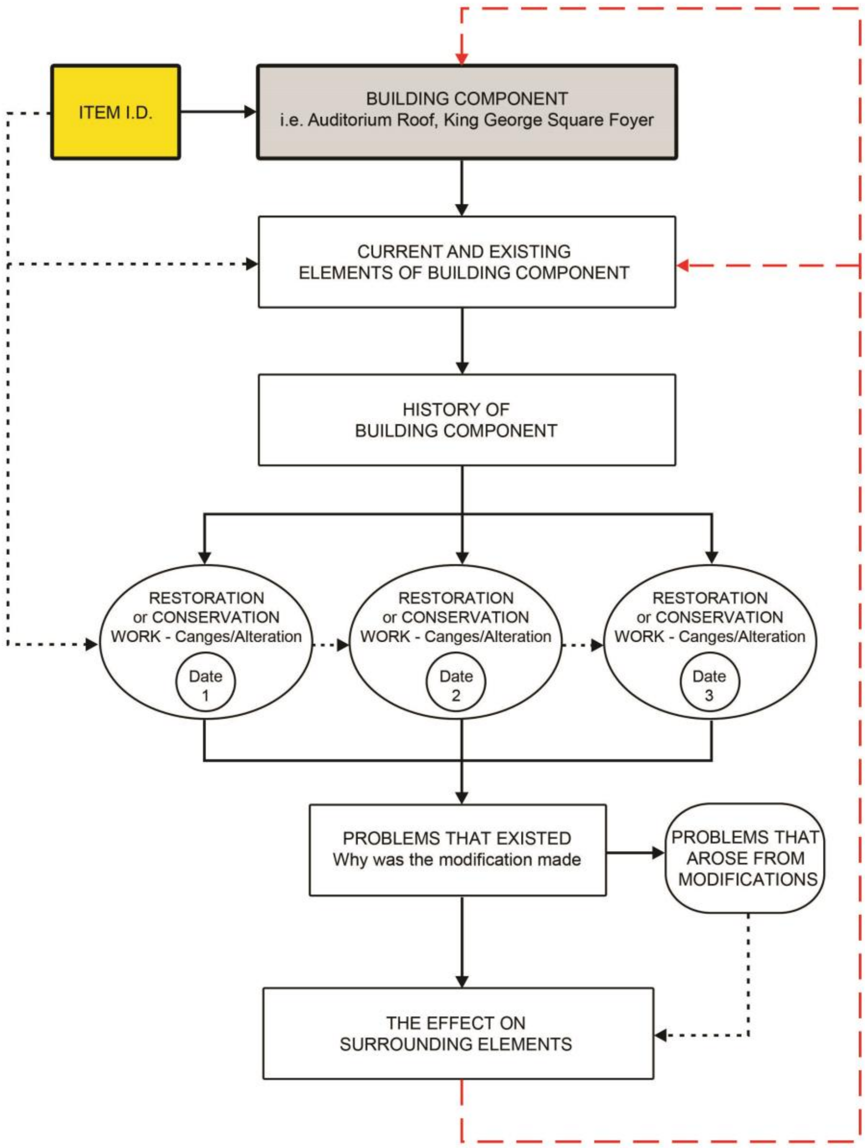


Figure 19: *Theoretical Framework of data query results within a heritage management system*

Figure 19 (page 76) shows the breakdown of the heritage management framework and the sequence of steps associated with building pathology analysis. This differs to the original outline of built pathology steps shown in figure 18 mainly due to the heritage management system not strictly focussing on a built pathology arrangement of information, but rather a system that can cross reference and include multiple facets of the building. This would be opposed to limiting the structure of the framework to only individual elements, and neglecting the surrounding bi-effects that most of these produce. Figure 20 represents the combination of the two processes previously investigated, and identifies the building pathology breakdown within the theoretical framework proposed.

