Thesis Title

A Common Structured Integrated Collaborative Digitised *(CrOsS)* Framework for the Historic Building Repair and Maintenance (R&M) Sector.

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Submitted for the degree of Doctor of Philosophy in

Construction Project Management

Heriot-Watt University

School of Energy, Geoscience, Infrastructure and Society

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ABSTRACT

The UK historic building repair and maintenance (R&M) sector generates £9.7 billion in output. However, challenging delivering quality R&M are project under-performance, a lack of collaborative project practices, resulting in poor communication, underpinned by persistent skills shortages. These are not solely UK concerns; various international studies have echoed similar issues, however, to maintain focus, the scope of the research is within the UK context, in particular Scotland's stone-built heritage. Adopting a four-stage qualitative participatory exploratory action research strategy; this research aims to develop a framework, to support an effective integrated multi-disciplinary, collaborative, structured, and digitised Project Management and on-site practice approach, to aid increased efficiencies.

Firstly, a synthesis of the relevant academic literature and industrial reports enabled direction towards the acquisition of appropriate intelligence, in order to guide and inform the study's theoretical foundation. Secondly, 14 semi-structured interviews with Scottish SMEs were executed, which bounded the key findings under three main themes; senior management, human resource, and technical. Concurrently, through co-operative industry engagement, the generation of a best practice historic building SME R&M four-phase process map was undertaken. Thirdly, a common structured collaborative process-standard framework was developed and finally, validated through active industry participation; a demonstration project, four semi-structured interviews, and two focus groups of six industry practitioners. The validation feedback confirmed that the developed framework is valid, credible, acceptable, and applicable as a process standard designed to offer a process model, map, and management tool.

Keywords: Historic Building, Repair, and Maintenance, Process Improvement, Demonstration Projects, SME, Stonemasonry.

DEDICATION

This dedication is an opportunity to express my thanks, appreciation and gratitude to the following for the capacity and ability to finish this research:

- To my wife who despite her long lonely days and nights, continued to provide unrelenting support throughout my course of study. Without such support, traversing this PhD pathway would not have been possible, I'm forever thankful, indebted to her ability to be my foundation.
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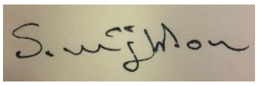
Signature of Candidate*:*		Date:	20/03/2020

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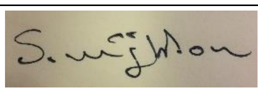
Signature of Individual Submitting:	
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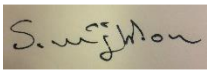
Signature:	
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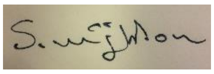
Signature:	
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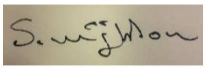
Signature:	
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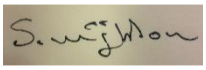
Signature:	
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GLOSSARY

Glossary of abbreviations

AIA American Institute of Architects

BGS British Geological Survey

BSI British Standard Institute

CBA Cost-Benefit Analysis

CDM The Construction (Design and Management) Regulations

CIRIA Construction Industry Research and Information Association

CIPS Chartered Institute of Procurement& Supply

CIOB Chartered Institute of Building

CITB Construction Industry Training Board

CPMF Construction Process Management Framework

DBIS Department for Business Innovation and Skills

DMAIC Define-Measure-Analyse-Improve-Control

GDP Gross Domestic Product

GVA Gross Value Added

FE Further Education

FGP Focus Group Participant

FGS Focus Group Sessions

FTE Full Time Employees

HS Historic Scotland

HES Historic Environment Scotland

ICOMOS International Council on Monuments and Sites

IHBC Institute of Historic Building Conservation

IPD Integrated Project Delivery

KPIs Key Performance Indicators

MSME and SMEs Micro and Small to Medium size organisations

NCC National Conservation Centre

NHTG National Heritage Training Group

ONS Office for National Statistics

PM Project Management

ROI Return on Investment

RIBA Royal Institute of British Architects

RICS Royal Institution of Chartered Surveyors

R&M Repair and Maintenance

SG Scottish Government

SHCS Scottish Housing Condition Survey

SHEA Scottish Historic Environment Audit

SHEP Scottish Historic Environment Policy

SIC and SOC Standard Industrial and Occupational Classification codes

SQA Scottish Qualification Authority

SSLG Scottish Stone Liaison Group

STBA Sustainable Traditional Buildings Alliance

SVQ Scottish Vocational Qualification

TAP Training Assessment Programme

TBR Trends Business Research Ltd

TQM Total Quality Management

UKCES UK Commission for Employment and Skills

LIST OF PUBLICATIONS BY THE CANDIDATE

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Sivanathan, A., McGibbon, S., Harper, S., Lim, T., and Ritchie, J. (2018) Control-display Affordances in Simulation-Based Education. *Proceedings of the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC2018, August 26-99, 2018, August 26-29, 2018 in Quebec City, Canada*

McGibbon, S., Abdel-Wahab, M., & Liang, Y. (2018). Digital surveying for historic buildings repair and maintenance: two demonstration projects from Scotland's built heritage. In *Heritage 2018: Proceedings of the 6th International Conference on Heritage and Sustainable Development* Granada: Green Lines Institute for Sustainable Development. *Spain 12-15 June*

McGibbon, S., Abdel-Wahab, M., & Sun, M. (2018). Towards a digitised process-wheel for historic building repair and maintenance projects in Scotland. *Journal of Cultural Heritage Management and Sustainable Development. DOI: 10.1108/JCHMSD-08-2017-0053* ...

McGibbon, S. and Abdel-Wahab, M., (2017) Towards a Digitised Process-Wheel for Historic Building Repair and Maintenance Projects in Scotland *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Ottawa, Canada, Conference paper*

Sivanathan, A., McGibbon, S., Lim, T., Ritchie, J., and Abdel-Wahab, M., (2017) A Cyber-Physical Gaming System for Vocational Training. *Proceedings of the ASME 2017 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference; IDETC201, August 6-9, 2017, Cleveland, Ohio, USA*

McGibbon, S. and Abdel-Wahab, M., (2016) Stonemasonry skills development: two case studies of historic buildings in Scotland. *Structural Survey, 34(3), pp.218-241*

McGibbon, S. and Abdel-Wahab, M., (2016) Emerging Digitisation Trends in Stonemasonry Practice. *Information Sciences, 1*, pp.177-183.

CHAPTER 1 – INTRODUCTION

Chapter 1 forms the research background and rationale while presenting a synopsis of the PhD study, which includes; the research's specific aim and objectives, a summary of the adopted research methodology, an indication of the research study's scope, and the thesis structure.

1.1 Research Background

With the historic building repair and maintenance (R&M) sector, recognised as an important driver for the well-being of a country (UNESCO, 2015); according to Balaras et al., (2005) 50% of Europe's national wealth is enclosed within the historic built environment, the scale of the economic, social and importance value of conserving, repairing and maintaining historic buildings cannot be underestimated. Promoting a proactive and sustainable approach to the process of historic building R&M has become a cornerstone of not only building conservation legislative frameworks, charters, and guides within countries worldwide but also for the UK (Forster and Kayan, 2009). This has led to various pre-emptive historic building maintenance schemes being positively implemented to stimulate such an objective, such as; the Danish Centre for Building Storage scheme, commonly acknowledged as the *Building Vision and Action Plan* (Michiels, 2013) and the Dutch *Monumentenwacht* scheme (replicated across Belgium and Luxembourg); whilst given the scope of the research is on the UK context, and it is estimated 6 million-plus UK pre-1919 historic buildings (traditionally constructed) buildings, albeit, with a particular focus on Scotland, numerous public and private funded grant schemes are available to support the cost of conservation-standard repair projects.

As the historic building repair and maintenance (R&M) sector is of equally strategic importance for the UK, within the last decade, several R&M specific studies (ECORYS, 2013; 2012; Scotland Historic Environment Audit (SHEA), 2018; TBR, 2016) have re-iterated the significance of the sector. For example, TBR (2016) and ECORYS (2012) estimated respectively for England and its 5.5 million-plus traditional (pre-1919) buildings, that: £3.8 billion is spent on historic building repair and maintenance; generating £9.7 billion in output (equivalent to 8% of total construction output or 22% of the total R&M output) (TBR, 2016) and £4.1 billion Gross Domestic Product (GDP), whilst supporting over 181,000 direct and indirect jobs (ECORYS, 2012). For Scotland

and its 488,000 pre-1919 buildings (around 20% of all Scottish residential and non-residential building stock); ECORYS (2013) and the latest estimated figures produced by Historic Environment Scotland (HES) bi-yearly report; SHEA (2018) suggests a perennial annual spend of between £0.6 billion and £0.72 billion (including grants), to service these types of building, resulting in an industry turnover of £3.3 billion, generating approximately £1 billion in respect of Gross Value Added (GVA) and supporting some 20,000 full-time employees (FTE) annually.

Currently, to help support the upkeep of Scotland's 488,000 pre-1919 buildings, the process of repair and maintenance has been embedded into primary and secondary legislation: facilitated through statutory vehicles such as the; *Historic Environment Scotland Act (Scottish Government, 2014a), Scottish Historic Environment Policy (Historic Scotland, 2011a),* supplemented with relevant technical building standards (*BS 7913: British Standards Institution, 2013*; and various guides to the conservation of historic buildings (Historic Scotland, 2013; Urquhart, 2007; Knight, 1995). Yet, despite the significant annual economic spend towards the pre-1919 historic building sector supported by the various standards, guides and legislation, aimed at promoting pro-active historic building R&M, particularly surrounding, reactive R&M and poor practice have continually resulted in neglect and disrepair across the pre-1919 residential and commercial building stock. For example, the annual Scottish House Condition Survey repeatedly produces yearly estimated statistics; assessing 90% (409,500) of the pre-1919 residential building stock requires routine repair (SHCS, 2016), as illustrated in Figure 1.1.

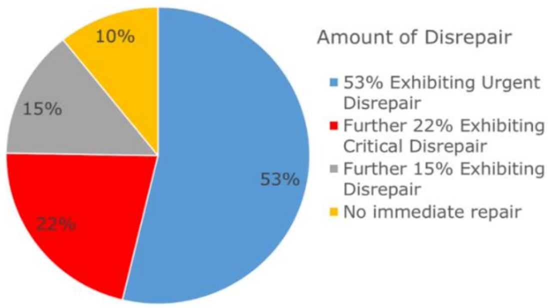


Figure 1.1: Pre-1919 Historic Buildings Disrepair Levels

Source: Chart is developed by the authors based on data provided by SCHS (2016)

Although no generated official statistics are available for the non-residential sector, it is believed to be suffering from the same levels of disrepair (Historic Scotland, 2012). With an increasing demand for quality, efficiency, and value for money R&M within the sector, clearly, there appears to be a gap between industry practice, guidance, and legislation, evidenced by continual neglect and poor practice. Thus, as a result of these problems, the Traditional Building Health Check (TBHC) scheme (based on the Dutch *Monumentenwacht* scheme (Michiels, 2012), was introduced in 2013; originally a five-year funded partnership between Historic Environment Scotland (HES) and the Construction Industry Training Board, piloted by Stirling City Heritage Trust, it was extended a further three years to 2021. Whilst undoubtedly a step in the right direction, at present, a lack of hard evidence exists, of the success of the TBHC model, in terms of uptake and improvements in historic building repair and maintenance quality, efficiency, and value.

With stone an integral part of the construction of Scotland's pre-1919 residential and commercial building stock, creating not only a unique and bespoke landscape but also providing a rich history of past societies and cultures, a strong connection exists between its vernacular architecture, its geology and stonemasonry skills (see Hyslop et al., 2006). Crucial to historic building longevity and durability is stonemasonry practice and its complex processes; the expert hand techniques and methods used to craft decorative elements and build structural components (see Purchase, 1896, Warland, 1929, and Hill and David, 1995). Indeed, from a historic building repair and maintenance perspective, it is evident, that masonry skills are not only economically critical but also underpin the survival of the built heritage.

1.2 Research Rationale

R&M Sector-Wide Challenges

Currently, a range of industry-wide and project level challenges face the sector, which obstructs current attempts to provide a stimulus and improvement within the historic building R&M sector. At a strategic level, several correlated persistent challenges exist, such as; *sector fragmentation; supply and demand (lack of level of detail and accuracy of demographic employment data); skills shortages and gaps; education and training; up-skilling the workforce in the use of new technologies and processes, current disrepair levels; economics; modernisation, process improvement, and performance measurement.* Moreover, it is further strategically challenged by environmental concerns, such as;

*climate change, energy efficiency, sustainability and the move to a low carbon economy (*Historic Scotland, 2011a, 2012a, 2012b; National Heritage Training Group (NHTG) 2007 & 2008; Pye Tait 2013; Scottish Government 2014 a & b; Scottish House Condition Survey, (SHCS) 2016; Scottish Stone Liaison Group (SSLG), 2006). As part of the focus of this research surrounds historic stone R&M projects, a small number of sporadic, targeted reports exist concerning Scotland's stonemasonry sector (see Hutton and Rostron (Firm), 1997; Historic Scotland, 2010, 2012b; Scottish Stone Liaison Group (SSLG), 2006); for example, SSLG (2006) discovered 97 percent of Glasgow's heritage buildings demanded historic stone repair works requiring approximately 4,715 stonemasons over the 20 years (236 per year) at a cost of £585 m. Whilst, they have provided an invaluable assessment of the sector and produced several perturbing findings across a wide spectrum of similar repair and maintenance sector issues and HES may have data of the number of historic buildings and a register of all listed buildings. Yet, the key challenges remain to determine specific repair requirements, establish specialised skill requirements, and ultimately enhance historic building R&M practice by using a structured and multi-disciplinary approach.

R&M Project Specific Challenges

On a Project Management and delivery level, a number of similar interconnected challenges exist, such as; *skills shortages and deficiencies (professionals and contractors), yet heavily reliant on specialist micro and small to medium-size organisations (MSME and SMEs) (businesses with either less than ten employees or between eleven and fifty employees); performance and productivity (i.e. projects and workforce); lack of Project management (PM) efficiency and on-site construction practice efficacy (e.g. project time and cost overruns, lack of communication and collaboration, in-adequate project specification, and poor quality of work)* (Abdel-Wahab and Bennadji, 2013; Dyson, Matthews and Love, 2016; Forster et al., 2011&2013; Historic Scotland 2012c; Hyslop, 2004; NHTG, 2007, 2008; Odgers and Henry, 2012; Pye Tait, 2013; Snow and Torney, 2015; Scottish Stone Liaison Group (SSLG), 2006; Torney et al., 2012; Torney and Hyslop, 2015).

Hence, in order to assure better outcomes in historic building repair and maintenance projects, from a PM perspective and being contingent on specialist MSME and SMEs; *to operate more effectively, reduce project delivery time and cost, improve productivity,* *performance, and quality, and enhance collaboration and communication* (Department for Business, Innovation, and Skills, 2015;2013a). Pre-1919 Historic building repair and maintenance projects require to modernise and align with the wider construction industry and look to deliberate the key function MSME and SMEs will play in raising project productivity and performance through *"process management and improvement"* fuelled by innovation, collaboration, integrated working (Barbosa et al., 2017) and optimising the opportunities afforded from digitisation, such as offsetting the risks of reliance on labour intensive techniques (Farmer, 2016; UK Government, 2016). For example, despite the inherent need for more objectivity, project data capture tends to be secured in an unstructured manner, relying heavily on professional subjective judgement (Forster, 2010). The manual and nebulous process of a paper-based workflow approach to on-site project data capture, make effective Project Management, a real challenge, which in turn, further fuels an inclination to adopt ad-hoc management approaches to administering both on-site and off-site processes. Perhaps, drawing on not only better data, but more objective, robust and valid data through a more collaborative, extensive, structured and objective PM approach can provide the stimulus and improvement required in process management, to aid informing planned and future repair and maintenance works, reflect better PM and identify an increase in efficient construction practice.

Yet, with a heavy reliance on the successful process co-ordination of both on-site and off-site activities across the supply and delivery chain required, the difficulty in tackling the area of modernising historic building R&M is faced by a paucity of research on investigating *"process management and improvement"*, in particular surrounding guiding PM processes and on-site practice. Much of the research is focused on the wider R&M sector: construction R&M (Bowden et al., 2006); facilities management (Amaratunga, Sarshar, and Baldry, 2002); and infrastructure (roads) (Denisov, 2013). However, these studies highlighted the development of such specific frameworks, based on proven approaches of organisation, planning, and operational processes, are more promising solutions for providing enhanced quality, efficiency, and value for money in project delivery.

Construction Process Management Frameworks

In order to provide a useful plan for managing and administering historic building repair and maintenance projects involving substantial works. There are a small number of PM guides and frameworks available from various professional organisations: *Royal Institution of Chartered Surveyors (RICS (2009); the Royal Institute of British Architects (RIBA), (2013); Chartered Institute of Building's (CIOB) (*2014) *and the British Standard 7913 (2013).* However, despite each framework, having their own individual merits and benefits, and offering invaluable guidance, they have a number of specific shortcomings such as; *more suited to their relevant professional organisations resulting in difficulty in for a clear lead to come from anyone consistent source, suggesting a propensity to promote silo working* but ultimately correlated inadequacy of a; *lack of specificity towards a fully tailored SME common defined process for guiding effective PM and on-site processes, as the tendency is to employ high level design and building conservation centric terminology more suited to high end conservation projects.* Inevitably, resulting in groups that operate as divergent professions across the supply chain, providing inherent multiple points of management (Architect, Contractor, Building Surveyor, Structural engineer etc.) all functioning in independent silos, which is then not necessarily agreed and communicated with other project stakeholders, as each is working with only *"parts of the puzzle"*, which fuels poor PM decision-making (Forster et al., 2013; Hyslop, 2004; Torney et al., 2012).

Recurrently, these are not solely UK or indeed Scottish issues; various international studies (Vandesande et al., 2016; Atakul, Thaheem, and De Marco, 2014; Michiels, 2013; Baars, 2012; Finke, 2008) have echoed the challenge is to improve the current management frameworks in order to reduce improper repair decisions and interventions as well as combat the lack of knowledge and information, and improve the uptake and adoption of an enhanced multi-disciplinary approach for historic building R&M supported by continually employing suitably qualified personnel.

Historic building Repair and Maintenance Digitisation and Innovative Project Management

With Pre-1919 building Historic building repair and maintenance sector and its projects requiring alignment with the wider construction industry, to not only be more efficient and sustainable but be technologically advanced and "smart"; with a highly skilled and diverse workforce (Vokes and Brennan, 2013). Perhaps, with current trends in digital technology and innovative PM methodologies having yielded a wide range of mechanisms and processes to support *"process management and improvement"* across the wider construction industry (Ibem and Laryea, 2014). Adopting such instruments may help eliminate, many of the protectionist and redundant processes that do not add value, as various studies have shown adoption and employment of such tools has been shown to achieve statistically significant improvements in project performance (El Asmar et al., 2013). For example; adoption of an integrated project delivery (IPD) based approach, whereby the contractual silo walls that separate the key participants, allowing early collaboration between key participants, can be removed very early in a project timeline, resulting in optimal project outcomes (i.e. time, cost, quality, and sustainability) (Garcia et al., 2015), as consideration is given to not just to the end product but the process itself (Ghassemi and Becerik-Gerber, 2011). Moreover, IPD helps support enhanced communication and sharing of tacit knowledge between team members and can result in increased connectivity and interdisciplinary knowledge (Zhang et al., 2012). In essence, a multi-disciplinary approach espoused by the literature and considered an essential requirement when dealing with the unique, bespoke, and complex environment of repair and maintenance projects. Yet, "traditional" contract project delivery processes are still used, in the majority of historic building projects and their adversarial nature presents troubling questions that hinder organisations from exploiting the full benefits of these types of collaborative methodologies (Crompton et al., 2014). Nonetheless, these studies are particularly relevant not only for change management but also for raising the awareness and highlighting, the efficient and effective use of IPD to help support the multi-disciplinary approach espoused by the literature and considered an essential requirement when dealing with the unique, bespoke and complex environment of repair and maintenance projects.