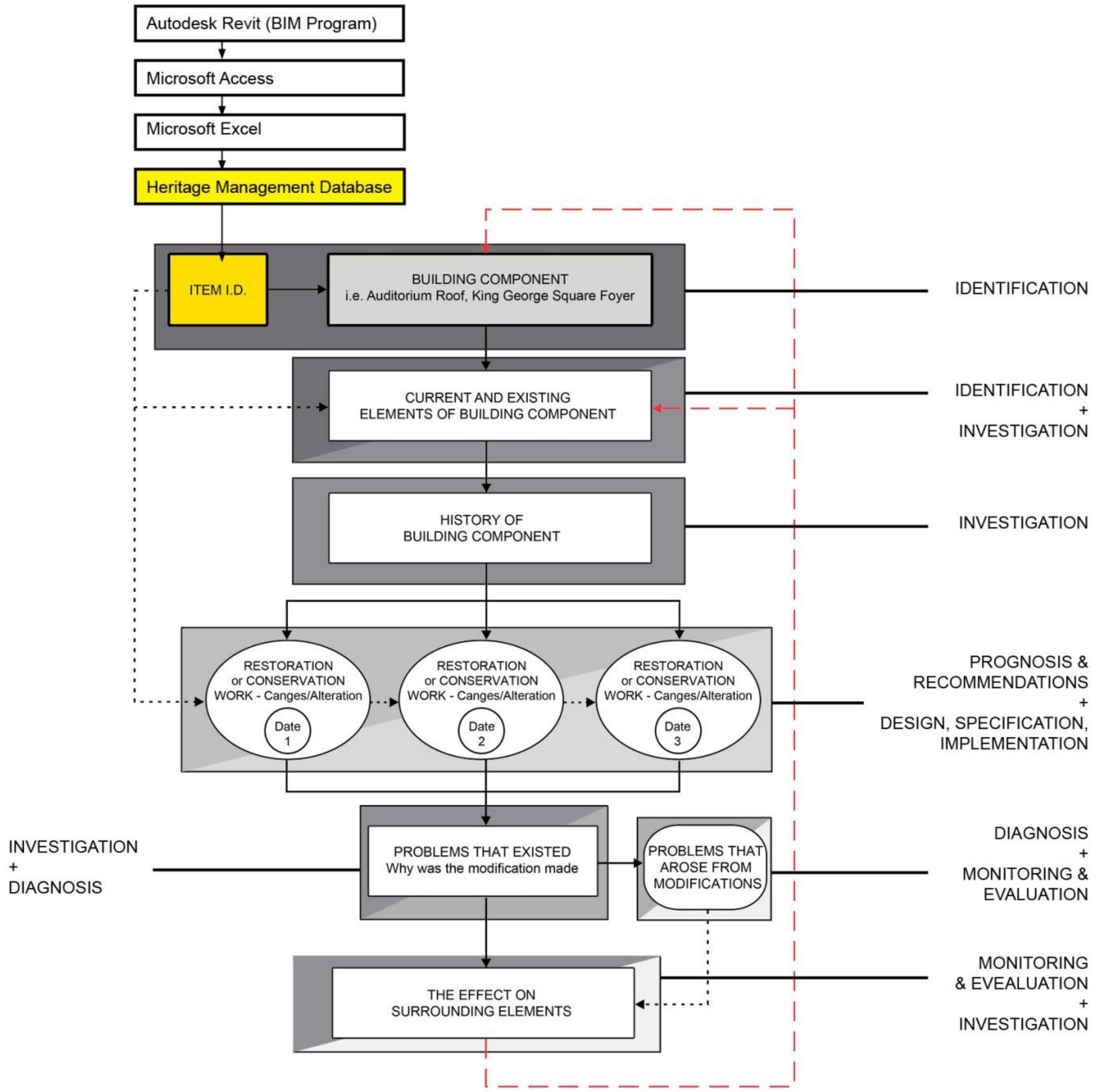


Figure 20: *Identifying building pathology breakdown processes within the theoretical framework of a digital heritage management system*

Using this analysis, and allocating the systematic breakdown of building pathology that was adapted from the Association d'Experts Europeens du Batiment et de la Construction (AEEBC, 1994) to the digital framework, the stages of procedures are adhered to but not presented in such a rigid fashion. The reason for this is because of the nature in which the data is returning search queries. In order to produce the required information retaining to a heritage application, there is a need of flexibility in the investigation of building pathology processes due to the fact that a heritage building already exists with a number of alterations or works previously carried out upon them. For such a plug-in to be utilised within a BIM program, the digital framework of a heritage management system must deal with a multitude of search results pertaining to different time periods, which instantaneously prescribes a very different approach when compared to an integrated database that is used on newly documented buildings.