Historic building digitisation is an area that has attracted growing attention in recent years. However, much of the research has surrounded culturally important historic stone buildings, tending to focus on digital documentation and the relevant workflows surrounding; *spatial documentation, modelling, surveying, and monitoring*. Nonetheless, given digital technologies and tools can provide objective data capturing for informing high-quality repairs and optimise on-site processes and performance, which can ultimately offer value for money to the client. Such studies (Bednarik et al., 2012; Casula, 2009; Clarke & Laefer, 2014; Ercoli, 2013; Kottke, 2009; Oses et al., 2014; Sun, 2012; Smith et al., 2013; Stefani, 2015; Yajing and Cong, 2011; Xi et al., 2015) are invaluable, as they have developed several opportunities relevant to R&M construction practice required to enhance project performance and realise process efficiencies; *from project* *surveying to building inspection and diagnostics, to building monitoring and evaluation, to project management.* Furthermore, there is growing research evidence (Hayes et al., 2015; Forster et al., 2018; Ouimet et al., 2015; Shaughnessy, 2015) for the accrued benefits of embracing relevant digital technologies and tools to help support the elimination of laborious, and inefficient construction processes. Yet, it cannot be assumed that one technology alone will be the panacea in addressing the challenging agenda, despite the benefits for embracing digital technologies, the current approach could be described as piecemeal, disjointed and sporadic. With the absence of SME specific PM guidance and standards targeted for carrying-out and managing on-site operations, along with a lack of sector modernisation and innovation. To help support a multi-disciplinary structured collaboration, to ensure process efficiency and maximisation of resources for successful project delivery. There is a need and requirement for the development of a common industry collaborative process standard framework, which accurately reflects current SME R&M practice, to support an effective multi-disciplinary approach, for carrying out building repairs. A simple, yet appropriate and systematic process-standard framework which in effect, is designed to offer a process model, map, and management tool, which informs digital technology and supports a collaborative, integrated working approach. In turn, this could help support SME-led initiatives to manage change towards the application of digital technologies and cultivation of an IPD based approach, especially when investing in new processes and technology, SMEs are inclined not to adopt such tools that require too much investment as they view this as too much risk (Sexton and Aouad, 2006).

Hence this research study provides for the inclusion of a large "digital data collection" section – as the centrality of such data is paramount to not only fostering an IPD and HBIM approach, but also the fact that current innovative surveying, monitoring and evaluating technology, such as 3D laser scanning and infra-red thermography (IRT) along with digital tools such as National Building Specification (NBS) Create and Building Information Modelling (BIM) are specifically intended for multi-disciplinary centralised collaboration of the kind advocated by the literature and absolutely relevant for R&M.

In terms of the relevance, for practitioners in not only Scotland and the UK, but also internationally as well; this thesis fundamentally facilitates the uptake and adoption of a collaborative structured approach for PM and on-site operations processes, as well as informs the application of historic building repair and maintenance digitisation and supports integrated working. The thesis deals not only with the historic building R&M sector, and the extent and level of growth opportunity that the sector affords but also recognises the relevance and importance of the wider RMI and construction industry-wide issues (concerning silo working, and the lack of communication and collaboration). Especially given, the industry's capacity to improve the condition of the existing building stock requires a scale and size of activity as generated by the wider RMI market per year (which yields tens of billions of pounds of output) (FHEIBC, 2016)

1.3 Research Question

The key question of this research study is; *"How can historic building repair and maintenance Project Management and on-site process management, particularly for SMEs be improved to facilitate multi-disciplinary collaboration and support successful project delivery?*

1.4 Research Aim

The primary research study's aim was to seek to develop a common structured collaborative industry framework, which can support an effective multi-disciplinary, collaborative and structured PM approach for carrying-out and managing on-site operations and processes, to aid increased efficiencies. Whereby, the framework facilitates transcending the boundaries of traditional professional and contractor roles, which is paramount for fostering genuine collaborative approach for a successful multi-disciplinary approach for historic building R&M project delivery, in order to provide a stimulus and improvement in Project Management and facilitate an increase in efficient construction practice. To fulfil the above aim, the research will centre on the following objectives:

1.5 Research Objectives

1. To gain an in-depth comprehension of the key challenges and issues facing the historic R&M sector, at both a sectoral and project level, with a particular focus on historic stone building R&M projects.

2. To appraise current frameworks for construction process management and examine their suitability in terms of supporting and enhancing PM and on-site construction process management practice.

3. To develop an in-depth and informed identification of IPD and suitable digital technologies for historic stone building R&M projects.

4. To develop a common structured collaborative industry framework for process management and improvement to support a collaborative, multidisciplinary approach which will facilitate an integrated approach, whilst inform digital technology application.

5. To evaluate and validate the newly developed process management framework (process road map and tool) capability for undertaking historic stone building R&M PM and on-site practice.

1.6 Research Methodology

The general philosophy of this research has its foundations in Grounded Theory, due to the nature of the study; exploratory in nature, unknown variables, complex frame of reference, and a lack of existing theory. Allied which suggested the need to provide a deeper, fuller comprehension of the phenomena under investigation (Creswell 2013). Hence, given the research is concerned with real life issues of direct interest to practitioners, this research has implemented a qualitative participatory action research approach through implementing applied research by adopting a practical project-based approach; proactive engagement with relevant key industry practitioners, allied to a case study of a *"live"* site based demonstration project of historic stone building repair, focusing on Project Management and the associated on-site processes and practices (e.g. surveying, logistics, on-site works, QA, etc.), across the supply chain, in order to provide the research with a representation and consideration towards enhanced collaboration and integrated working. Action research was selected and adopted as the most suitable underlying approach, allowing the association between research practice, to synergistically inform each field i.e. research informs practice, and practice informs research (Bryman et al, 2012).

Therefore, with the research study having dualistic aims and goals: the aims of action (bring about change) and research (increase researcher understanding); and the goals of improvement and knowledge generation. To help support the detection of convergent findings, achieve triangulation of the research subject by addressing it from multiple viewpoints and provide robustness in the findings of the research (Creswell 2013). The study employs a methodical conceptual framework (Figure 1.5), whereby a four-stage mixed method research strategy was adopted, consisting of multi-method qualitative approach to data collection, consisting of the combination of the following methods: on-going literature review, semi-structured in-depth interviews, framework development, case study and focus group validation/evaluation, which are outlined in the following sections and discussed in detail in Chapter 4:

(1) Stage 1 involved research gap, defining the study's; aim, its objectives, and the research methodology adopted through presenting detailed literature reviews and their findings (Chapters Two, Three, and Four). The synthesis of the literature (Chapters Two and Three) satisfied research objectives 1, 2, 3 and to some extent research objective 4.

2) Stage 2 (fieldworks and analysis) involves semi-structured interviews with industry practitioners from both contractor and professional MSME/SMEs; who possessed extensive experience and knowledge of current historic building R&M industry processes and practice; held senior management positions; and had been involved in the Project Management (PM) design team and/or construction team (Chapter 5 & 6). This stage satisfied research objectives 1, 2, 3, and to some extent research objective 4.

(3) Stage 3 (framework development) consisted of the; literature review findings (chapters two and three); and the semi-structured interviews (chapters five and six), all carried out in the first two stages, leading to the development of a common structured, collaborative and holistic framework, incorporating digital technologies, aimed at supporting PM of historic building projects (Chapter 7). The developed framework harnessed the integrating of the Business Process Modelling Notation (BPMN) and the Generic Design and Construction Process Protocol (GDCPP) model, satisfying research objective 4. the study employs a methodical conceptual framework (Figure 1.5).

(4) Stage 4 (framework validation and evaluation) entailed a combination of a case study (Chapter Eight) and 2 no. focus group discussions with experts (Chapter Nine). This stage satisfied research objective 5.

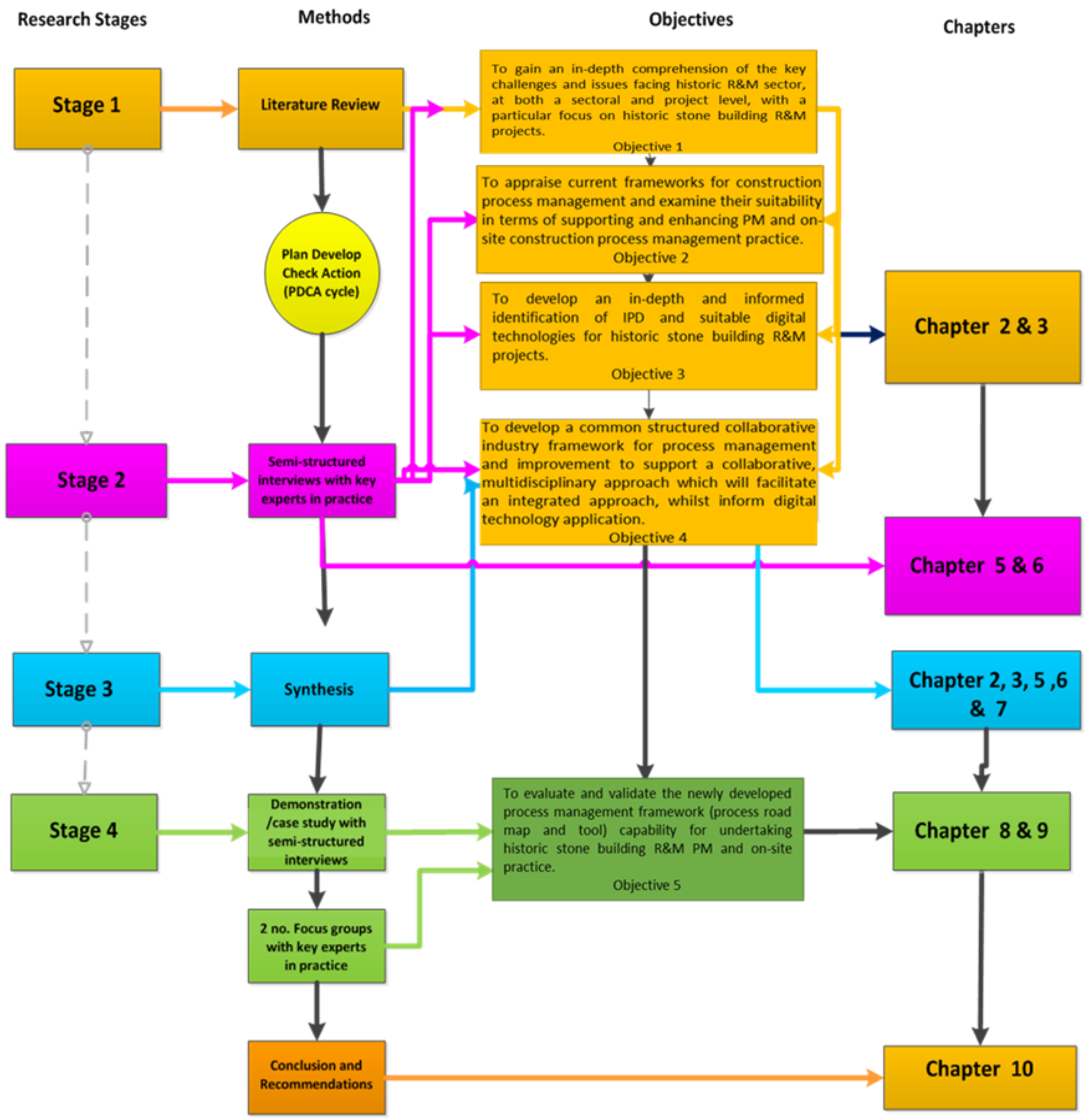


Figure 1.2: Graphical Representation of Research Programme Design

1.7 Scope and Limitations of the Study

The research study grounded in its sector specific context, cannot pretend to address everything within the historic building repair and maintenance domain. Therefore, it is necessary to state the research scope and the limitations of the study. In terms of the research scope, the initial orientation was towards Scotland's residential and non-residential pre-1919 solid wall construction buildings, under different levels of historic building protection, undergoing complex historic stonework repair interventions (stone/mortar replacement, structural issues). Furthermore, the scope was orientated towards stonemasonry MSMEs and SMEs, focusing on organisations who are responsible for; the tender submission, the subsequent delivery of awarded projects (timeframe, cost, and quality); and operate under a traditional organisational structure.

In terms, of the data collection, the semi-structured interviews enacted for the pilot study, the demonstration project, and for the focus groups were limited and restricted to selected MSMEs and SMEs within the Scottish historic building repair and maintenance sector, in particular; stonemasonry specialists (Professionals, Contractors, Sub-Contractors, Suppliers), with a minimum 15 years of experience; diverse professional experience; held top-level management positions within their organisations, and from a PM perspective they could be classed as part of a project design team and project construction team. As part of the action research process, through co-operative industry engagement, the generation of a best practice historic building SME R&M four phase process map was undertaken during the pilot study, which supported the formulation of the developed common structured collaborative industry framework.

Accordingly, to enable prospective observation and documenting of the potential benefits of using a common structured collaborative industry framework to support enhanced collaboration and integrated PM and on-site practice, in detail as it progresses, rather than retrospectively, research data was sought from a *"live"* project. In addition, it was necessary to represent the broad scope of currently offered classic PM knowledge areas that support successful project delivery (see Project Management Institute (PMI), 2013; Association for Project Management (APM), 2012). However, it was decided to focus on only four core PM knowledge areas (Scope, Time/Schedule, Cost/Budget, Quality), as from a MSME/SME perspective this would provide more user-friendly and applicable PM and Key Performance measures that are simple, quick, relevant and practical (Meister, 2006) allowing for a basic level cost benefit analysis (CBA) (see Table 1). It should be noted, that the domain of Historic Building R&M also encompasses the processes of risk, procurement, health and safety, and design, thus the exploration of the *"process management and improvement"* of these management workflows emerges as several possible areas that this research can inform and help address.

The Development of a Framework for Supporting Successful Project Delivery in the Scottish R&M Sector					
Area of Historic Building R&M	Project Type/Characteristics	Size of SMEs	Project Definition	Project Scale	Project "complexity" factor
Historic stonework R&M projects.	* Pre-1919 solid wall masonry construction * Under different levels of historic building protection *Private and Public sector *Residential and non-residential	Micro and small businesses (MSMEs and SMES) defined as businesses with less than ten employees and businesses with between eleven and fifty employees respectively.	*Small scale	* Projects with a budget of £15,000 - £100,000, and a timescale of 4-12 weeks	Scope, Time / Schedule, Cost / Budget, Quality

Table 1.1: Overview of the Scope of the "live" project

However, considering the two main research study limitation; limited resources of the study (timescale and budget) and industry fragmentation, the following research dynamics bounded the study:

(1) Due to the limitation of research time, and budget, it was not possible to explore all the phases of the proposed framework and as such only the project appraisal phase of the framework could be demonstrated; as it would be difficult to resource all the intended technologies within the designed framework. Hence, the research pressed the priority to seek out digital technologies that were readily accessible and available; low cost, easy to use, off-the-shelf, mobile, whilst being of high quality, although expensive, complicated technology that required a high-level training was not disregarded.

(2) Industry fragmentation and the prevalent practice of silo-working would present difficulty in terms of the full agreement from all project stakeholders when selecting a suitable case study, which could place the research under pressure, given part of the research methodology was action research-based case study and would compel the study to investigate an alternative research methodology. Therefore, it was deemed appropriate to focus on small scale size projects and discount medium to large projects, as the management of small size projects is an essential component of MSMEs and SMEs core business (NHTG, 2007, 2008; Pye Tait, 2013); thus, the following "small scale project"

project level definition assumption was posited: an overall budget of £25,000 -£100,000 with a timescale of 4 -12 weeks, although from a PM perspective the project's "complexity" factor was significant as it incorporated structural and intricate historic stonework interventions, allied to the need for effective communication, and collaboration between the numerous stakeholders involved in the project;

1.8 Thesis Structure

This research is divided into ten distinct chapters with content as shown in Table 2 below:

Chapter 1:	This introductory chapter offers a summary of the research background, its rationale and presents a synopsis of the PhD study; research aim and objectives, adopted research methodology, the research study's scope, and thesis structure.
Chapter 2:	This chapter offers an extensive review of available industry intelligence reports and academic literature pertaining to the sector wide and project specific level challenges and issues and also provides direction for the research.
Chapter 3:	This chapter provides a comprehensive literature review to support modernisation and innovation historic building R&M Project Management and on-site construction practice. First, a critique review of existing frameworks for construction process management which are designed to promote a more collective approach to project delivery are discussed. This identified the potential issues associated with current CPMFs and their subsequent suitability to support PM and onsite practice *"process management and improvement"* for SMEs in order to provide validity to the argument for the need for a developed framework. This is followed by an overview of Integrated Project Delivery and its influence upon improved project management, in terms of performance efficiency and enhanced communication and collaboration. This is then followed by a discussion by current literature surrounding historic building R&M digitisation and suitable digital technologies, concluding with a critique review of existing conceptual HBIM Frameworks. This identified the potential issues associated with current attempts to support historic building digitisation, which provides further validity to the argument for the need for a developed SME based framework. The chapter concludes with a literature summary and identification of the literature gap.
Chapter 4:	The aim of this chapter is to provide an overview of the theoretical concepts that guided the adopted research strategy and methodology. Highlighting their associated methods, data collection tools, and their strengths and weaknesses, in order to accomplish the research aim and its objectives, allowing the critical evaluation of the knowledge generated. The chapter begins with a brief definition of research strategy and methodology, followed by a brief synopsis of Construction Management (CM) research. The chapter then explains the theoretical model employed to inform and guide decisions on methodology, namely: Saunders et al., (2016) research "onion" model. As headings from the model's layers direct the discussion on the research strategy adopted and the reasoned rationale on the decisions made.
Chapter 5	This chapter presents the qualitative data analysis findings from the pilot study; stage 2 of the research study and discusses the findings from the 14 semi-structured interviews carried out with Scottish historic building R&M industry SMEs and practitioners to; investigate and reveal the key general and project specific challenges facing SME's within the R&M sector.

Chapter 6	Chapter 6 discusses the findings from the identification and exploration of the key industry practitioners' views and issues related to the management of current on-site processes and conventional practices used in historic building R&M projects, based on the iterated generic best practice Historic Building R&M project process map generated from the pilot study. It also presents the results of qualitative data analysis and identification of the awareness and understanding of CPMFs, Digital Technologies, and IPD.
Chapter 7:	This chapter presents the development of the common structured collaborative process-standard industry (*CrOsS*) framework for historic building R&M PM. The chapter begins with an overview of the developed framework, the approach adopted, and its key elements followed BPMN/GDCPP process maps of the framework
Chapter 8:	This chapter's objective is to evaluate and validate the proposed framework. A "live" demonstration project supported a proof of concept for using the developed *CrOsS* Framework in practice; and to provide a verification of the efficiency and applicability of the proposed framework in terms of cost benefit analysis (CBA) surrounding quality, time, cost and health and safety.
Chapter 9:	This chapter's objective is to evaluate and validate the proposed framework. Two focus groups of six professional practitioners/ experts, who had extensive experience in historic building project delivery were organised to evaluate the credibility, suitability, applicability, and clarity of the framework.
Chapter 10:	This chapter summarises the overall research findings and presents conclusions, in relation, to the specific objectives set at the beginning of this PhD study. In addition, this chapter discusses and clarifies the study's contribution to academic theory and industry practice knowledge. Followed by sections discussing the limitations of the research, and recommendations for further research.
References	Provide useful sources and information for further reference.
Appendices	Appendix A: Heriot-Watt University Ethics Form Appendix B Participant Interview Consent Forms Appendix C Pilot Study Interview Guide Appendix D.1 Case Study Interview and Focus Group Questions Guide Appendix D.2 Focus Group; Framework Validation Questionnaire Appendix E Structured Document Pro-formas Appendix F Illustration Appendix G Publications

Table 1.2: Thesis structure and content

Chapter 2

The Challenges facing the Historic Building Stonemasonry Repair & Maintenance Industry

2.1 Introduction

The following chapter offers a review of the relevant literature surrounding the key challenges, issues, and impacts facing the pre-1919 historic building repair and maintenance sector. The chapter begins by covering pre-1919 historic stone buildings definition; the concept and definition of historic building repair and maintenance; and an overview of the key practice of stonemasonry, and to finish, concludes with a chapter synopsis. During the chapter, it discusses the key concerns and impacts confronting historic building R&M practice (management and technical), at a strategic and project-specific level, focusing on stonemasonry R&M works, in terms of future efficiency, productivity and performance enhancements. In order to understand their main characteristics and provide direction towards identifying the key areas for process management and improvement within the industry. Furthermore, parts of Chapter 2 findings are published in the following Academic journal: International Journal of Building Pathology and Adaptation (formerly Structural Survey) (McGibbon and Abdel-Wahab, M., 2016) (see Appendix G).

2.2 Defining Pre-1919 Historic Building Stonemasonry Repair and Maintenance

2.2.1 Pre- 1919 Historic Stone Building Definition

Currently, there are approximately over 2 million stone-built structures in Scotland, with approximately 20% of this amount being a mixture of residential and non-residential property pre-1919 stone buildings (Scotland Historic Environment Audit (SHEA), 2016; Gillespie and Tracey, 2016). Pre-1919, is generally considered, the cut-off date, whereby construction technology began moving towards cavity wall construction use (Rye and Scott, 2012). Therefore, it follows that pre-1919 historic stone buildings are defined as;

structures built of solid wall construction, crafted of natural stone or a combination of natural stone and brick. Therefore, it follows, with almost 76% of pre-1919 property stock being privately owned (SHCS, 2016), effectively repairing and maintaining these buildings, is of utmost importance to several significant internal and external stakeholders (building owners, local authorities, businesses, heritage organisations, professional and contractor supply chain, funding agencies, regulatory bodies, policy makers, etc..).

Figure 2.1: Stakeholder Map

2.2.2 Pre- 1919 Historic Building R&M Definition

Over the course of the past two decades, much debate and discourse have occurred within the academic literature surrounding a robust definition of repair and maintenance (see Dann, Worthing, and Bond, 1999; Feilden, 1993; Jokilheto, 1993; Worthing et al., 2002; Worthing, Dann, and Hills, 2003; Forster and Kayan, 2009). The discussion invariably tends to surround semantics; surrounding the distinction between maintenance and repair, which makes determining a clear definition difficult (Forster and Kayan, 2009). Although Forster and Kayan (2009) argued that adopting a minimum intervention approach, enables a greater clarity and distinction between maintenance and repair, there is validity and weight to Forster and Kayan's (2009) perspective, given the logical motivation of adopting such an approach is to reduce historic fabric harm (Australia ICOMOS Burra

Charter, 2013). However, based on anecdotal evidence in MSME and SME practice, maintenance and repair are not two separate concepts as they often co-exist; as such organisations tend not to work exclusively on pre-1919 historic buildings that are protected by the UK and Scottish legislative system (NHTG, 2007,2008).

However, for the purpose of this research, an in-depth discussion on this discourse is not within the parameters of the study. Hence, the study adopts the pragmatic perspective held by the current technical standard British Standard 70913:2013 *Guide to the conservation of historic buildings*, the Scottish Historic Environment Policy (SHEP) (Historic Scotland, 2011a), which calls for appropriate technical knowledge, materials, skills, and methods of working to retain the historic character and future performance of older buildings. In addition, being underpinned by historic building conservation philosophy; an internationally recognised ethical and principle-based framework, established for over 130 years, which supports practical decision making, and the implementation of appropriate fabric repairs to historic structures (Kayan, 2013). Whereby, the key objective of repair and maintenance is to provide systematic protection to prevent further decay, by establishing a consistent level of good repair, in order to keep a historic building in good condition.

2.2.3 Historic Building Repair and Maintenance and Stonemasonry Practice

Historic stonework repair and maintenance is a highly specialised sector, presenting a unique and bespoke MSME and SME landscape, comprising of a wide range of these business types, such as; contractors, professionals, manufacturers and various supply chain organisations, covering numerous traditional products, resources and services (Gillespie and Tracey, 2016; PYE Tait, 2013). Unsurprising, given Scotland's strong architectural, geological, and skills connection evidenced by the construction of some of the most important monuments and structures around Scotland (Yarrow and Jones, 2014; NSI, 2005; Scottish Executive, 2007). Indeed, this has created a distinctive and complex repair and maintenance environment, as each geographical region and period in history has its own characteristic, way of building walls (Hyslop et al, 2006; Natural Stone Institute, 2005). This in turn presents the challenges of R&M vs. building typology, although a small number of guides exist for specific repair and maintenance based on historic building type (see Construction Industry Research and Information Association (CIRIA), 1994; Davey, 1995; Historic Scotland, 2003 and 2015). With regards, historic stone building repair and maintenance, it tends to surround principally, five common types of masonry fabric repair: (i) stone replacement, (ii) dismantling, record and re-build (iii) pinning and consolidation, (iv) mortar replacement, and (v) "plastic" repair (lime-based materials applied to porous sandstone) (Forster et al, 2011a) (Figures 2.2).

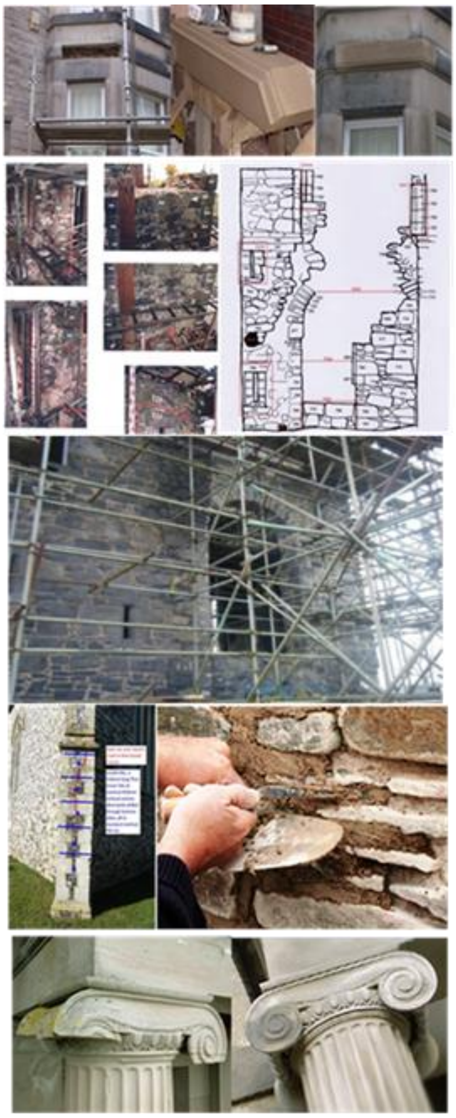


Figure 2.2: (i) full stone replacement; (ii) dismantling, record and re-build (iii) pinning and consolidation, (iv) mortar replacement, and (v) "plastic" repair

These generic methods of masonry fabric repair have numerous sub-sets as well as an adaptability and flexibility of techniques dependant on the repair required (Forster et al, 2011a). Therefore, the processes and practices developed in order to construct Scotland's historic buildings; the expert hand techniques and methods used to craft decorative elements and build structural components (see Purchase, 1896, Warland, 1929, and Hill and David, 1995) have become even more crucial to historic building longevity and durability. Yet, despite the resurgence of interest in lime mortar and stone allied to the widespread acknowledgement of the value of stone repairs, particularly, as current and future required quality and performance standards; in relation to sustainability, have become increasingly important (see Forster et al, 2011; Forster et al, 2013; Kayan, 2015; Kayan, Forster, & Banfill; 2016); and that private investment accounts for three quarters of all funding for the historic environment (SHEA, 2018), historic stonework repair and maintenance normally transpires as a necessity rather than regarded as part of a pro-active approach, particularly for the private sector (Historic Scotland, 2012). For example, Historic Scotland (2012) investigated the level of external masonry fabric repair demand, and estimated country wide that over 183,000 pre-1919 buildings required routine stonework repair, and that a further 44,000 required masonry structural works, whilst also offering a generic classification of repairs required; ranging from re-pointing, to very extensive stone replacement (Table 2.1).

Masonry Repair	*Type of Repair*
Re-pointing	Routine repair
Stone replacement (isolated and widespread)	Disrepair to critical elements
Structural Repair	Extensive Repair

Table 2.1: Common Masonry Repair; *Reproduced from HS report* (2012)

Furthermore, when involved in a historic building stonework repair and maintenance campaign, it is vital that, to not only play a crucial part in the continued endurance of these buildings but also ensure that, the socio-economic and environmental capital investments made are not wasted (Forster et al, 2011a), but fundamentally at both a contractor and professional level, it is crucial to have the appropriate knowledge and understanding of the skills and processes required (see PYE Tait, 2013). For example, an important component of historic stone building repair skills is not only the ability to manufacture and install traditional material components but also accurately survey, specify and manage the implementation of stone fabric repairs (Lott, 2013). Hence, when considering stonemasonry repair and maintenance, and contemplating the multitude of options at disposal, the decision-making process regarding the selection of appropriate repairs is a complex process underpinned by a number of practical influences. Although invariably it is driven by two main factors; the budgetary constraints of the project as well as historic building conservation philosophy ethics and principles (Forster, 2011a; Daniels, 2012).

2.3 Overview of the pre-1919 Scottish Historic Building R&M Sector

2.3.1 Size of Scottish Historic Building R&M Sector

Currently, the Office for National Statistics (ONS) produces Standard Industrial and Occupational Classification codes (SIC and SOC) codes, to define the economic and occupational footprint of a sector, in order to gain data surrounding labour market analysis (Elias, and Birch, 2010). SIC codes classify businesses, according to ONS are grouped by the type of economic activity in which they are engaged (ONS, 2007), whilst SOC codes provides a common classifying and grouping of occupational data for the UK, in terms of skills (the level and content) (ONS, 2010). In terms of both codes, a safe postulation and assumption would be to envisage relevant codes for the historic building repair and maintenance sector are available. On the contrary, while this might appear logical, despite the size and the economic value of the combined UK sector, in actuality they provide a lack of coherence in determining an accurate estimation of the size of the sector and its workforce is problematic. For example, there are several correlated strategic issues with regards the lack of occupational detail, specificity, granularity and accuracy of data in this field such as; no official published precise statistics surrounding the true size and scale of the UK historic building repair and maintenance market; resulting in a lack of determination of the number of MSME/SME companies working in this specialist sub-sector; identification of the companies with a dominant market share in the industry; and an accurate level of scale of R&M activities they are involved in

In reality, this is unsurprising, as both SIC and SOC codes have parallel issues that affect them by providing a meagre definition and classification of the wider term construction repair and maintenance. Moreover, there is a lack of coherent individual codes for the skilled trades and professionals working, as well as the services and product areas, within the sector. For example, the SOC code (ONS, 2010), without giving a description of the specialised skill or equipment, situates and subsumes all three main areas of stonemasonry (skills, services, and products) within the occupational classification for bricklaying. Yet, in reality, stonemasonry and bricklaying are two separate specialist areas, who have divergent skills sets, knowledge, and experience requirements. Furthermore, for professionals, the situation is similar; there is no distinction between the professional occupations who practice in the historic building field as opposed to those who deal with new build construction only; further adding to the difficulty in classifying and aggregating occupational data (SOC, 2010).

These deficiencies not only suggest the possibility of misleading analysis of national statistical evidence regarding current and future supply, demand and skill requirements in this specialist arena but also, having no officially published precise statistics, presents not only major challenges in sector health determination (supply and demand) but also in addressing sector performance and productivity shortcomings. Thus, it is questionable whether developing knowledgeable decisions, strategies and policies could be cultivated further to help support opportunities to modernise, and upskill the sector. However, non-action for the historic building repair and maintenance sector is not an option, as such, in attempt, to overcome this distinct lack of reliable and consistent official statistical data collation undertaken in the field, several industry wide and practice specific studies on the traditional buildings sector have provided sector specific evidence and data sets surrounding economics, supply and demand, and skills. Thus, the following sections will provide a brief discussion.

2.3.2 Economic Impact

Much like the wider construction sector; the negative impacts of the "credit crunch" and its lingering effects, with lacklustre activity growth, amid Brexit-related uncertainty and poor productivity levels (see Eight International, 2017; Sala-i-Martín et al., 2018) are replicated across the Scottish historic building repair and maintenance sector. Nonetheless, the scale of the importance and economic value of the historic stone building repair and maintenance sector in Scotland cannot be underestimated. Based on the latest estimated figures produced by Historic Environment Scotland (HES) bi-yearly report; Scotland's Historic Environment Audit (SHEA) (2018) and supported by previous research on the economic value and impact of the sector (see ECORYS; 2013; Chapter 1; section 1.1). On average, approximately between £0.6 billion - £0.72 billion (including grants) was spent on repairing and maintaining the pre-1919 residential and non-residential building stock during 2011 – 2016. However, care must be taken when interpreting these expenditure levels; when on closer inspection of the labour and skills analysis needs of the Scottish traditional buildings sector (see PYE Tait, 2013) it presents a paradox; reporting the sector was faced with a decline in demand due to the economic conditions, yet the aforementioned audit reports suggest year on year, the sector is attracting a similar level of demand and thus attracts a comparable level of sustained investment. Suggesting the sector cannot simultaneously be both suffering from both a demand reduction and a demand increase. However, this incongruity appears due, to not only several issues with the baseline data used to count the historic building repair and maintenance sector's contribution to the economy but also due in part to the sector's internal inconsistency surrounding its footprint and classification (refer to section 2.3.1), which in turn creates difficulties in determining future skill needs and requirements.

	Housing			Non-Housing			Total			
Year	Public	Private	Total	Public	Private	Total	Public	Private	Total	% Private
2011/12	£173	£547	£719	£271	£132	£403	£444	£678	£1,122	60%
2012/13	£178	£562	£740	£235	£141	£376	£413	£703	£1,116	63%
2013/14	£146	£462	£608	£238	£146	£384	£384	£608	£992	61%
2014/15	£147	£465	£612	£232	£165	£396	£379	£630	£1,008	62%
2015/16	£177	£561	£739	£261	£188	£448	£438	£749	£1,187	63%

Figure 2.3: Repair and maintenance of historic buildings expenditure; £ millions; reproduced from *Scotland's Historic Environment Audit (SHEA) report (2016)*

2.3.3 Sector Specific Reports

Over the last decade, in attempts to determine the labour and skills needs of the Scottish traditional buildings sector. Several industry wide reports (Angus College 2009; Historic Scotland, 2012; Traditional Building Crafts Skills National Heritage Training Group (NHTG) Research Report; 2007 and UK Built Heritage Sector Professionals NHTG Report, 2008; Pye Tait, 2013), albeit only providing a "snapshot in time" of the state of the sector, have provided invaluable sector intelligence at a national, and regional surrounding a wide spectrum of sector issues (supply and demand, training, demographic make-up etc.) encompassing both the professional and contractor fields, and indicated that sector structure, comprised of predominantly MSME and SMEs. NHTG (2007) estimated 10% were one person businesses, whilst 15% of firms had over ten employees, self-employment was 24% and the average percentage of the work carried out on pre-1919 buildings by these organisations was 35% and 40% respectively. Yet, a lack of coherence, between the reports, in a similar vein to ONS exists, despite them providing a statistical baseline, suggesting it is debatable, whether the statistics provide a sufficiently verifiable baseline indication of the current nature of the industry. For example, NHTG (2007) estimated, to meet future demand, there was a need for an increase to a projected 17,370 workers over a five-year period, in order to undertake work on traditional (pre-1919) buildings. Yet in 2012, PYE Tait (2013) estimated an additional contractor workforce of 6,750 was required to satisfy the then, current and future demand. Yet, paradoxically, PYE Tait (2013) found 44% of contractors reported no shift in demand between 2008- 2013, and 50% expected this to remain unchanged to 2015. Nonetheless, one might argue, they provide a starting point, in which to guide and inform future sector plans and approaches needed to help support opportunities to modernise, and innovate within the sector.

Thus, with the increasing demand to measure and monitor changes in the labour market, driven by a number of external forces such as; developments in new technologies, innovative project delivery mechanisms, complexity of project execution and occupational training and qualification revisions, allied to demand shifts in products and services. Perhaps, there is a need to gain a deeper assessment of the size and scale of the historic building repair and maintenance at the micro-scale; at an individual occupational industry level to encourage greater long-term planning of resources and achieve a suitably up-skilled workforce. Fortunately, for historic building stonemasonry practice, a small number of targeted studies (see Hutton and Rostron (Firm), 1997; Historic Scotland, 2010, 2012b; Gillespie and Tracey, 2016; Scottish Stone Liaison Group (SSLG), 2006) have provided an invaluable assessment, producing number of perturbing findings across a similar spectrum of sector wide issues (supply and demand, training, modernisation etc.). SSLG's (2006) localised study on stonemasonry skills needs for the repair and maintenance of Glasgow city's pre-1919 building stock provided similar symbiotic data and information as the sector intelligence reports, discussed. However, it provided a much more detailed and accurate landscape of supply and demand needs; discovering 97 percent of Glasgow's heritage buildings would demand stone repair requiring approximately 4,715 stonemasons over the next 20 years (236 per year) at a cost of £585 million, based on 2006 prices. Historic Environment Scotland may have data of the number of historic buildings and a register of all listed buildings, yet the key challenges remain to determine specific repair requirements, establish specialised skill requirements and ultimately enhance historic building R&M practice by using a structured and multi-disciplinary approach.

2.4 A Review of the Sector Wide Historic Building R&M Challenges

Sector Wide Challenges

2.4.1 The Impact of the Economic Downturn

Given the historic building repair and maintenance sector, HES (SHEA, 2018) have estimated the expenditure levels are more or less the same as the expenditure levels, felt over the last five years. Calculating the actual impact of the economic downturn on the sector is difficult, as the available academic literature and industry-related reports lack the foresight or the will to ask broader business and economic questions or to consider economic business models (Brightman, 2013), in part due to being hampered by a number of re-occurring factors, such as: industry classification deficit, sector fragmentation, and lack of clarity in activity and orders for new contracts. Nonetheless, it would appear to be relatively safe to assume the economic impact of the downturn mirrors the wider UK construction industry outlook; declines in current and future work accompanied by rises in input costs, being driven by fragile client confidence and reduced tender opportunities (Chartered Institute of Procurement& Supply (CIPS), 2017; Thornton, 2018). For example, PYE Tait (2013) acknowledged that there was a reduction in available money to enable pre-1919 historic building repair and maintenance, resulting in a decrease of work contracted. However, the report remarked; it was not only an economic issue but also a lack of a pro-active approach to repair and maintenance by traditional building owners, suggesting this was fuelled by an obsolescence towards non-essential work, indicating owners only undertook major repair, as a matter of necessity. Althoug they did concede, despite the economic recession, increases could occur, by addressing the residual latent and subsequently completing the work to appropriate standards.