Chapter 7: Conclusions

7.1 Summary

According to the original restoration objective produced by City Design in the *Schematic Design Report* (Brisbane City Council, 2009), it is noted that the study findings on BCH are based on "*a thorough assessment of known information*" (Brisbane City Council, City Design, 2009) and that further physical investigation of the building may reveal an unknown scope that will require further assessment. Upon this additional investigation, it was clear that the state in which BCH stood was clearly underestimated, and that the known knowledge of the building was severely lacking. The underlying factor of this research pertains to the information that was known against the information that was unknown. This evolved primarily from the lack of documentation (of all typologies) that has beleaguered BCH since its construction. The number of inconsistencies between what was thought to have existed within BCH and what actually resided in its place were considerable. As the BCC continued with its initial assessment of BCH, and City Design provided its preliminary goals and action plans to restore the building, the unforeseen extent of dilapidation changed the output of the project, and external parties were introduced to continue with more complicated facets of conservation and restoration. This switch between who was working on the project however raised further issues. Of the research conducted into BCH there is a clear intention on what conservation/restoration work needed to be carried out in order to meet heritage guidelines and BCA requirements, however it is unclear if the actual as built results adhered to the conservation practices and initial school of theory that were originally employed.

Resulting from the research undertaken to answer the research question proposed of '*Does the 2010 – 2013 restoration project of Brisbane City Hall provide a suitable case study for the implementation of a heritage management system that outlines the buildings history through its built pathology?',* the collected data suggests that BCH provides a prime example of a heritage classed building that could benefit significantly from such a management system. This can be justified through the collected data of the auditorium, which revealed inadequate building knowledge of what actually existed within the space, which ultimately resulted in fragmented built pathology records. The interviews conducted also indicated this as a principle issue with the BCH project. A singular source of record keeping, contained within the digital format to adhere to the current technology, confined inside a management system that is designed to integrate the processes of analysing built pathology, would eliminate this reoccurring facet, allowing for a greater grasp of BCH's built history.

The overall aim of this research was to investigate the 2010 – 2013 BCH restoration process and evaluate possible strategies to record and manage data in direct relation to the building's pathology. Four objectives were met in order to thoroughly explore and asses this research aim. A thorough examination of the restoration/rehabilitation projects of not only current, but previous projects, dating back to the buildings initial conception and completion, has provided the necessary background for one to grasp the flaws and inconsistencies that have been integrated within the buildings pathology, highlighting the failures in data recording and management. Further exploration into the underlying conservation theories that the restoration projects have adhered too has also resulted in an amalgamation of ideals, resulting in an incoherent formulae, and subsequently leading to further loss of building information. The current methods and employed building data management systems that are in place have been proven to be severely outdated, and in most situations, many building documents have yet to be updated into digital form. Within this inspection of management systems utlised, a clear need for a heritage specific digital organisational tool has been exposed, primarily relating to BCH, but also for the architectural heritage field. Finally, the last objective involved the provision of the aforementioned digital heritage management system in the form of a theoretical framework subjective to the relevant factors that limit heritage projects (Burra Charter guidelines), and refined by the conservation theories employed. As these objectives were carried out, the results produced by a thorough exploration into BCH, and more specifically its auditorium space, identify not only limiting documentation factors, but also its consequential aspect of physical 'as built' existence versus its historically/heritage documented intent and perception.

7.1 Assessment of Heritage Management Framework for BCH

As previously stated, BCH supplies an ideal case study for which a theoretical framework for the implication of a heritage management system can be applied. The overwhelming rational to apply such a system directly relates to BCH's primary issue, that being its loss of building data/records, as well as the unidentified and unknown building pathology. As the framework of this heritage management system was created specifically with BCH in mind, the direct relationship of the frameworks structure is in accordance with the principles of built pathology and the integration of conservation ideologies and philosophies. Considering the scope of the 2010 – 2013 restoration project of BCH, the possible integration of such a management system could enable an up to date digital reflection of the physical building, along with all the materials, structural reasoning, and restoration processes employed and carried out. As such an in-depth and monumental project was used as a base component of the framework for a heritage management system, it can then be proposed that this tool could incorporate all types of heritage related ventures. Strictly related to BCH, the proposed heritage management system would be considered fundamental at this point in time, to be able to address the loss of information that has plagued the building, and to finally provide a centralised source of information that will put a stop to the continuing trend of various information outsourcing locations.