Moreover, adding to this double-edged challenge is the inherent obstacle of 20% Value Added Tax (VAT) on historic buildings repair and maintenance. Such is the significant economic liability imposed, the Institute of Historic Building Conservation (IHBC)

(2014) stressed that VAT tax has placed a number of substantial financial barriers in front of the sector suggesting MSME and SMEs within this specialised sector are under even more increasing tension in the pursuit of increased workloads, improved productivity and performance. However, the IHBC (2014) suggested with the distinctly uncertain outlook regarding worsening business conditions across the whole industry; a reduction of VAT to 5%, would encourage the provision of a valuable sector stimulus and a move towards high quality historic building repair and maintenance delivery. Whilst such a reduction would also drive a number of key benefits, in the economy at both a national and local level, in terms of employment, skills, income tax etc., such as: stimulate and incentivise the private and public sector spending; and encourage spending by not only building stock owners but also SMEs (contractors, consultants, manufacturers and suppliers), to significantly boosting economic activity. However, this has not yet materialised, therefore for the foreseeable future; MSME and SMEs (contractor and professional) are faced with operating in an increasingly competitive sector, due to the reduction, on works being procured.

2.4.2 R&M Demands

Given the specialist nature of the sector, allied to the continuing weak economic recovery, determining accurate statistics for supply and demand, whilst gaining valuable regional information regarding the level of demand for repair and maintenance, is an essential necessity. Previous research by the Built Environment Forum Scotland (BEFS) (2013) highlighted Scotland’s stock of pre-1919 buildings faces a multi-billion-pound backlog in essential repairs, due to ineffective major multi-million-pound programmes of tenement housing repair and maintenance interventions implemented in the mid-1970s through to the mid-1990s. Whilst, IHBC (2014) remarked, inappropriate repairs were not only specified and applied to tenement buildings but extensively across the pre-1919 building stock in many areas of the country, which has led to the need for a “maelstrom” of demand, despite these campaigns based on the objective of prolonging their lifespans by thirty years. Furthermore, in a recent report commissioned by RICS (2019), indicated that there are various examples of tenement buildings under multiple ownership (a mixture of residential flats and commercial properties) being unable to agree on maintenance resulting, in a long-term need for extensive repair or local authority intervention (Robertson, 2019).

Based on the aforementioned, it is unsurprising that both the pre-1919 residential and commercial building stock requires; over 90% (409,500) of routine repair; 67% (340,000) exhibit critical disrepair, and 53% (240,000) display urgent disrepair (Scottish House Condition Survey (SHCS), 2016; SHEA, 2018) (see–section 1.1; as shown in Figure 1.1). Moreover, there is substantial variation of the number of pre-1919 traditional buildings across Scotland, which has created a varying demand; in North Lanarkshire only 3% of all properties are made up of pre-1919 traditional buildings, whereas this figure is up to around 37% in the Orkney Islands (Historic Scotland, 2012). Thus, demand is greater in some areas than others, with certain geographical locations displaying a varying level of repair needs; 59% of the City of Edinburgh's historic buildings exhibit critical disrepair, while 96% of South Ayrshire's buildings display similar condition as illustrated in Figure 2.4.

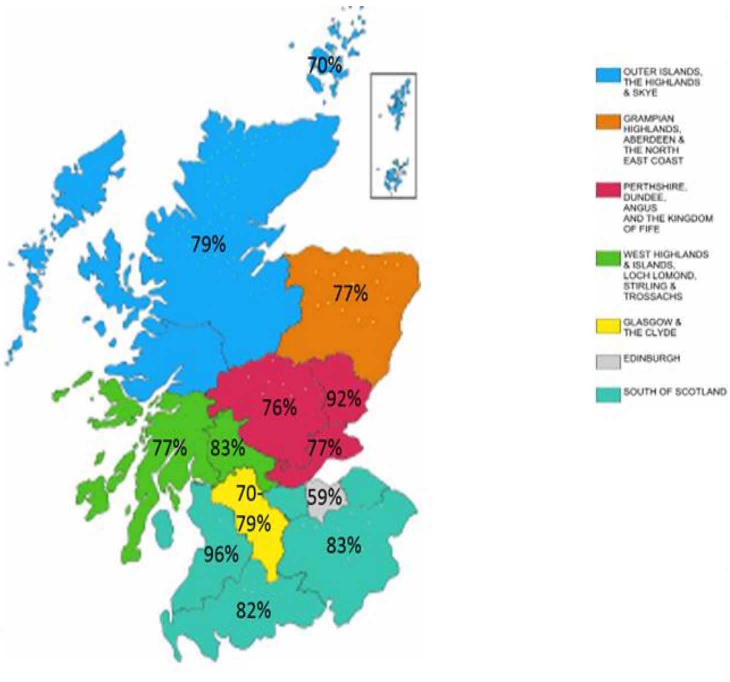


Figure 2.4: Distribution, Percentage of critical disrepair to pre-1919 residential buildings

Source: Chart is developed by the author based on data provided by SCHS (2016) and Historic Scotland (HS) (2012c).

Therefore, it can be said with relative confidence that demand is not in question, with the overall demand at strikingly high levels, and that it is an essential necessity to consider carefully, not only targeting the areas to address the subsequent demand but also carefully consider the demand for the types of repair that are required. Whilst, from a material perspective, stone production for repair and maintenance sector is resourced predominantly from English stone quarries, as currently there are fewer than 20 quarries in Scotland (Gillespie and Tracey, 2016), could provide a platform for re-invigoration of Scottish stone quarries, necessary to meet future demand needs.

2.4.3 The Impact of Sustainability Factors

In the drive towards a low carbon economy, and the need for "sustainable development", it is widely recognised; a holistic, integrated approach that reflects environmental, social and economic dimensions, must be considered to find long-term growth and prosperity (Rodwell, 2007). In the context of Scotland's historic building repair and maintenance practice and addressing climate change, energy efficiency and sustainability, they are now firmly part of the Scottish conservation agenda, underpinned by the Scottish Government world leading climate change targets; to reduce carbon emissions by 80% by 2050, with a target of 50% by 2020; central to achieving these targets is the repair and maintenance of the 20% of the pre-1919 building stock (HES, 2018). Moreover, the British Standard 70913:2013 *Guide to the conservation of historic buildings,* exists to not only confront the issue of ensuring optimum quality of conservation work but also addressing climate change, energy efficiency, and sustainability, all of which are now firmly part of the Scottish conservation agenda (Scottish Government, 2014a).

Yet, a disconnection exists between sustainability and sector practice, as evidenced by the number of ever-increasing studies investigating the improper use of lime and stone, yet, these materials are themselves by nature, inherently sustainable (see Forster 2010a; 2010b; Forster and Carter, 2011; Forster et al., 2011; Henry and Stewart, 2012; Hughes, 2012; Hyslop, 2004; Lott, 2013; Odgers and Henry, 2012; Snow and Torney, 2015; Torney et al., 2012; 2014; Torney and Hyslop, 2015). Whilst, within the realms of building conservation philosophy, there exists a historic building repair and maintenance dichotomy between the tensions of appropriate repair vs. the most sustainable in terms of whole life expenditure (Forster et al, 2011). An issue, further complicated by the substantial errors in the way that traditional buildings are treated, in building standards, regulations and assessment systems (Sustainable Traditional Buildings Alliance (STBA), 2012).

Therefore, there is a need for the development of a wider knowledge base of the sustainability challenge, to help in delivering successful sustainable repair and maintenance (design, application and use) (STBA, 2012). Fortunately, in the drive towards environmental sustainability, a number of research studies exist across the UK, particularly from Scottish based researchers (see Baker, 2010; Forster et al., 2011; 2013; Kayan, 2013; Kayan et al., 2016; Naeeda, et al, 2010; STBA 2012; HES, 2012-2019) have investigated various innovative solutions (materials, technologies and practices); which has resulted in the development and production of a number of tools, frameworks, and models, as aids and devices to support the decision-making process.

For example, STBA (2012) developed a simulation tool, to provide systematic and holistic guidance towards clearly identifying various benefits and concerns; whilst, Forster et al. (2011; 2013); Kayan (2013: 2017); and Kayan et al. (2016) posited the interesting concept of *"Green Maintenance.* They argued, there was a distinct correlation between the quantity, type and longevity of repair and maintenance interventions specified, and their relevantly expended embodied energy and CO_2; in essence, the greater frequency of the intervention, the greater embodied carbon expended (Forster et al., 2013). Thus, they proposed a methodology; developed a formulaic expression for selecting repair options based on environmental suitability (see Figure 2.4); and termed the phrase *"Environmental Maintenance Impact (EMI)"* (repair techniques that have high longevity and durability).

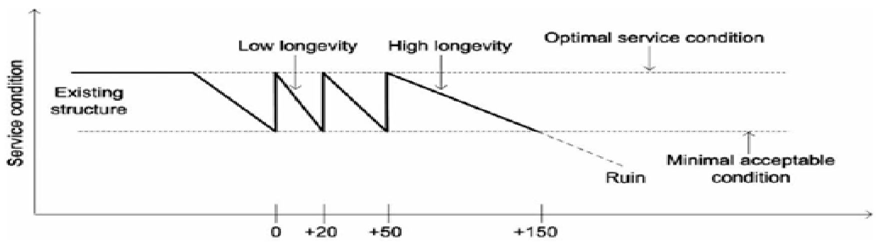


Figure 2.4: Relationship between longevity of repair and embodied carbon expenditure. Source: Forster, et al., 2011 and 2013; Kayan, 2013.

Given the apparent intricate web of terminology and the shroud of apparent mystery enveloping sustainable historic building repair and maintenance. Such pragmatic tools, models and frameworks for practitioners, in particular those involved at the "sharp end" of project delivery (surveying, specifying and application), will be influential as practical decision-making tools; as they could be adopted and employed (individually and mutually), during a substantial campaign of historic building repair and maintenance. Furthermore, in the attempt to satisfy attaining the "triple crown" (sustainability, philosophy and the most appropriate repair and maintenance intervention) such an agenda should also be considered part of higher-level heritage skills development needs (Abdel-Wahab and Bennadji, 2013 and Pye Tait, 2013).

2.4.4 R&M Skills Shortages and Gaps

Recent industry reports (Construction Industry Training Board (CITB), 2017; CIOB, 2014, 2016; Farmer, 2016; Volk et al., 2014) have re-iterated the recurrent emphasis, the role of industry "skills" has in maintaining prosperity, raising productivity, and, generating economic growth as it moves into the 21st century (Chang-Richards et al., 2017). Whilst, the reports have only provided a "glimpse", into the subject of skills intrinsically, it is a complicated issue, very much underpinned by the re-occurring challenges of skills shortages and skills gaps (Chan and Dainty, 2007; Dainty, Ison and Briscoe, 2004). *Skills shortages* are deficiencies in available talent with the required skill set, which results in a distinct shortcoming, in terms of recruitment ability to source people with the appropriate skills and knowledge, in order to satisfy long-term vacancies and understaffing issues (Lobbo and Wilkinson, 2008). Whereas, defining *skills gaps* are considered: the deficiencies in knowledge and competency of the existing workforce, resulting in profitability and productivity deficiencies, such as the capability to tender for and fulfil new work as well as leading to reduced performance, quality and safety (Chan and Dainty, 2007).

2.4.4.1 R&M Skills Shortages

For the Scottish traditional building sector, the various industry based reports (Angus College 2009; NHTG; 2007; 2008; Pye Tait, 2013; SSLG, 2006) have highlighted, there is an inadequate level of labour and skill, at both a contractor and professional level, and suffers from continual workforce reductions in terms of numbers and training uptake (existing and trainee workforce). In terms of contractors, despite, a Construction Skills Certification Scheme (CSCS) card for heritage skills existing, there is a lack of data available, as to the numbers who are in possession of the card or the impact it is having on the sector (Pye Tait, 2013). However, anecdotal evidence (Financial Times, 2016), remarked the level of new apprentices and trainees in traditional building sector dropped 78% between 2005 and 2013-14. Unsurprising, as the Scottish construction sector tends not to interview, but relies on informal means such as people turning up on site, endemic of a craft labour market (Clarke and Hermann, 2007; Lockyer and Schlarios, 2007). Yet, with the skills crisis, perhaps reaching critical mass and now beginning to increase in pace, these are not new issues for the sector (PYE Tait, 2013). For example, SSSLG (2006), NHTG (2007) and PYE Tait (2013), have consistently identified, the six most difficult craft areas to recruit and employ; e.g. ranging from stonemasonry to plastering to traditional joinery. In part, due to the sector's proclivity to engage heavily in the use of self-employment, and employment opportunities for apprentices and craftsmen tend to not be advertised (PYE Tait, 2013). Perhaps, to retain the existing workforce and recruit new blood into the craft sector, encouraging and offering the best/most suitable skills development is an opportunity to "promote the craft as a valued alternative to academia" much like the highly regarded dual apprenticeship scheme training found in Germany, Austria, and Switzerland (Fuller and Unwin, 2008). To achieve this, there requires a change in perception of apprenticeships and the construction industry, by promoting that it is high-tech and not for underachievers (Abdel-Wahab, et al., 2011).

However, the skills shortage is not solely a challenge for MSME and SME contractors, with over half a million building professionals in the UK, accurately quantifying the number of professionals working on pre-1919 buildings is difficult, especially given they are spread over a number of professional organisations (e.g. *RICS; RIBA; CIOB* etc.). Nonetheless, NHTG (2008) attempted to observe and quantify the number of conservation-accredited architects and surveyors available and portrayed a distressing geography across the UK, with a severe lack and disparity of professionals who were conservation-accredited. From a Scottish perspective, the historic building professional field finds itself burdened with a disturbing and distressing landscape; 73 conservation-accredited architects; and 11 conservation-accredited surveyors available to service 488,000 pre-1919 historic buildings, makes for worrying reading. Yet, the CIOB (2019) postulated that, 50% of all UK construction works are on traditional buildings, suggesting, a safe assumption, would be that most construction professionals, during their career, will at some point work on historic buildings.

Therefore, whilst, it is clear from the reports that both the contractor and professional landscape are faced with a number challenges, the timescale between reports suggests; in terms of accuracy and reliability, could give rise to misleading analysis of national statistical evidence regarding current and future skills supply and demand, given interpreting periodic findings can lead to anomalies in data determination (Dainty et al, 2005). Thus, caution requires exercised in the interpretation of the reliability of the data, as such expositions are inherently unsatisfactory, because they fail to resolve the contradictions provided by the deficiencies within the coding systems currently used (SIC, 2007; SOC, 2010) to interpret national statistical evidence (see section 2.3.1). For example, the demand assessment model used by the majority of the reports is dependent on the use of verifiable ONS intelligence data and determined using the co-efficient derived from Construction Skills Network (CSN) analysis (PYE Tait, 2013); which, relies on data captured from the CITB-Construction Skills Levy Register; a centralised database of companies that are "in scope" and pay a levy. Whilst, in essence appearing verifiable and reputable, a considerable number of companies regularly involved in historic building repair and maintenance are simply "out of scope" to CITB. Hence, the call for caution and restraint is valid, given these anomalies present major difficulty in accurately assessing future provision needs, which gives rise to the question; how can quality be achieved, when the number of suitably qualified professionals and craftsmen are unknown specifically by industry which in turn informs the public sphere?

2.4.4.2 R&M Skills Gaps

With regards, the skills gap, it mirrors the issue of skills shortages within the sector, as they are, inextricably linked; as the various reports (NHTG, 2007; NHTG, 2008; Pye Tait, 2013) provided an overview of current training options and current requirements, albeit from a globalised perspective. Nonetheless, a Historic Scotland funded report; *Scottish Traditional Building Skills: Audit Scoping Exercise* (2010) was commissioned to identify, where the gaps lie between current training options and current requirements in the sector, to some extent professionals, but more particularly for MSME and SME contractors and operatives. The research report (HS, 2010) proposed a wish list of traditional historic building skills requirements, across a number of craft areas (stonemasonry, brickwork, slating etc..), which were then compared against current content to determine areas of missing content; disturbingly, it identified a distinct lack of relevancy towards historic building R&M. Taking stonemasonry as an example, within current stonemasonry apprenticeship training content (Training Assessment Programme (TAP) (SVQ Level 3), despite being governed by National Occupational Standards (NOS), only covered 13% of the stakeholder wish list, which rose to 41% if the individual continued to advanced craft level (Professional Development Awards at SCQF level 7) (Figure 2.5). As such, a specialist apprenticeship programme (SAP) across a number of craft areas were established by the sector, in conjunction with the NHTG (CITB, 2011), to help bridge this deficiency, but unfortunately widespread knowledge of this option is low, as currently no FE College in Scotland delivers this training programme, which can be partly explained by the specialist and expensive nature of traditional craft training.

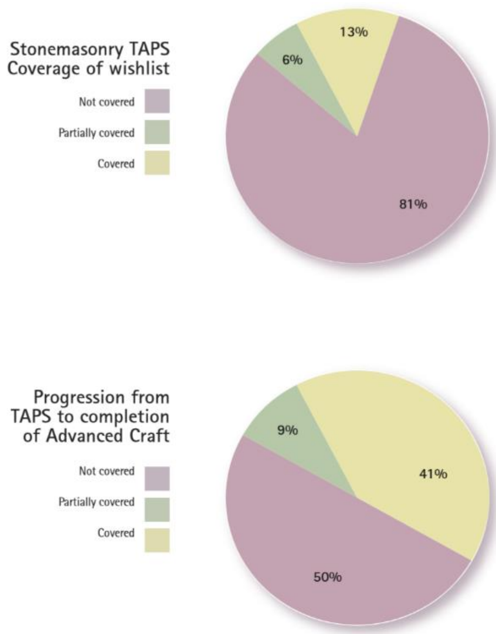


Figure 2.5: Percentage of Stonemasonry wish list covered by awards; Reproduced from HS*; Scottish Traditional Building Skills; Audit Scoping Exercise (2010)*

Likewise, the skills shortages, the skills gap is not solely a challenge for the craft workforce; both the NHTG (2008) and Pye Tait (2013), observed the same core challenges; a deficiency and lack in formalised training, along with a lack of defined educational pathway. Further correlation between the reports emerged, as a distinctive pattern surfaced with continual statistics of between 65%-71% of building professionals surveyed, intimating; formal education was deficient in preparation for working in the sector. Furthermore, the reports remarked, the majority of higher education curricula delivered at post-graduate level, tends to have a less than adequate coverage of traditional building materials and techniques and lack practical learning elements. This suggests that a majority of current professional skills and knowledge acquired was achieved through working experience and tacit knowledge, although it was found there was a lack of a defined training and development strategy, as the majority interviewed remarked having had only approximately 2 days Continuous Professional Development (CPD) training (over a period of 12 months). Perhaps adopting an inter-disciplinary approach to training is a way of providing a pathway for the workforce to gain the necessary skills and knowledge needed to achieve successful historic building repair. In addition, there needs to be not only an integrated approach, but also a move towards a demand-led system (Leitch, 2006), resulting in an evolution towards a more coherent system of training and skills provision, in a similar vein to the German dual apprenticeship scheme, whereby a set of interconnected and mutually supportive institutions, incentives, and attitudes is agreed between government, employers, trade federations and professional bodies (Vogler-Ludwig et al, 2012).

The aforementioned reports have established a benchmark against which progress measurement and quantification can occur, but ultimately, these industry reports have emphasised modern construction practice drives the Further Education (FE) and Higher Education (HE) course content. Moreover, highlighting that not only do conflicts exist within the existing training content and provision, but upskilling becomes an area that is faced with a number of issues, such as; funding, articulation and being industry relevant, particularly with the move to a low carbon economy and the need to address the skill gaps in this area. However, developing and delivering specialist skills are arguably not possible without having understandings of what these skills needs are (Chan and Moehler, 2007 and Abdel-Wahab et al, 2008).

Hence, to achieve a suitably skilled workforce and long-term planning of resources to meet industry requirements and to not only arrive at a deeper determination of historic building repair and maintenance needs and clarify sector skills development requirements, but also inform current skills development strategies and practice whilst informing a wider skills strategy. There is an urgent requirement for more similar and up to date project-based data on future skills needs, in a similar vein to SSLG (2006) and HES (2012-18); 29 refurbishment case study series, to provide valuable data on quality, performance, and effectiveness of current repair application. Allied to the provision of an up to date technical handbook for the repair and maintenance of historic buildings to meet current/future quality and performance standards, thereby attempting to address the current gaps in training provision.

2.5 A Review of Historic Building Repair and Maintenance Project Management and On-Site Practice Challenges and Issues

2.5.1 Historic Building R&M Project Management

In order to, successfully Project Manage, and drive a historic building repair and maintenance project forward, it is vital to understand the key project specific PM and on-site operations challenges and issues that require addressed. In terms of this research, in order to satisfy the area of focus *"process management* and *improvement",* the following sub-sections provide an insight and discussion on the key challenges and issues facing historic building R&M PM, beginning with a brief discussion on the definition of PM.

Various academics and industry experts (see Koskela, 2002; Harrison and Lock 2017; Meredith et al., 2017) have attempted to define the term Project Management (PM), whether that be from a managerial or a strategic perspective. In broad terms, PM can be described as; the successful process of delivering, controlling and completing a project's objectives (involving a succession of resource consuming activities and tasks), in line with an agreed and established specification, within definitive start and end dates, by utilising and implementing a collection of tools and techniques (Harrison and Lock 2017). Thus, Construction Project Management (CPM) is a management approach used to lead construction projects using best practice, underpinned by PM theories, tools and techniques (Fewings and Henjewele, 2019). In essence, CPM seeks to achieve project success by specifying and establishing the; scope, and level of work, the resources designation requirements, then administer the processes of work planning, execution and progress, whilst accommodating any adjusting any project divergences from the original schedule (Munns and Bjeirmi, 1996).

2.5.1.1 Historic Building R&M Project Management and SMEs

Mirroring the wider construction industry description of Construction Project Management, the historic building repair, and maintenance PM process, is similar in nature. However, given that the application of established systems developed for typical projects transpires to be inappropriate for complex projects (Baccarini, 1996; 1999); it is reasonable to assume, due to; the inherent complexity, bespoke, diverse nature of historic building R&M projects, industry fragmentation and a substantial proportion of sector projects having a reliance and prevalence skewed towards self-employed specialist and sub-contracting MSME and SMEs consultants and contractors. Historic building R&M projects demand both a divergent and convergent level of management, as their innate intricacy and bespoke nature, dictated by distinct expertise, skills, knowledge, and understanding requirements for each occupation (craft and professional), often over-lap. Unsurprisingly, given the structural composition of the sector, a major challenge in PM stems from the fact the majority of MSME and SMEs (professional and contractor) tend to work as silos, that operate as groups of diverse vocations across the supply chain, as reflected in the wider construction industry (McKinsey Global Institute, 2017)

Furthermore, due to the disaggregated and bespoke nature of projects, it is arguable MSME and SMEs effectively finance the project; as these organisations, operating in the sector provide the majority of the supply chain, and the subsequent workforce perform the bulk of the work. Further emphasising, they are a critical part of the complex historic building R&M project ecosystem, yet it should be recognised that anecdotal evidence suggests, that the majority of historic building MSME and SMEs, do not engage in PM theories, models and conceptual frameworks, much like their counterparts across the construction industry (Turner et al, 2009; 2012). Where there is a growing body of evidence on MSME and SMEs, PM and the use of such tools has observed these types of organisations tend to have poor PM practices, in order to monitor and control projects, as they have blurred PM positions and arrangements (Turner et. al., 2009). Yet, wider research (Turner et al., 2012) suggested there was an implicit assumption that these types of management methodologies, albeit developed in large organisations were relevant and directly applicable to MSME and SMEs. However, in reality, the CPM community in general do little to provide micro businesses/SMEs with guidance on managing projects (Turner et al., 2012).

Furthermore, with the historic building sector being organisationally complex and highly fragmented with a predominance of MSME and SMEs, allied to the tendency to be involved in small-scale localised projects working within heavy budgetary constraints, suggests that that no single management approach can embrace all project situations. Moreover, historic building R&M projects have a high level of risk (Dyson, Matthews and Love, 2016; Bullen and Love, 2011 b; Shipley et al., 2006), and an unpredictability in terms of time, cost and quality (Smith, 2005) driven by a lack of understanding of the complexities involved in historic building PM (Bullen and Love, 2011a). This is partly due to the absence of qualifications in staff for such skills but mainly because a lack of interest exists within the workforce of such organisations for managing projects in a systematic and structured approach (Aquil, 2013). As well as often being disinterested in a process or a technology that may appear, from the outside, to be an expensive and time-consuming irrelevance (Hardie and Newell 2011), which is further compounded by the stark fact performance analysis tools are rarely used (Forster and Kayan, 2009). Hence, the following section provides a brief overview of this issue.

2.5.1.2 Historic Building R&M Project Performance Measurement

To ensure continual improvement in project delivery and execution, an essential element of Project Management, can be achieved through performance measurement, which in turn is a methodical way of evaluating projects and identifying the gaps between current and desired performance (Eadie et al., 2013; Weber and Thomas, 2005). In order to achieve greater investment in innovation and skills, to increase industry productivity and performance requirements. (UK Government, 2017); having the availability of up-to-date Key Performance Indicators (KPIs) data, for most projects in the sector, whether, small, medium, or large in scale. Furthermore, Vogl and Abdel-Wahab (2015) in their review study on international comparisons of construction productivity performance stated for UK construction statistics reporting; difficult decisions are required when deciding upon the list of KPIs to measure and monitor given reliable data is vital for determining the industry's productivity performance. Although they warned, there is always the trap of focusing on performance indicators, that are more accessible, even if they are not akin to the most relevant indicators. Whilst further adding, that a substantial effort is required to determine, a dependable evaluation to establish a knowledgeable orientation towards the dynamics that disturb industry productivity and performance (e.g. workforce skills) (Vogl and Abdel-Wahab, 2015).

Indeed, by allowing the estimated and actual performance of both workmanship and materials to be measured, in terms of value, efficiency, and quality; could help identify areas for continual improvement and offer the chance to better predict the value and cost of historic building repair and maintenance. Yet, given the need for such performance analysis tools (e.g. KPIs, Cost Benefit Analysis (CBA) Return on Investment, (ROI), the current literature tends to focus upon building and material performance as opposed to project performance (see Dyson et al., 2016; Kayan et al., 2016; Mohamad et al., 2015). Several studies, reasoned that the scarcity of employing performance analysis tools, was due to varying factors; from a distinct lack of: awareness and recognition of the need for the measurement of "quality" or KPIs (Dann and Wood, 2004); to a dearth of significant lifecycle data of previous R&M (Forster and Kayan, 2009); to an insufficiency in motivation and practical support (Dann, Hills and Worthing, 2006).

Hence, with the aforementioned lack of sector specific construction statistics, presenting an indistinct and unclear image, constraining the understanding of any current and future productivity and performance improvements. In the attempt to produce successful project outcomes, guide to better management, improve efficiencies, and enhance communication, there is a need to have some form of performance measurement to identify how successful they have been. However, it is beyond the scope of this research study to explore this area in depth. Nonetheless, with the myriad of MSME and SMEs within the sector, as a starting point, to provide a deeper insight into the applicability of KPIs to drive process improvement and management for historic building R&M activities. It would be prudent, to perhaps focus on measuring performance with reference to time, cost and quality (Sarhan and Fox, 2013); although, with Health and Safety (H&S) and sustainability, key project elements, it is not unreasonable to include the measure of these vital influences. Undeniably, there is a need for adopting these five fundamental KPIs, when assessing projects, as this will support establishing future project understanding, as well as making objective judgements, to ensure that the evidence and lessons learnt, are widely realised, communicated and applied, in order to pull strategic levers to improve sector performance.

2.5.1.3 Historic Building R&M Construction Project Management

As previously mentioned, Construction Project Management (CPM) is the process of directing, regulating and supervising a project from early development to completion, with the main concept of connecting procedural and technical boundaries such as, internal and external stakeholder communication, project budget and execution (Cartlidge, 2015). For historic building CPM a small number of practical guidance documents, standards, and frameworks exist, produced by a several professional organisations and heritage organisations. In terms of guidance; the Royal Institution of Chartered Surveyors (RICS), who generated the *"Historic building conservation; RICS guidance note; 1st edition*

(2009)"; whilst, the Royal Institute of British Architects (RIBA), based on their RIBA Outline Plan of Work 2013 model, developed the *"Conservation: RIBA Plan of Work 2013"* guide (although more directed towards high–end conservation works). With regards to standards; *British Standard 7913:2013* and *SHEP* (2011) states the Project Management process should be as simple as possible and sufficiently robust enough to ensure supervision, inspection, communication, and documentation are viewed as key elements of high-quality repair and maintenance. Whilst, concerning frameworks, the emergence of updated construction process management frameworks (CPMF) such as; the Royal Institute of British Architects (RIBA): Outline Plan of Work (2013); Chartered Institute of Building (CIOB) 2014; Code of Practice for Project Management for Construction and Development, supplemented with regulations such as the Construction (Design and Management) Regulations 2015 (HSE, 2015), are vaunted as being relevant for historic building CPM.

Whilst, in essence, all these guides, standards, and frameworks, do in essence, provide useful plans for managing and administering historic building R&M, and are beneficial as a starting point in CPM of historic building R&M. A key shortcoming of these tools is the tendency to be generic in focus, suggesting that the only general assumption that applies to projects is the need to; assess all the concerns upfront; provide enough time within the project programme to deal with these issues, and explain the essential activities required at each stage of the project. Yet, with the numerous professionals and contractors involved in projects, creates difficulty for a clear direction to emanate from any one consistent source, in a similar fashion to the wider construction industry (Pinsent Masons, 2017). Moreover, there are a number of further inadequacies, such as; not stipulating specific guidance for carrying-out and managing on-site operations; not specifying a defined PM process; not defining or naming the work stages or reflecting the terminology that is used by the majority of the sectors MSME and SME businesses; they tend to be, directed towards the construction industry's relevant professional organisations and their members, resulting in guidance inclined to promote silo working, furthering highlighting the sector's fragmentation (Pinsent Mason, 2017). Furthermore, there are several additional issues constraining an extensive adoption of the wider construction industry frameworks (see CIOB, 2014;RIBA, 2013) across historic building R&M projects, (which is examined in Chapter 3 (see section 3.3), such as; having a greater focus on large projects; reflect the increasing need for design and construction sustainability and digitisation (they have incorporated Building Information Modelling

(BIM) and a *"Green Overlay"* into the new guidance), whilst the RICS guide does not include any form of these concepts. Additionally, they are.

Yet, regarding such divergences, given an estimated 85% of projects fail to meet delivery goals (Shenhar and Dvir 2007), due in part to; the variability in terms of the project scope of works (final content, extent, and specification) (Smith, 2005), although, anecdotally, from a Project Management perspective, such unpredictability is considered part of the inherent nature of historic building repair and maintenance; whilst the sector's intrinsic adversarial communication and collaboration barriers, throughout the project lifecycle, between the contractor, sub-contractor and professionals, adds to this already incomplete information, resulting in an ineffective system of process management and implementation. Given this lack of a relevant Project Management framework, and historic building notoriously problematic repair and maintenance processes, driven by variability, volatility, and subsequent rising costs, could threaten to increase and pressurise the cost, quality and timely delivery of projects. Thus, these support measures, ultimately provide marginal relevance to carrying-out and managing on-site operations for MSME and SMEs, evidenced by the number of studies surrounding; the incidences of previous poor practice and neglect; the challenge of hidden defects; increases in project budget/planning/programming and difficulty in workforce recruitment. Clearly, there appears to be a gap between sector practice, guidance, standards and frameworks.

Therefore, with the increasing demand for high quality economical and sustainable historic building repair and maintenance allied with the perennial problem of skills shortages (Project Management and on-site practice) coupled with the complexity and diversity of projects. When dealing with historic building Project Management and practice, in terms of *"process management and improvement",* it is a case of being more efficient and effective from a Project Management perspective, and move towards a defined approach, more suited to the multi-disciplinary approach espoused by academia and industry alike. As, anecdotally, the manual and paper-based workflow process approach to on-site project data capture makes effective PM a challenge, given successfully co-ordinating and managing both the supply and delivery chain processes and activities is highly dependent on project stakeholder collaboration. Invariably the "scope of work" relies on the contractor to provide their own interpretation of the specific work to be executed along with developing robust method statements for on-site operations. A discrepancy between what the Architect or the Building Surveyor specifies and what the contractor finds-out on-site because of in-adequate project specification is often the case.

Therefore, drawing on not only better data but also more structured, robust and valid data, through a more systematic, extensive and objective PM approach to surveys can provide much more realistic costings and help overcome the apparently inherent issue of spiralling costs associated with historic building R&M and help support a tripartite approach (quality, performance, and effectiveness) towards historic building repair whilst protecting stakeholders from hidden costs.

2.5.2 On-Site Practice Management Challenges

Within Historic Building repair and maintenance project delivery, on-site practice, covers both the technical operations and management processes and is, typically divided into four key phases, with each phase having sub-phases and associated processes: (1) Project appraisal phase; (2) Project set up phase; (3) On-site Operations phase; and (4) Post-project completion phase. While, each phase is critically important, relevant Project Management standards and guides do not cover these phases in detail, nonetheless, the work to be undertaken, should only be embarked on by competent and suitably experienced contractors and personnel (British Standard 7913, 2013; SHEP, 2011). Yet, a number of industry reports have highlighted, that in reality they do not have the technical expertise or adequate training in order to produce a high standard of work to maintain Scotland's traditional buildings. This results in a shortage of available craft and professionals with the necessary skills to maintain traditional buildings (Brechin Townscape Heritage Initiative, 2009; Historic Scotland, 2010; National Heritage Training Group (NHTG), 2007; 2008; PYE Tait, 2013). Many at craft and professional level profess to follow such guidelines and be properly qualified in historic building R&M. However, in essence, the industry has not changed significantly over the last few decades, as the core knowledge and skills, usually being interpreted as traditional methods (Gillespie and Tracey, 2016).

As the majority of Scottish pre-1919 historic buildings are constructed of stone, various studies of external stone masonry in Scotland's towns and cities (Hyslop, 2004; Maxwell, 2007; SSLG, 2006; Snow and Torney, 2015; Torney et al., 2012; Torney and Hyslop,

2015) have been undertaken, highlighting a range of on–site process management issues when undertaking, Historic Building repair and maintenance work, from; inadequate surveying (building and quantity), to poor specification and scoping of works driven by subjective data capture, to poor on-site practice, to a disconnect between project stakeholders, in terms of communication and collaboration. Given, there has been a continual use of inappropriate stone and other materials for repair (Torney and Hyslop, 2015), drilling further down into these issues, they include the need to; correctly assess the condition of stone facades (SSLG, 2006); have an in-depth understanding of the critical factors affecting the masonry fabric performance of historic buildings (critical in diagnosing appropriate R&M solutions) (Torney et al., 2012); and to recognise the importance of selecting appropriate replacement stone by industry professionals. Such, insensitive repairs can easily deteriorate the historic fabric, through the incorrect use of materials and techniques, which can cause future problems and exacerbate the condition that the repairs are attempting to remedy (Beckmann and Bowles, 2004; Feilden, 2003). For example, Hyslop, (2004) in a detailed examination of 14 case study stone buildings in Edinburgh's new town estimated that over 90% of the sandstone used for repairs had been sourced from quarries in North East England and the lack of adequate specification, in terms of compatibility had led to an increase in decay to surrounding areas. Hence, the methods used for the selection and application of masonry materials, has not always resulted in the most appropriate repair being used, resulting in damage to adjacent masonry (see Hughes, 2012; Lott, 2013; Torney et al. 2014). This is not just a common problem for historic buildings – there is lack of understanding of building physics across the wider R&M sector (The Royal Academy of Engineering, 2010). Yet, it is vital to understand these complex materials and techniques, as unequivocally a higher degree of skill application will be required to meet current and future quality and performance standards (Forster et al., 2011; Kayan, 2013).

Furthermore, the effects of the implementation of an incentive-based payment scheme by the contractor to the craft operative, has led to a lack of effective and efficient construction practice such as mechanical saw marks on stone surfaces and an increase in damage to neighbouring masonry (Hyslop, 2004). Hence, it is not too difficult to think of an example of stone replacement not affected by this process. For example, as illustrated by Figure 2.7; the use of modern power tools for improved productivity, resulted in an increase of poor practice and poor-quality surrounding standards of workmanship and knowledge of stonemasonry practices. Due to a lack of objectivity in data capture, allied to skills deficiencies, resulted in poor specification (original poor product dimensioning) leading to poor practice (on-site fabrication deficiencies such as under cutting of specified stone), which in turn nullified the ability of the repair to perform successfully; i.e. the excessive removal of decayed stone, when implementing stone replacement by allowing overzealous accommodation within the recipient void resulting in possible undermining of the structural integrity of the repair;

Figure 2.7: Example of poor practice; overzealous removal of replacements stone to enable fixing

Therefore, increased productivity must be balanced with the need to retain quality, however, to lay the culpability solely at the door of productivity would be ill-advised, particularly given the study did not provide any real data to solidify this assumption. Nonetheless, the predilection of the historic building repair and maintenance sector to engage heavily in the use of self-employment (NHTG, 2007; PYE Tait, 2013), has resulted in a high proportion of the labour working to price or output specifications; typical of UK construction and is typified by the "craft" production system; the selling of labour products (Clarke and Hermann, 2007).

Hence, the process of Quality Assurance (QA) should be a pre-requisite of the project delivery process, as many recognise the benefits of adopting a pro-active quality assurance strategy (carry out site work inspections and reviews as the works proceed)

(Carrillo, 2005). Yet, anecdotally, "traditional" contract project delivery processes and their characteristics, whereby typically the only criterion for selection of a contractor is based on the lowest cost submission. Inviting contractors to submit a tendered estimate relies on project documentation and the selection is centred on four fundamental criteria: price, quality, timing, and confidence, whilst considering the client's relative order and importance of these elements.

Moreover, the tendency is to appoint the architect under a separate contract, based on a negotiated professional fee, accentuates the already widespread industry inherent issues, such as; adversarial nature; lack of collaboration; silo working etc. This combination of issues results in reduced project delivery efficiency and a lack of true communication and collaboration between project stakeholders (silo-working) (Baiden, Price, and Dainty 2006; Baiden and Price, 2011). Clearly, accepting the lowest-cost tender selection, the risk of carrying-out on-site operations is transferred onto the contractor and it becomes unsurprising that delivering value for money for building repairs is a common industry problem. For example, when auditors Deloitte (2014) reviewed Edinburgh's statutory repairs system, a legislative system introduced in 1991 to protect its historic tenement buildings, they discovered original compulsory repair works to almost 700 projects had vastly grown in scope. This had resulted in the final repair costs far exceeding expectations, on average an increase in work between 25-50%. In one project, repair work amounting to more than £1m was carried out, with about £500,000 worth of work done which was not on the original specification. Fundamental to historic building R&M projects is their intended scope of works, yet common industry practice involves either the Architect or the Building Surveyor passing on their assessment of the proposed work to the contractor through *"a scope of work"* which is often in a generic form. Moreover, anecdotally, it is not unusual, for clients to engage with a building professional to generate an initial low-level condition survey and subsequent report and proceed to enlist the services of a specialist SME, who then has to carry out a further in-depth survey.

Yet, historically there is a belief that a dichotomy exists between value and lowest cost/price, whereby they are not mutually inclusive, is not a new concept (Latham, 1998). Which gives rise to the question; with their bespoke nature and need for highly experienced and skilled workforce (PYE Tait, 2013), how can quality be achieved, when it is based on a production basis especially in the R&M of the historic built heritage? Perhaps, by adopting a common defined approach to QA approach, could help identify and track such issues, especially defects, as they are often the subject of legal disputes, not only at completion but also when handed over (Chong and Low, 2005). Thus, with the further adoption of a Project Review, conducted with the aim to assess how well the project has been managed, rather than the overall success of the project, will support the identification of any lessons learned and take this forward to future projects (Eleyan and Loucopoulos, 2011).