7.2 Key Findings

BCH's auditorium and dome were thoroughly examined within this research. In addition to the literature reviewed on that building, three separate topics were explored that reflect the ideologies and theories that encompass the current methods of investigating heritage qualities and the conservation processes that accompany them. Reflecting on the conservation of built heritage, it discussed how the building pathology of architectural heritage is evaluated, and the theoretical arguments presented for each of the popular methods used worldwide. The exploration into how these methods of building conservation are explored and managed within a digital realm exposed an underdeveloped area of digital integration within the architectural heritage and heritage management fields.

The key findings of this research have been discussed in detail, and the main issue that has, and still is residing within BCH, is its lack of, or poorly kept building documentation. A simplified breakdown of this researches findings can be outlined as follows:

1. The state of records pertaining to all relating documents on BCH; not only are the sources located at various archives around Brisbane, but the manner in which these documents are kept and organised are vastly out of date.
2. In the majority of circumstances, building records do not exist or have been lost/misplaced.
3. Although original conservation methods developed by BCC's City Design adhered to a combination of known heritage restoration schools of theory (primarily Italian, or 'hybrid' between English and French theories) and complied with the Burra Charter guidelines, the resulting work carried out by external contractors supply no guarantee or indications that these underpinning constraints were applied.
4. In terms of digital programs utilised within the architectural and engineering fields there are minimal uses for the integration of architectural heritage and building pathology specifically.

These findings have been projected and evaluated within the results and discussion chapter, along with the digital compatibilities proposed in the framework of a digital tool in chapter 6. In direct response to the key findings previously outlined, the culminating research has incorporated all facets discussed and has provided the essential needs to amend the failing practices currently and previously employed by the overseers of BCH. With respect to the four key points raised, the following list outlines the contribution of the amassed research:

1. Provide a single archive location and upgrade the database to a digital format; this will allow for a single source of information that contains all information on BCH and is easily updateable.
2. The 2010 – 2013 restoration project of BCH provided a primary opportunity to comprise and document what previously existed and what was not known within that building. Unfortunately, this opportunity seems to have been lost as the documentation of the collective contractors has not been correlated or organised. With this being the case, there will undoubtedly be aspects of the BCH that will be lost.
3. After thorough revision of the works undertaken on the auditorium, both of the past, and of the present, it can be assumed that the 'hybrid' Italian school of theory was followed when restoration was carried out. This is not uniform across the entire project however, as both the French theory and the English theory was applied. As this is the case, it is appropriate to assume that what could be kept original was done so, and what needed new technologies to save the building, be it structurally or economically, was implemented.
4. With no known program to inject within the lacking data management system, the best use of digital integration was found to be applied to pre-existing software of a BIM nature. The integration of an external database that can be conformed and developed to plug-in to such programs that will display additional building data via a acknowledged building pathology breakdown.

There are also contributing factors that apply specifically towards BCH as much of the information relating to the BCH restoration work was difficult to get hold of because it was part of a closed statutory process. Based on these facts, this research could only provide the information that was allocated or personally retrieved. Regardless of this limitation, BCC, as well as the contracted external firms who worked on the 2010 – 2013 BCH restoration project, discovered that multiple works had been carried out on the building with minimal or nil documentation. To counteract this long-lasting and ongoing concern, the proposed heritage management system could potentially eliminate the information gaps found within its build pathology. Once this is achieved, one of the most important and historically significant buildings in Brisbane will be up to date with its documentation and underlying cause and effect history within a digital format. A more important feature that the heritage management system will be able to provide is the benefit of updating its files to reflect what the physical building represents. This factor comes down to the overseeing bodies (primarily architects) who control the BIM interface that is incorporating the heritage management system. With all the buildings built history located within a single digital source, the reoccurring loss of information will be halted.

7.3 Possible Mechanisms and Exploration of the Results

The proposed digital framework of a heritage management system should be developed as an external standalone resource that correlates all the data on the BCH project. To be utilised within the BIM field, a plug-in application that is derived from the encompassing management system will be incorporated into the BIM platforms that currently exist. Of the most prominent BIM programs currently on the market, Autodesk's Revit and Graphisoft's ArchiCAD already have the inclusion of external databases built into their software. As Revit was the initial file type that the BCC used when first exploring the conservation project of BCH, and the required output of external architectural parties, this platform has been used as an example of implementing an external heritage based data system. Further exploration of the results produced within this research indicate the need for initial user input for a digitised data system to document the 'unknown' building factors that have occurred throughout BCH's lifetime in order to justify this resource as containing all the built data under a solitary source. One must be aware that by completing this course of action however, the 'contextualisation' argument presented by Charlton (2010) on meaningless digital data should be referenced and adhered too.