It is clear that, current industry processes need to improve, as discrepancies such as discussed are evident through many projects which experience cost overruns and poor quality of work (Hyslop, 2004; Maxwell, 2007; SSLG 2006; Snow and Torney, 2015; Torney et al., 2012; Torney and Hyslop, 2015). In turn, generating a critical period for Scotland's uniquely diverse stone-built heritage, further endangering historic building stability and functionality e.g. reactive repair and maintenance allied to poor workmanship have continually resulted in neglect and poor practice (Historic Scotland, 2012b). Nonetheless, the Historic Building repair and maintenance concept is simple (i.e. to repair buildings to improve their longevity and durability), despite the relative complexities of the process, and the need to take into consideration, a plethora of philosophical and practice factors. Hence, adopting a multi-disciplinary, collaborative approach to on site practice such as repair specification and application throughout a project lifecycle (from planning to completion) is fundamental for effective repair and maintenance.

2.6 Summary

An extensive literature review, focusing primarily on Scotland reveals a range of challenges facing the historic building repair and maintenance sector both at an industry wide and project specific level, as well as a number of issues related to the current processes and conventional practices used in historic building R&M projects, which include; *education and training, recruitment, supply and demand, disrepair levels, economics, technology, sustainability, modernisation, process improvement and performance measurement*. Historic Scotland may have data of the number of historic stone buildings and a register of all listed stone buildings, yet the key challenges remain to determine specific repair requirements, establish specialised skill requirements and ultimately enhance historic building R&M practice by using a structured and multi-disciplinary integrated approach.

Given the undoubted importance of the sector and its impact on the economic wellbeing of the country (ECORYS, 2013; 2012), there is a distinct lack of studies exploring the specific Project Management issues that contribute to project poor performance (time, cost, quality). Particularly, in terms of specific PM guidance and standards, the literature review has identified an absence of such guidelines targeted for carrying-out and managing on-site operations. Several PM guidance documents do exist to support the PM process; stressing it should be as simple as possible and sufficiently robust, yet, they provide broadly generic guidance on procedures and have the tendency to stimulate numerous sector issues, such as; silo working, and poor communication and collaboration. Hence, in the absence of specific guidance and standards targeted for carrying-out and managing on-site operations, such deficiency directly influences project cost, time, quality and overall performance e.g. there is a tendency to adopt an ad hoc approach for managing on-site processes relying heavily on subjective knowledge, expertise and subsequent judgement of both professional and contractor MSME and SMEs.

Moreover, whilst the highlighted research gap is indeed a cause for concern, the paucity of research concerning sector "*process management and improvement*" correlates to the research focus; despite overall, the Historic Building R&M being a professional, highly skilled industry, with vast experience and expertise, the efficiency of current processes leaves much to be desired; projects are in fact still experiencing poor performance (e.g. elongated timescales, resulting in extended budgets). Therefore, adopting a multi-disciplinary, structured, collaborative approach to throughout a project lifecycle (from planning to completion) requires a need for the industry to develop its own tailored project management as well as on-site practice process delivery framework/model, in order to manage project success with better processes and operations.

Arguably, there is a need to identify a structured, multi-disciplinary, and collaborative model/framework, tailored towards MSME and SMEs. Perhaps, through adopting a tailored Construction Process Management Framework (CPMF), which embraces innovation and modernisation tools, to aid multi-disciplinary project delivery and on–site practice, such as; innovative PM approaches like Integrated Project Delivery (IPD), and the progressive application of digital technologies, becomes paramount for modernising practice. However, any Historic Building R&M sector augmentation has mainly focused on the direction of technical development rather than PM advancements, as such it is important to evaluate current project management strategies in order to aid process improvements within the industry as well as being essential to develop new frameworks, models and theories, which are explored in the following chapter.

Furthermore, it is, however, important to recognise in the broader sense there have been significant developments in promoting a more collective and collaborative approach to construction project delivery, with innovative practice, such as Integrated project Delivery (IPD) and digital technologies, such as Building Information Modelling (BIM), increasingly being used to modernise and support the execution of all aspects of the CPM. Therefore, adopting new technologies and innovative practice to historic building projects, will be fundamental, in supporting the augmenting of PM and on-site practice to enhance project performance, hence the need for the inclusion of an in-depth discussion of such tools in Chapter 3.

Chapter 3: Historic Building Repair and Maintenance Modernisation and Innovation

3.1 Introduction

Chapter 3 provides a comprehensive review of the literature related to, supporting the modernising and innovation of historic building repair and maintenance Project Management and construction practice. Firstly, this chapter, provides an introductory overview of the construction process and construction process management frameworks (CPMF), centred on evaluating two relevant wider construction industry CPMFs (CIOB, 2014; RIBA, 2013), in an attempt to identify the need for a SME specific framework which is more suited and effective to the historic building R&M Project Management process and on-site practice. Secondly, this chapter further explores the studies related to Integrated project Delivery (IPD), followed by examination of historic building repair and maintenance digitisation, by providing an overview of the studies that have developed approaches that are relevant to historic building repair and maintenance Project Management and on-site practice and the impact this could have on project processes, such as surveying, building diagnostics, scheduling, progress monitoring, and evaluation, etc. Furthermore, parts of Chapter 3 findings are published in the following Academic journals: Information Sciences, 1, pp.177-183 (McGibbon and Abdel-Wahab, M., 2016), and Journal of Cultural Heritage Management and Sustainable Development (McGibbon, S., Abdel-Wahab, M., & Sun, M., 2018) (Appendix G).

3.2 Construction Process Definition

In the broadest sense, the construction process is similar in nature to other industrial procedures; whereby, a collection of tasks and activities (steps, actions, operations, etc.) that together transform inputs into outputs, by adding value, to a product, service, or information supplied to a client (Bennett, 2007). However, several Construction Management (CM) studies (Koskela 1992; Griffith and Watson, 2003; Jackson 2006) have offered several rather more elaborate definitions of the construction process. Griffith and Watson (2003) characterised it as; a sequence of a co-ordinated and standardised flow of multi-faceted activities/works performed within a context of combined project delivery objectives of timely, cost conscious, safe, technical and quality performance standards. Whereas, Jackson (2006) described it as the complex process of taking a project from a set of two-dimensional drawings to a three-dimensional structure. Implying, that CP is the execution of an operational system of design, development, and production. Whilst, Koskela (1992) in his early work surrounding Lean Construction PM, likened the construction process and its sequential or linear procedural form, to a production practice; arguing the integrated transformation-flow-value (TFV) generation production concept and its subsequent TFV process model is very useful in understanding the construction process and Construction Process Management (CPM); such has been the impact of Koskela's TFV-process model; it is regarded, as a more appropriate way to manage projects (Biton and Howell, 2013).

Yet, in reality, construction projects are not truly linear like a production environment, due to their complex and individualistic nature (Ashworth, 2006). Furthermore, the close relationship between the design and construction, presents difficulty when attempting to make changes to existing processes, in order to, enable and lead process improvement (Ashworth, 2006). At the foundation, exist a number of inherent generic issues, within the construction process, as illustrated in Figure 3.1, which intensifies the likelihood of adverse instances of risk towards project time, cost and quality (Vrijheof and Koskela, 2005).

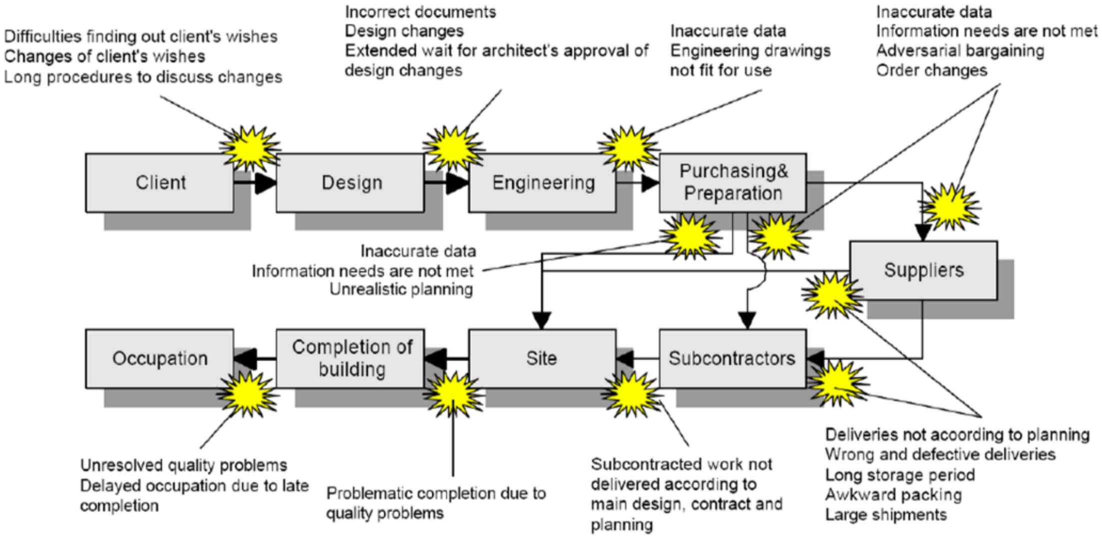


Figure 3.1: Generic Issues in the Construction Process (Vrijheof et al., 2001; 2005)

Undoubtedly the dynamic, deterministic and non-linear, nature of the building design and construction process and its integral complex systems, often exists on the edge of chaos; the transition from order to disorder (Bertelson, 2003; Fernandez-Solis, 2008). For example, Bertelson, (2003) and Fernandez-Solis (2008) proposed drawing on two conceptual theories: Chaos Theory, the study of apparently random or unpredictable behaviour in nonlinear systems which are governed by deterministic laws, yet are difficult to effectively predict (Gleick, 2011); and fractal theory, whereby, an initially simple process goes through infinitely much iteration and becomes a very complex process (see Mandelbrot, 1982). Suggesting, that combined, they could be considered as a valid scientific approach, to understanding the building design and construction process and its complex ecosystem; in order to develop appropriate CPM tools, as complex systems, although apparently contradictory, are not always chaotic or completely chaotic, as they have their own underlying order (Bertelson, 2003)

Whilst, the bespoke and complex nature of a historic stone building repair and maintenance project is indeed not only non-linear, but in fact, highly dynamic, driven by the highly fragmented and siloed disposition of historic building repair and maintenance stakeholders, compounded by an omni-present prevalence of specialist MSME and SME sub-contracting; and the persistent problem of skills shortages and skills gaps (Abdel-Wahab and Bennadji 2013; Pye Tait, 2013). The historic building repair and maintenance process can be considered a complex ecosystem (people, processes, technology, and structure) which begins initially as a simple process, then evolves through infinitely many iterations, becoming a very elaborate process, often requiring cyclic feedback and adaptation, and is open to; the systemic emergence of internal and external variations, such as a change in specification or level of quality required. Although it could be argued that such an approach is highly relevant for a historic building repair and maintenance project, in order to support describing the; underlying management patterns, decision making interconnectedness, need for constant feedback loops, and operational complexity. Perhaps, this perspective is feasibly at step too radical for historic building repair and maintenance Project Management, nonetheless, the important conclusion is that, no longer, can the complexity of historic stone building repair and maintenance process (design and construction), be ignored. Hence the following section outlines the study’s definition of a CPMF.

3.3 Construction Process Management Framework Definition

With Construction Process Management (CPM) defined as, the comprehensive planning, monitoring and administration of a project's tasks and activities, in terms of performance (Cartlidge, 2015). The purpose of Construction Process Management Framework is to support the delivery of a viable project, on time, within budget and meet the required quality, in terms of functionality, as well as meeting the client's demands and needs; whilst, objectively attempting to eliminate errors at the design/planning stage and provide a reasonable construction sequence prior to and during the construction works stage (Heng Li et al., 2008). Yet, whilst defining a Construction Process Management Framework (CPMF) appears straightforward; in reality, it can become problematic, when looking to develop alternatives, fuelled by three key factors; (1) a variety of similar terms exists; (2) dynamic and complex process of construction; and (3) discrepancies in the value afforded to the role and scope of construction project manager field (Cartlidge, 2015). Such discourse is out with the parameters of the study, thus for the purpose of the this research, the study has adopted, Kagioglou et al., (2000) definition of a CPMF whereby; the practices and measures are incorporated by a project delivery team, in order to employ improvements across a number of areas, such as; project implementation and delivery; supply chain partnering; and the fabrication and installation of building elements (Kagioglou et al., 2000).

3.4 Relevant Construction Process Management Frameworks

On the basis, that applying contemporary Project Management concepts in historic building repair and maintenance practice, is highly relevant and should not be discounted; several updated managerial, operational procedural frameworks are available, such as; the Royal Institute of British Architects (RIBA): Outline Plan of Work (2013; CIOB (2014) Code of Practice for Project Management for Construction and Development, supplemented with the Construction (Design and Management) Regulations 2015 (HSE, 2015) (Chen, 2019). The professional organisations involved in their development have defined the standard processes, construction projects require to function, which include pre-design, design, planning, construction, and post construction (CIOB, 2014; RIBA, 2013), and designed them as both process maps and management tools, to promote a more collaborative project delivery collective approach, by providing shared management frameworks for the co-ordination and administration of building projects. Adding to this development, with the emergence of the onset of digital transformation across the UK built environment, and the push towards a BIM environment; with its technology, methodology and associated processes, as a fully collaborative delivery system (Eadie et al., 2015), whereby its ability to capture, the complexities and the dynamic interactions among all the systems involved in the construction process (Volk et al., 2014). It would be prudent to provide a discussion of existing Construction Process Management Frameworks (RIBA, 2013; CIOB, 2014) deemed relevant for use within historic building repair and maintenance projects, particularly as both internationally and UK wide, building conservation researchers have investigated BIM technology and its associated processes, as a new system of recording and surveying historic structures. Whereby, it provides not only valuable heritage digital documentation and modelling, but in heritage management, planning, building repair, along with environmental and structural analysis, assessment, and monitoring of built heritage structures (Conor and Murphy 2017). Hence, the following sections present a synopsis and critique of each relevant Construction Process Management Framework.

3.4.1 Royal Institute of British Architects (RIBA): Outline Plan of Work 2013 Framework

Over the course of the last 50 years, the RIBA Plan of Work, first developed in 1963, has underwent numerous iterations (RIBA, 2013). The latest was in 2013, when the structure of the RIBA Plan of Work 2007 and its stages A-L were overhauled; in order to address limitations in the 2007 version, such as being predominantly architect focused, evidenced by only providing a single stage to the construction process and lacked flexibility (Liu et al., 2015). Thus, the revamped RIBA Plan of Work (2013) as illustrated in Figure 3.2, sought to allow a more integrated approach across a project lifecycle, whereby the framework defines the project lifecycle into predefined contextual and individual stages, tasks and outcomes, from initiation to handover and use, which are sequential in nature but depend on the project requirements and the selected procurement method, (RIBA, 2013). Whilst, in essence, it still focuses predominantly on the design process; the RIBA (2013) uses more design-centric terminology to describe its eight stages e.g. strategic definition, preparation, and brief etc..; Although, with the movement towards sustainability and a digital construction industry, both a Green Overlay and a BIM Overlay has been provided, in order to provide a systematic structured process to support both professional and contractor stakeholders. Whereby, the provision of generic guidance on; the activities needed in a BIM environment, at each RIBA work stage, to successfully deliver construction projects; whilst supporting embedding sustainable environmental design approaches and management strategy in projects (Liu et al., 2015).

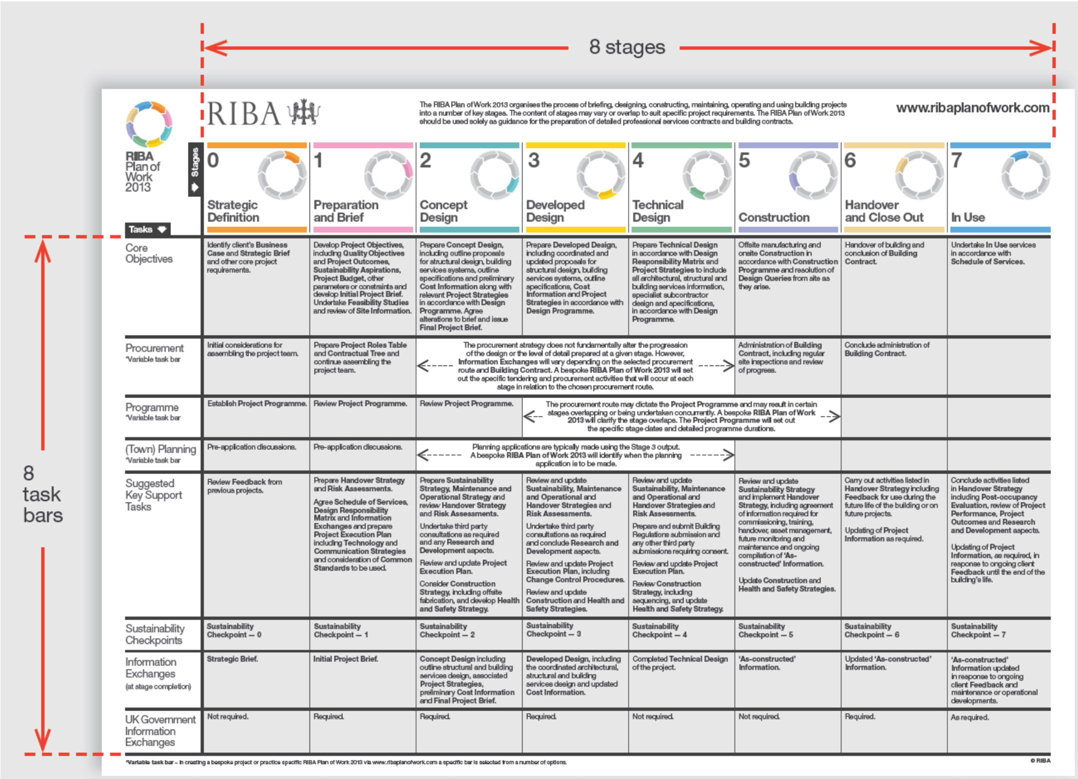


Figure 3.2: RIBA Plan of Work 2013; Reproduced from RIBA (2013)

In terms, of sustainable strategies and BIM-enabled projects, the reasoning sought to improve the need for; greater transparency of project information, be more procurement methods adaptable and flexible, and locate a greater influence on design and production information integration (Pomponi et al., 2015). For example, it outlines and identifies where crucial BIM activities and the relevant data delivery exchange and storage points are within each project stage, regarded as vital and significant new guidelines for Architects and BIM managers (Alreshidi et al., 2018; Pomponi et al., 2015). This suggests that it would support how professional institutions and bodies, strategise the employment of “Green” design and BIM, both individually and holistically (Ganah and John, 2014). However, Alreshidi et al., (2018) illustrated that, approximately 29% of construction companies are still using RIBA Plan of Work 2007, since its overhaul and publication. Therefore, the wider construction industry still has a long way to travel, before projects and their delivery teams can utilise the framework’s fully inherent capabilities. For example, in the most recent National Building Specification (NBS) National BIM Report 2018, the key finding was that only nearly one in five (18%) use BIM on every project they work on. The report also highlighted a fundamental of BIM was collaborative working, supported by structured and standardised information. However, it stressed that a caveat for truly effective collaboration was the need for governance by commonly agreed ways of working.