When presenting the framework for a heritage based management system, the underlying layout, in which the data is presented, is the most important element. This provided the focus of the digital tool, for strictly concentrating on the application opposed to the framework would provide an inferior or nonexistent method of deciphering a buildings pathology. In addition, one must create a database for today instead of creating for the future, as the methods of record keeping and architectural planning are unknown, and it is more than likely that technology progression will alter the media/programs used. Once the framework exists, and the conservation theories and building pathology processes are incorporated into its design, then the framework can always be adapted to match the current technology.

7.4 Limitations

A number of issues have prevented further exploration into the buildings pathology, with particular problems arising in the research of previous conservation work undertaken. Although adequate information has been made available for this research to be completed, certain outcomes have, at times, seemed odd, and certain members of the BCC have alluded to the fact that the reasons for these peculiarities will be buried beyond the accessible means provided by BCC to uncover them. Upon further exploration into the restoration work of the past, which utilised all the described research methods, it was found that in many instances the salient influences of building adjustments may not have been recorded or documented at all, or, if it had, the government in power at that particular time may have taken all the information with them once a new government replaced them.

Another issue is presented in the form of new emerging technologies and the changing nature of human interactions with all types of media and storage. This is all too evident in the process to uncover hard copy historical information via a digital means. Unless that physical copy of the historical record had been digitally recorded at some point in time, then the proposed heritage management system cannot succeed in identifying the relevant information required. To implement the projected digital method of heritage management, then there must, at some point, allow for initial human interaction and itemise such data from a physical entity to a digital representation. Prior to this occurring, the framework of a heritage management system that can be integrated within a BIM program cannot be accomplished.

7.5 Implications of the Findings for Future Research and for Clinical Practice

Future research pertaining to the proposed heritage management system could exist in the form of further exploration by means of program database development, and the logical progression of a theorised framework to a developed heritage management database. This resource could provide significant benefits in the heritage documentation field, and enable a greater integration of heritage data within prominent BIM systems. The proposed heritage management system also updates the stagnant database structure that is currently employed by the BCC, the results of which are only too evident by the loss of information and the large amount of unknown work found within BCH.

The framework projected with this research is designed to accommodate any built heritage project, and is not restrained to only BCH. The use of a developed heritage management system in clinical practice on a variety of heritage projects would enable verification of its adaptability and interchangeable applications. Such a management system could potentially provide the missing correlation between heritage references and the now prevailing methods of digital interaction and documentation in both new and old building development modus operandi.

7.6 Concluding Remarks

This research has examined a vital historic building in the form of BCH that is of the upmost importance to its city's identity and cultural values. For decades this city monument was neglected with its up keeping, which inevitably led to major restoration works in 2010. This latest period of restoration has provided an ideal opportunity to examine what mistakes have been made in the buildings past, in terms of conservation work, and what needs to be adjusted or introduced to minimise these. It was quickly apparent that the severe lack of building data and documentation recorded on BCH was detrimental in allowing anyone to completely understand the buildings pathology. As a response to such a systematic failing of record keeping, this research has proposed an up to date, and updateable, heritage management system, which would work to resolve any lost or misplaced building data and enable a single source and location of historic records. The framework provided for such a scheme follows a recognised structure of built pathology analysis, and has been adapted to accommodate all the necessary information that would be required by professionals of the heritage and historical conservation field, such as architects and engineers, as well as catering for the more simplified tasks of searching historical records.

As its major contribution, the presented research has delivered a responsive framework for a heritage management system that is defined by BCH's built pathology. By utilising the case study of BCH and focusing on the centralised elements of the auditorium, this building has enabled a comprehensive investigation of its defects and generated resolutions, which aided and informed the production of the suggested framework for a heritage management system. With such a system in place, the buildings history, including building methods and materials, are clearly outlined and defined, ultimately eliminating future data loss and misinterpretation of heritage values.

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