3.4.2 Chartered Institute of Building's (CIOB) 2014; Code of Practice for Project Management for Construction and Development

Several research studies (Lock, 2016; Love et al., 2002) have considered construction as a dynamic system, susceptible to planned and unplanned dynamics, and the principles of Project Management being the same for any size of project regardless. Thus, the CIOB framework (2014), regarded as definitive guidance to the values and practice of Construction Project Management has, similarly, been revamped. The latest edition (5th), formulated in conjunction with several key professional organisations (RICS, ICE, Association for Project Management (APM) and Construction Industry Council (CIC) (CIOB, 2014), has considered the increasing levels of complexity and technological prowess, required, in the necessity to deliver projects within an agreed budget, timescale and to an acceptable level of quality (CIOB, 2014). Similar to RIBA (2013), the CIOB (2014) framework separates the processes associated with projects into eight stages with the added concept to provide deeper Project Management guidance on; the integration of BIM and sustainability issues at each stage of the project life and placing more emphasis on the early pre-construction stages (CIOB, 2014.

The CIOB framework (2014) itself, is divided in two sections; the first mirrors generally the Project Management process itself covering eight stages; using terminology based in key Project Management concepts, such as inception, feasibility, strategy, pre-construction etc. (see Figure 3.3). Each of the eight stages is supported with illustrations, flowcharts and checklists; the second part comprises of; a project handbook, complete with documentary guidance and additional checklists (CIOB, 2014). Whilst both the RIBA (2013) and CIOB (2014) frameworks separates the processes associated with projects into eight stages. From a Construction Project Management (CPM) perspective, the CIOB (2014) believes the new version, offers a fundamentally imperative guide, to practice, in the age of evolving digitisation and environmental considerations in the context of building functionality and its requirements.

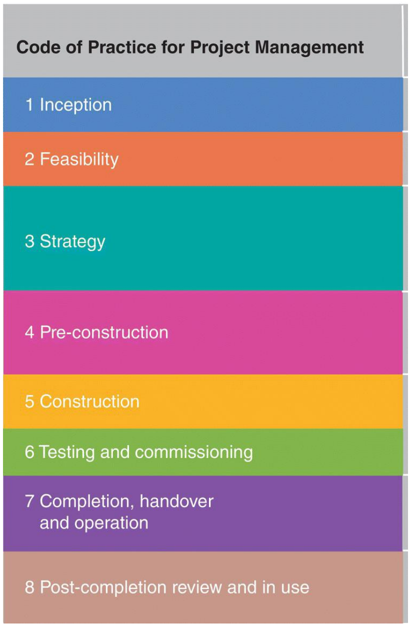


Figure 3.3: Chartered institute of Building (CIOB); Reproduced from Code of Practice for Project Management (2014)

Yet, only a very few studies investigating Construction Process Management (CPM), have cited the updated CIOB (2014) framework, tending to use the guide as a point of reference, instead of investigating its tangible benefits in practice. For example, in a study of 4th version of the code of practice, Fotwe and McCaffer (2000) stated that the skills, knowledge and expertise required for managing projects are influenced, by professional organisation recognition such as the CIOB and the RIBA. In respect of the updated CIOB (2014), Kissi et al., (2014) only provided "lip service" to the framework itself, reporting, that it separates the function of management from design of a project and is aimed at meeting client requirements. Whilst, Zulch (2014) who examined Project Management communication, and the need for a well-defined integrated and prior agreed project communication plan; pointed towards the CIOB (2014) framework as an essential guide for best practice, in order to provide a clear project direction for all stakeholders, particularly for complex projects, and the ability to subsequently apply the acquired knowledge, yet, the study did not expand on what the CIOB requirements were for such a plan.

3.4.3 Critique of RIBA (2013) and CIOB (2014) Construction Process Management Frameworks

From the examination of both CIOB's Code of practice for PM (2014) and the RIBA Plan of Work (2013), much of the review has come from the relevant professional organisation's own literature. As there is, a lack of academic studies which investigate their physical employment, given the studies published, have tended to provide the concept of tokenism to the frameworks themselves, in part, due to their administrative nature and predisposition to be regarded as best practice guidelines (Alreshidi et al., 2018). Nonetheless, despite, the lack of academic studies, a re-occurring theme, in terms of relevancy within the wider construction industry emerges; such process models (RIBA, 2013; CIOB, 2014) facilitate successful work on projects, as they promote a more collective and collaborative approach, offering indicative work stage junctures, employed by a multiplicity of project and contractual documents (Tzortzopoulos et al., 2005). Moreover, both are configured as *"procurement-neutral"*; in other words, they do not presume a traditional form of procurement, but instead allow contractual and appointment documents to be created to fit the needs of a specific project. As such, RIBA (2013) and CIOB (2014) report they are as simple, adaptable, flexible, customisable, suitable for all sizes of projects, and support a continuous cycle of improvement. Yet, whilst, each has their own individual merits and benefits, by providing comparable frameworks for the design and execution of construction projects, which offer both a process map and a management tool to facilitate work on projects that incorporates the use of digital technology and sustainable practices, on closer inspection, the similarity is realistically, only generic in nature.

The RIBA (2013) framework appear to be more suited as a Project Management methodology to those involved in the design phase, evidenced by the intricacy of the design processes involved in each of its individualised stages, suggesting the design team has control over the execution of a project, as opposed to the construction team and its SME make up; who are, predominantly tasked with construction stage and operate on small-scale projects. Yet, academic evidence (see Alreshidi et al., 2018) presents further ambiguity, suggesting many design and construction teams still prefer to use the 2007 RIBA framework, intimating it better reflects the terminology used within the wider construction industry, which in turn further fuels the lack of uptake of the RIBA 2013 framework by the historic building repair and maintenance sector.

In relation to the CIOB (2014) framework, for all intent purposes, it appears to be more suited to the construction team and its SME, yet, the CIOB (2014) framework suffers from similar issues; being aimed more towards professionals within its domain e.g. Construction and Project managers and their relevant professional organisations (CIOB; RICS; RIBA; ICE etc.), as well as having a greater focus on large new build projects. Yet, from anecdotal evidence and experience, when taken in the context of bespoke and specialist nature of historic building repair and maintenance projects. The highly fragmented Project Management structure (both horizontally and vertically) of both MSME and SMEs within the sector and the procurement and delivery of over 50% of work, within the private sector on small-scale projects (PYE Tait, 2013), further adds to the lack of uptake of Construction Process Management Framework by the historic building repair and maintenance sector.

In an attempt to provide a more straightforward guide tailored for MSME and SMEs and smaller scale projects; the RIBA (2016) have developed a *"Small Project Plan of Work"*, for use on smaller projects employing a traditional procurement, which offers simplified overview of the project lifecycle, its eight contextual stages, and associated tasks. However, whilst a step forward, in essence, the developed streamlined version echoes the main RIBA (2013) framework, it still is more design centred in make-up and terminology focused on core design and regulatory matters such as; Health and Safety, planning and building control, along with suggested levels of design progression to help explain the process of the design sequence (RIBA, 2016). Furthermore, it has perhaps been over-simplified, as it is more concentrated towards providing a simplified representation to better enable a closer working project lifecycle relationship between Architects and their clients, surrounding process discussions rather than towards SMEs, evidenced by the fact it states that it requires employed in conjunction with the RIBA Plan of Work 2013, as many tasks are omitted, done to keep it uncomplicated as possible, in terms of client understanding. Moreover, from a historic building R&M project context, whilst, undoubtedly a step in the right direction. This simplified version still suffers from a lack of reflection of the terminology used within the specialist sector, such as the definition and naming of the work stages, the terminology and the work-processes, undertaken by the vast majority of historic building R&M SMEs.

Returning to the two main frameworks (RIBA, 2013; CIOB, 2014), a recent industry wide report by law firm Pinsent Mason (2017) on the theory and practice of collaborative working in construction, argued that the industry's fragmentation and its numerous bodies and organisations makes it difficult for a clear lead to come from any one consistent source. Moreover, the report concluded these frameworks tend to promote silo working, as they are more suited to their relevant professional organisations. They found numerous barriers to collaboration, such as; the perception that collaborative processes are likely to be more expensive, time consuming and resource hungry; an industry inertia to encouraging team working, as professionals tend to focus on their own individual disciplines, working in silos and are cautious of early contractors and supply chain engagement. Compounding these issues is a ack of MSME and SME awareness of such Project Management frameworks, which in turn, questions their relevance for true collaboration, given the industry's risk averse culture (Pinsent Mason, 2017).

Moreover, with managing projects becoming more complex and the need to rapidly respond to changing economic, and technical situations, the speed of project change is becoming significantly faster than ever (Ramazani and Jergeas. 2013). Hence, the simplistic perspective of MSME and SME contractors role in delivering projects, whereby they are focused on on-site operations, has changed (Carvalho and Rabechini, 2015); as they now have a wider remit in a project, through the drive for greater integration and collaboration as the need for successfully mitigating risk and uncertainty increases (Carvalho and Rabechini, 2015). For instance, given the need to combine innovation, management, and efficient coordination of SME work packages, whilst striving to implement improvements in CPM (Westney, 2017). They are required now to possess a combination of soft and hard skills e.g. Project Management processes and tools, leadership, communication, administration, etc.; all essential for effective decision-making (Carvalho and Rabechini, 2015). Yet, it follows that there is a disconnection between current Project Management process frameworks for construction, as they are not integrated with processes and practice undertaken by SMEs (Poirier et al., 2015). Especially, given MSME and SMEs have been identified as key protagonists in stimulating project productivity and performance through *"process management and improvement"* driven by modernisation, co-operation, and cohesive working (Barbosa et al., 2017)

By definition, both the RIBA and CIOB frameworks provide valid guidance, however, in the context of historic building repair and maintenance sector and its specialist MSME and SME organisations, the supposition that these frameworks (RIBA, 2013; CIOB,

2014) have a tendency to: *promote silo-working; are more suited to their relevant professional organisations; and lack SME awareness and relevance,* is absolutely relevant. These Project Management frameworks may include repair and maintenance as part of their agenda, however, for sector projects, their modification, is not explicit and only infers that they can be adapted for such inherently complex project types. In reality, they are more suited to projects which involve a combination of new build, refurbishment, retrofit, and regeneration process, whereby projects can be classified as large-scale projects, not only in terms of value, but also resources, time and scheduling complexity with not solely being focused on one work area. For example, the RIBA (2013) has been deployed as the project methodology, on a number of such types of UK projects, such as; the Whitechapel Crossrail station development, in East London (value £110 million); the £330m regeneration works to the iconic Manchester Town Hall; and the £35million restoration of Glasgow's famed Mackintosh Building (prior to a second significant fire-outbreak which has led to areas of damaged and unstable masonry being taken down to ensure structural integrity). Whilst, interestingly, the RIBA (2016) *"Small Project Plan of Work"*, was adopted on a project in Cambridgeshire, comprising of the conservation refurbishment and conversion of a group of 18th Century Grade II listed historic barns and agricultural buildings, into eight luxury conversions with a further four new homes on the site, valued at £7.66 million (Construction Manager, 2016). Thus, re-iterating the earlier assumption of such frameworks' suitability towards the new build, refurbishment, retrofit, and regeneration process. Paradoxically, current historic building R&M standards, guidance, and legislation (see BS 7913; RICS, 2009; SHEP 2011) replicates the aforementioned issues, with their propensity to use high-end building conservation terminology.

Moreover, for the numerous stakeholders involved in historic building repair and maintenance projects from a Project Management perspective, and the inherent multiple stakeholders involved (Client, Architect, Contractor, Building Surveyor, Structural engineer, etc.). These demerits, rather than enhance the aim of adopting a multi-disciplinary approach, espoused by a plethora of guidance and academic studies (see Delegou et al, 2019; Forster et al., 2018; Paoletti et al., 2013), instead, they appear to demarcate the prevailing traditional culture of silo-working (Egan, 1998; Wolstenholme et al., 2009). Indeed, all operating in independent silos, allied to *"traditional"* contracting practices, creates workflow constraints, and collaborative barriers, that lack a multi-dsiplinary process alignment, which in turn stimulates poor Project Management decision-making across the supply chain (Dyson et al., 2016; Forster and Kayan, 2009; Kayan et al., 2016). Indeed, this is further magnified, and accentuated by the perennial problem of skills shortages and skills gaps, such as the lack of understanding of the technical knowledge, as well as complexities involved with historic building Project management (Dyson et al., 2016; Tokede et al., 2018; Torney et al., 2012; 2014).

Yet, with the basic aim to support and improve the process of planning and managing projects, founded on the belief that framework implementation makes Construction Project Management easier and success more likely (Chinowsky et al., 2008). Whereby, the performance of complex operations are reliant on the way the work is organised and managed, in term of sequence, interdependencies, technologies, control mechanisms, etc. (Aziz and Hafez, 2013). Construction projects successes are historically dependent on two central components; (i) the capability to plan and manage the project's technical elements (i.e. tasks, activities, and resources); and (ii) the efficacy of collaboration and communication between project stakeholders (Chinowsky et al., 2008). Thus, the inadequacies of the frameworks, in the context of historic building R&M MSME and SMEs, which points towards the need for a structured, multi-disciplinary, and collaborative model/framework, tailored towards such organisational types that could support and help augment historic building repair and maintenance Project Management to enhance project performance.

Therefore, as a complex problem, it requires process-focus improvements, thus, perhaps with a growing trend toward the integration, flexibility, and adaptability, consideration towards the emerging construction project delivery system, known as integrated project delivery (IPD), as an alternative delivery method, may be more, readily accepted within the sector. IPD is a project delivery methodology that coalesces stakeholders, processes, and methods into a collaborative integrated system (American Institute of Architects (AIA), 2007). Hence, the following section provides a deeper insight on IPD and provide a more insightful examination of IPD, offering more detail on IPD principles, benefits, and differences from traditional project delivery, stakeholders involved and the subsequent challenges of implementation, as well as an overview and a subsequent discussion, in terms of historic building R&M PM.

3.4 Integrated Project Delivery (IPD)

Due to the combative nature of traditional contracting procedures, Integrated Project Delivery (IPD), is emerging as an effective approach for reducing construction inefficiencies, labour and extra costs while boosting project outcomes (Garcia et al., 2015), driven by the three main types of mechanisms: (1) contractual; (2) organisational; and (3) technological (Mitropoulos and Tatum, 2000). In its ideal form, IPD embodies and embraces highly collaborative processes, which are reliant on the shared knowledge and proficiency of project stakeholders (professionals', contractors, sub-contractors, and clients) (El Asmar et al., 2013). It is based on the reliance of the fundamental principle of integration, and having clearly defined standards, exhibiting the following characteristics; (i) Shared Respect, Trust Benefit, and Reward; (ii) Early Goal Definition and Collaborative Decision Making; (iii) Enhanced Communication, Performance, and Leadership; and (iv) Appropriate Technology. Whilst in essence, IPD and its various tenets appear to be relatively straightforward; IPD is slightly more intricate than at first glance. Hence, Yee et al., (2017) through a meta-analysis of current IPD literature, developed a conceptual IPD integration framework, aimed at creating a better appreciation of the requirements and relationships of IPD principles, was founded on embracing four key themes: Contractual and Technology (true collaboration), Behaviour (team integration), and Structural (streamlined process) (Figure 3.4).

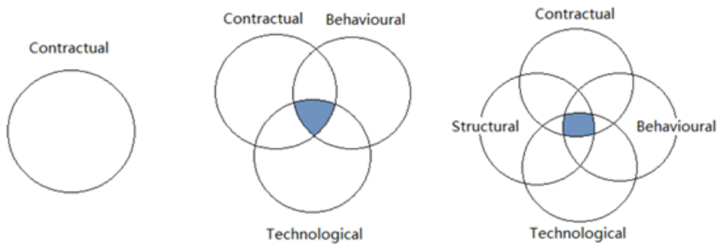


Figure 3.4: Developed four key themed conceptual frameworks of IPD integration; Source; (Yee et al., 2017)

Thus, an IPD integration level guide was developed (see Figure 3.5), as a starting point for possible practitioner IPD adoption, to highlight IPD can be adopted at varying levels of integration e.g. level 1 integration focus is more on IPD philosophy, to level 4 integration which considers IPD as a "real" project delivery method.

	Level 1	Level 2	Level 3	Level 4
Integration level	Lowest			Highest
Delivery method	IPD as Philosophy	IPD as Philosophy	IPD as Delivery Method	IPD as Delivery Method
Known as	Lean Delivery	IPD-ish, IPD-Lite, IPD like, Integrated practice	Pure IPD, Relational contracting, Lean Project Delivery	Actual IPD
Nature of Agree-ment	Transacti-onal	Transactional	Relational	Relational
Charac-teristics	No contract-ual language Mutual respect and trust	Some contractual bonded collaboration Early involvement of key participants Co-location of team Intensified early planning / intensified design Lean Principles of design, construction, and operation	Multi-party contract / Single Purpose Entity Collaborat-ion decision making and control BIM implement-ation	Single Purpose Entity Liability Waivers Shared financial risks and rewards Fiscal transpare-ncy Jointly developed and validated project goals and objectives Shared BIM model Team Flexibility
Value Added	Limited risk sharing No blame culture Open Commun-ication	Shared risk and rewards / Mutual benefits BIM used by project participants Less assign liability Unrestricted shared information Fiscal transparency Joint development and validated project goals and objectives Collaborative innovation	Liability Waivers Operation without boundaries Shared BIM model Organisation and Leadership Team Flexibility	

Figure 3.5: Comparison of IPD philosophy among practitioners' perspectives, and white papers offering proposed re-categorised principles; Reproduced from Yee et al., (2017)

3.4.1 Differences between IPD and Traditional Delivery Approaches

A number of differences exist between traditional delivery methods and IPD (Mihic et al., 2014), therefore, to provide a basis for comparison, Table 3.5 outlines, more clearly the divergences between traditional project delivery and IPD.

Traditional Project Delivery	Feature	Integrated Project Delivery
Fragmented, and Siloed basis, compiled when required, intensely hierarchically controlled	Teams	Integrated transparent collaborative team comprised of design and construction teams assembled early in the process
Adversarial Siloed linear approach to information sharing, expertise and knowledge.	Process	Shared trust, respect, expertise, and knowledge. Transparency across all teams
Dealt with separately, significant/heavy transfer	Risks	Communally distributed and administered
Independently practiced;	Compensation/ Reward	Correlation of team and project success
Analogue Paper-based	Communications/ Technology	Digitised
Fosters individualistic nature, risk allocation	Agreements	Transparent, shared collaboration, risk, success

Table 3.1: Differences between Traditional Project Delivery and IPD; Adapted from AIA (2017)

As highlighted in Table 3.5, central to the design of IPD is the integration of the key project stakeholders, within both the design and construction teams, thus increasing the interdisciplinary nature of the project (Mihic et al., 2014). Whilst, from a contractual perspective, employs a multi-party contract, whereby, jointly developed project goals have contractually imposed economic risks and rewards, shared among project team members (e.g. client, architect, and contractor) (Ghassemi and Becerik-Gerber, 2011). Furthermore, IPD provides a significantly efficient construction project workflows, as many protectionist and redundant processes, that do not add value can feasibly be eliminated, as it has been shown to achieve statistically significant improvements in project performance (El Asmar et al., 2013).

3.4.1.2 Benefits and Challenges of IPD

A number of studies have gathered both qualitative and quantitative data, highlighting the comparison between IPD benefits projects, and those, which are not IPD projects, revealing several correlated findings. Asmar et al., (2013) presented a quantitative statistical based comparison study of IPD and non-IPD projects and developed a data collection instrument. This enabled performance data from 35 completed IPD projects to be analysed, resulting in demonstrating substantial improvements across fourteen-project metrics (e.g. cost, quality, schedule, safety etc.) covering six performance areas, namely: economic, quality, programme, variations, communication, and environmental. Similar findings were reported from several parallel case study approach studies (Ghassemi and Becerik-Gerber, 2011; Garcia et al., 2016; Paolillo et al., 2016), although they considered benefits under the three themes of profit, people, and planet. Nonetheless, the studies re-iterated the previous studies findings; that none of the IPD projects suffered from the inherent efficiency and performance issues found in traditional projects, notably delivering; reduced construction project costs, increased workforce competence, reduced life cycle costs, and increased operating efficiencies. With the increasing adoption of digital construction, it has been intimated that combining BIM tools, such as 4D modelling with IPD can further enhance the project delivery (Umar et al., 2015) and illustrate how industry silo mentality fragmentation and discontinuity can be addressed (Lu et al., 2015). As such, IPD projects typically use some form of cloud computing to facilitate the free exchange of ideas and project data (Cooley and Cholakis, 2013), given IPD has the ability to provide a collaborative platform for enhanced communication and sharing of tacit knowledge between team members, resulting in increased connectivity and interdisciplinary knowledge (Zhang et al., 2012).

In terms of SME and specialty contractors' benefits, IPD projects and the reward-sharing ethos offer significant values, such as; receiving higher fees, as they have they have the capability to use their experience and knowledge, by contributing in the planning, designing and delivery process of a project, to help support improvements across the project lifecycle (ELECTRI International (the Foundation for Electrical Construction), 2016). Thus, the integration of all project stakeholders, and its propensity to be flexible and adaptable, encourages SMEs to improve quality and service, embrace sustainability, reduce time and costs, and enhance overall organisational effectiveness (Fakhimi, Sardroud, and Azhar, 2016).

Despite its many benefits, IPD faces a number of challenges, Yee et al., (2017) identified twenty-seven project dynamics influencing IPD adoption, such as; the lack of a collaboration model, lack of IPD awareness, the restructuring of procurement strategy and increased costs at the design and planning stage. The authors classified these challenges under their conceptual four-layered IPD integration level guide: Contractual (e.g. lack of new legal framework/collaboration model), technology (e.g. data protocol and copyright), behavioural (resistant to change, lack of awareness), and structural (e.g. over-elaborate work process, scheduling issues). However, what is noticeable here is that all these studies were carried out in the Northern hemisphere; USA, and Canada to be exact, whereas there are limited studies conducted in the Southern Hemisphere, Europe, and the UK, due to limited IPD adoption. For not only Scottish but also UK historic building R&M projects, results in a curbed IPD awareness and appreciation of such an innovative project delivery system. Indeed, it could reason that given IPD is a very learning-intensive process, without appropriate knowledge and skill project team members, the ability to fully implement IPD might be questionable (Nofera et al., 2011). Nonetheless, despite the challenges faced with IPD implementation, the undoubted benefits gained from adopting an IPD are evidently plain to view, given the findings from the literature. Indeed, they provide sufficient evidence to suggest IPD adoption could be the beginning of a new construction industry pathway that revolves around sustainable design, construction and life cycle planning, implemented with integrated construction methods, supported by innovative technology and innovative practice.

3.4.1.3 Adopting an Integrated Approach for Historic Building R&M Projects

Contemporary management concepts such as Integrated Project Delivery (IPD), offer the opportunity to improve the Project Management of historic building repair and maintenance construction process, as it has emerged as an important methodology to enable the potential success of more complex and dynamic construction projects (Baiden, Price, & Dainty, 2006). With this evolving construction project delivery system referring to the multi-disciplinary collaboration of various project stakeholders to ensure process efficiency and maximisation of resources for successful project delivery in-line with the client expectations (Garcia et al., 2015). With current traditional delivery and contracting approaches within historic building R&M tending to yield inefficiencies, particularly when communicating information from one stakeholder to another, such as the allocation of information, work packages or change orders, due in part to the fundamental nature of separate silos of contractual responsibility (AIA, 2017). Adopting an IPD approach whereby integration and collaboration can disconnect the adversarial nature of projects, which can be removed very early in a project timeline, resulting in optimal project outcomes (i.e. time, cost, quality, and sustainability) (Garcia et al., 2015).

With historic building R&M projects hindered with issues, including, among other things; repair specification change delays; added costs; fragmentation among the key project stakeholders (Dyson, Matthews and Love, 2016; Shipley et al., 2006; Smith, 2005); and the tendency to adopt an ad hoc approach for managing on-site processes relying heavily on subjective knowledge, expertise, and subsequent judgement. Employing an IPD based approach could signify a cultural industrial transformation by deconstructing current silos of practice and provide a truly collaborative and multi-disciplinary approach, which is fundamental for historic building R&M projects. Indeed, the inherent issue of its bespoke and specialist nature combined with the prevalence of specialist sub-contracting (PM and on-site practice, technical knowledge and experience) represent a key set of skills necessary for participating in IPD driven projects. For example, highly specialised, high-performing MSME and SMEs may have a higher initial cost., however, anecdotally they are more likely to find ways to reduce costs as the project unfolds and are better able to avoid problems that create costly overruns or change orders.

With many researchers, advocating IPD is a team sport and for some it is a mind-set, a spirit, and a philosophy, believing it bridges the gap between the inherent silo practices within a project's design and construction phases, and has the potential to provide numerous project benefits (Fakhimi, Sardroud, and Azhar, 2016). Current Historic building R&M project phase terminology will need to be amended and simplified to assist not only the integration of the terminology employed by the majority of the sector's specialist SMEs but also accommodate an integrated project team. Given the unique nature of built heritage projects, its supply chain and the role MSME and SMEs play in the historic building R&M sector, two key overriding obstacles face IPD implementation in the R&M sector. Firstly, convincing building professionals and contractors, to communicate, share information, and be project-centric focused, instead of profession focused. Whilst, secondly, “Traditional” procurement strategies do not lend themselves to true integration as they tend not to facilitate early contractor in the planning and design stages (Cunz 2009).

Combined, these obstacles present a considerable challenge to overcome decades of mistrust, opposition, poor communication, and collaboration, yet, IPD intends a project, in which everyone can learn from each other (Fakhimi, Sardroud, and Azhar, 2016). By, improving not only the project performance, but everyone’s performance; reducing schedule delays, cost overruns, conflicts and other issues often associated with historic building projects. However, with inherent risk of additional costs to historic building R&M projects, due to changes in specifications and scope of works, IPD, creates opportunity from such risks. For example, if historic building R&M projects adopted an IPD based approach (professionals and SME contractors); bringing together all stakeholders and harnessing their combined expertise early in the planning phase, where it is essential to have the knowledge and skills necessary. This could help identify and explore all the issues surrounding the project in order to mitigate risks, given IPD techniques and its high degree of collaborative effort, can substantially reduce on-site construction issues such as change orders and requests for information (Hellmund, Van Den Wymelenberg and Baker, 2010).

Thus, the application of a contemporary management concept such as IPD can offer a synergetic effective approach (Aziz. and Hafez 2013) to not only promote a multi-disciplinary approach for historic building R&M, but also helps support efficiency improvements in historic building R&M industry. Moreover, with IPD projects employing digital technologies to increase and facilitate integration, communication, and collaboration (Cooley and Cholakis, 2013), and with the continual trends in digital technology yielding a wide range of new technologies, and associated tools available and their subsequent and potential applications to support the construction process (Froese, 2010). Construction digitisation shows great potential in not only improving CPM, but also across a number of Construction practice (CP) areas, creating increases in efficiency regarding project time, quality, cost, safety, and its environment. From construction management data acquisition needs (positioning, tracking, progress monitoring and quality control) to actual construction practice application (masonry construction, prefabrication/off-site manufacturing, wall assembly, foundation work etc) (Vähä et al., 2013). Hence, it is not unreasonable to assume similar potentialities could occur within historic building repair and maintenance projects, although there is a need to understand what new technologies and processes that could be most likely used and what investments in skills will be required to make this achievable. Thus, the following section provides an overview and discussion of available suitable digital technologies and tools.

3.5 Historic Building Repair and Maintenance Digitisation

3.5.1 Definition of Construction Digitisation

Digitisation is the process and ability to convert analogue and physical data into digital data outputs, which in turn enables the leveraging and improving of business processes (Prange, Schmidt and Sonntag, 2017), and is absolutely relevant to enhance Construction Project Management. Particularly, with its ability to provide interconnectedness; increased transparency; swifter decision making; enhanced trust and integrity; reduced delays; and information abundance (Khan, 2016). Various studies over the last decade or so (see Ibem and Laryea, 2014; Kylili et al., 2014; Rohani, Fan, and Yu, 2014; Sun et al., 2013; Valero, et al., 2014; and Vähä et al., 2013; Shen et al., 2009) have systematically reviewed the existing extensive literature, surrounding Construction Digitisation; identifying the various types of digital technologies and associated tools available, highlighting the potential benefits, challenges, and any limitations. The consensus was; Construction digitisation and its "digital fabric", will create a "digital construction ecosystem" that provides symbiotic connections to projects, people and processes, whilst simultaneously realising the value and benefits of collaboration and integration (Shen et al., 2009). This in itself is unsurprising, as much, has been written of the need to integrate people, technology, and processes (Erdogan, Abbott, & Aouad, 2010). Whereby, construction practice and its outputs, information distribution, communication and collaboration, precise project progress evaluation, quality control/quality assurance (QC/QA) and building environmental improvements (Golparvar-Fard et al., 2011) will result in performance and productivity impacts on workforce, materials and plant management (Schweber & Harty, 2010).

3.5.2 Definition of Historic Building Digitisation

Historic Building Digitisation is the ability to convert historic building data capture into a digital format as a way to digitally document, interpret and visually access these buildings, due in part to the influence global organisations such as, UNESCO, have exerted on national heritage organisations to document and archive historically important structures for the future benefit of society (Chalal and Balbo, 2014). Foni, et al., (2010) presented the development of a 4D conceptual taxonomic framework of digital visualisation strategies and choices (see Figure 3.6), enabling a visual insight into the respective benefits, shortcomings and highlighting which technological solutions might best address specific project characteristics.

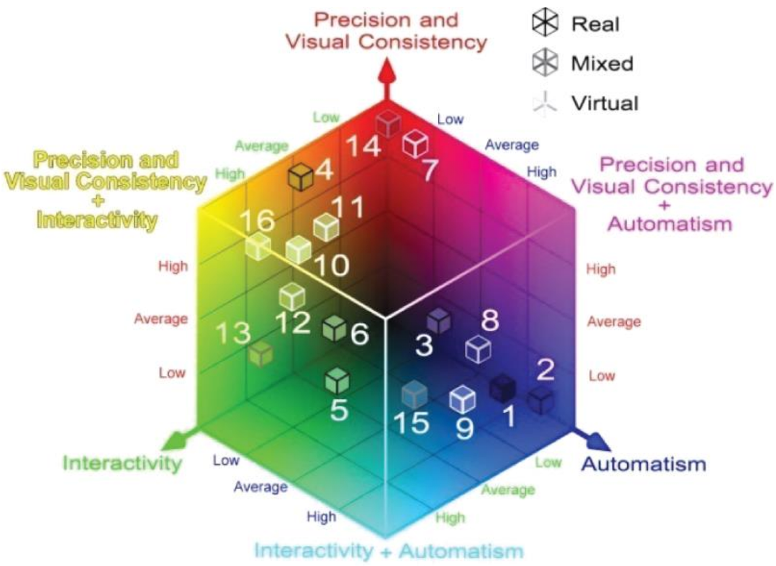


Figure 3.6: 4D conceptual framework Taxonomical space visualised as 3D RGB colour cube with coloured cages: Source; Foni, et al., (2010)

Moreover, work undertaken by the Scottish Government, to digitally document ten iconic historic structures across the world, as part of their Scottish Ten project; a five-year collaborative initiative; delivered by HES in partnership with the Digital Design Studio at Glasgow School of Art and CyArk (a non-profit organisation founded to digitally document the world's cultural heritage); has led to HES embarking on a campaign to digitally capture properties which are both under their care, such as Rosslyn Chapel, Scotland (Figure 3.7) and Edinburgh’s Old Town (Wilson et al., 2013). The aim is to generate more objective and accurate digital data, in order to support current and future safeguarding of Scotland's built heritage (Wilson et al., 2013).

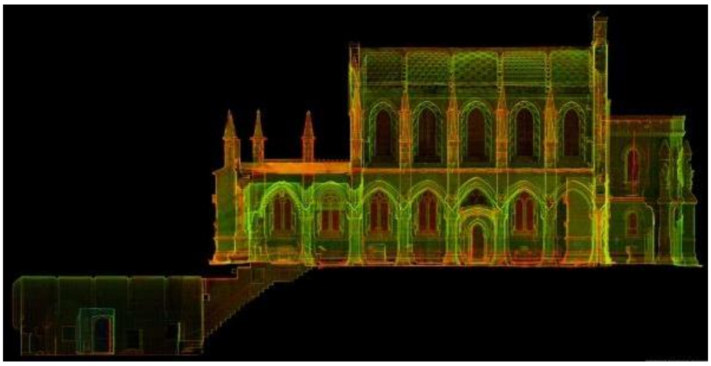


Figure 3.7: 3D Laser Scan of Rosslyn Chapel; Source; Wilson et al., (2013)

3.6 Emerging Historic Building Repair and Maintenance Digitisation Trends

An increasing number of built heritage studies (Al-Omari et al., 2014; Brunetaud et al., 2012; Stefani et al, 2014; Janvier-Badosa et al., 2015; Hallermann and Morgenthal 2015; Hayes et al., 2015; Bosché, Forster and Valero , 2017) have investigated, utilising a varied range of 3D reality data capture, fabrication and documentation technologies, as well as mobile/cloud computing technologies. Hence, they have offered numerous applications relevant to repair and maintenance areas from project management, to project surveying, to building diagnostics, to monitoring and evaluation. In addition, the non-destructive nature of these technologies aligns itself both ethically and principally with building conservation philosophy.

Faced with the dual-modernisation and innovation challenge of addressing current performance shortcomings as well as incorporating the sustainability agenda. A paradigm shift in thinking by the historic building repair and maintenance sector, has been initiated, as it embraces itself to be ready towards a focus on harnessing digital construction technologies and the subsequent converting of digital data into tangible project benefits. Moreover, Digitisation of historic building repair and maintenance practice is absolutely relevant and will be fundamental to Project Management and on-site practice *"process management and improvement"*. Thus, the subsequent sub-sections present a synopsis of the key technologies available and their possible use as tools for historic building repair and maintenance practice digitisation.

3.6.1 Reality Data Capture Technologies

Reality capture in the context of historic building repair and maintenance relates to the ability to acquire accurate information and precise record of the current condition of a historic building (Bosché, Forster and Valero, 2017); a fundamental starting point in a repair and maintenance projects. Thus, as a means for capturing valuable 'as-built' documentation, Reality Data Capture technologies such as 3D laser scanning, as shown in Figure 3.8, infrared thermographic (IRT) cameras, hand-held High Definition Resolution (HDR) Digital cameras (Photogrammetry), unmanned aerial vehicles (UAVs; for drone data) and Historic Building Information Modelling (HBIM), have offered new possibilities for capturing, mapping and analysing historic building information. In turn, Reality data capture can provide numerous benefits to Project Management and on-site practice processes, such as; informing site logistics, enhancing quality control, and progress monitoring. However, identifying which source of reality capture can be a challenge, particularly, given the selection is driven by project schedules and/or cost constraints and different technology can be used depending on the projects scope of works. (Valero et al, 2017).

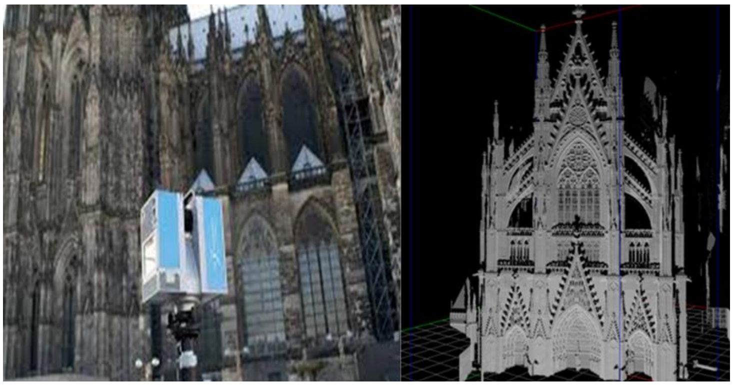


Figure 3.8: 3D Laser Scanning of Cologne Cathedral; Source; Reproduced from Pritchard, et al., (2017)

Thus, an important first step, is to not only have an in-depth understanding of industry practice, but also a good understanding of the capabilities of the technology and its limitations is essential for informing the application of appropriate digital technologies (Forster et al., 2018). Yet, there is no single system or application that can support the execution of all the functions in the historic stonework R&M process, therefore it cannot be assumed that one technology alone will be the panacea in addressing the challenging agenda and the resultant higher-level skill development needs. For example, there is a continuum of complexity when involved in digitisation of the surveying process; at one end, there is simple capturing of building characteristics through employing structured data capture documents to the application of 3D laser scanners and UAVs with infrared cameras to construction of a dimensionally accurate and precise, intelligent 3D model-based documentation process for effective maintenance management (Arayici, 2008) (Figure 3.9). Interestingly, Bosché, Forster and Valero's (2017) similar conclusion; that whilst such tools are invaluable, without the pre-requisite knowledge and expertise, the enhanced data captured will struggle to be exploited effectively and efficiently.

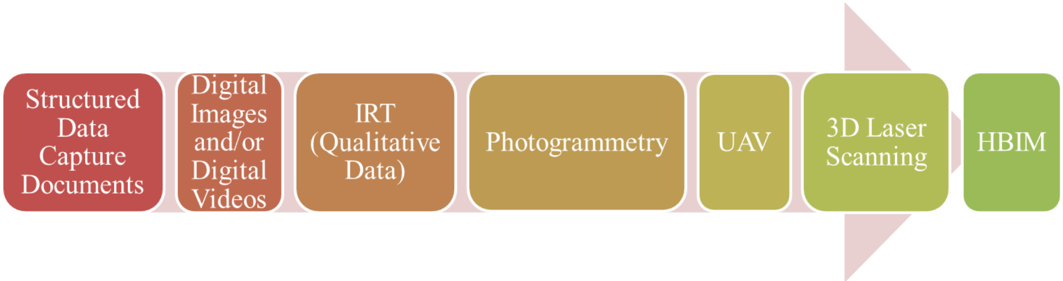


Figure 3.9: Continuum of Complexity for Historic Building Digitisation when involved in the surveying process: Developed by Author

3.6.1.1Photogrammetry

Close-range digital photogrammetry (PG) is a relatively low-cost technique, based on the use of a High Definition Range (HDR) camera; which enables generation of a 3D historic building model, created by capturing the geometry of the building, its facades and elements, and constructed from a set of acquired 2D digital images (Mitka and Pluta, 2016; Swallow et al., 2016; Historic England, 2017). Several parallel studies (Al-Omari et al., 2014; Brunetaud et al., 2012; Stefani et al, 2014 and Janvier-Badosa et al., 2015) using low-cost, simple, easy to use and highly portable PG techniques, such as structure from motion (SfM) techniques have illustrated PG versatility and applicability over a wide range of scales, demonstrating great value as a foundation point for digitally documenting a historic building requiring repair and maintenance attention. These studies have shown employing PG for the realisation of a 3D model combined to the collection of various types of data can provide a low-cost, easily accessible, and mobile "digital health" monitoring and decision support tool for recording and displaying repair interventions on an online portal platform. Indeed, such a "digital health record" could support defining priority actions of R&M by extracting "objective" survey data as opposed to the current "subjective" evaluation of R&M solutions and their relative priority.

For example, Stefani et al, (2014) in their study of stone conservation and monitoring at Chambord Castle (Loir-et-Cher, France) generated a 3D model combined with a mapped structured and systematised heterogeneous data at the architectural scale (defined descriptions concerning materials, degradations, and dating) and established a "digital health record" of the current condition of the building. In order to permit balanced and economical programming of future repair and maintenance works operations. In addition, they harnessed the use of the ICOMOS (2008) classification glossaries and an open source web platform (NUBES web platform) for sharing, communicating, and collaborating (Figure 3.10).

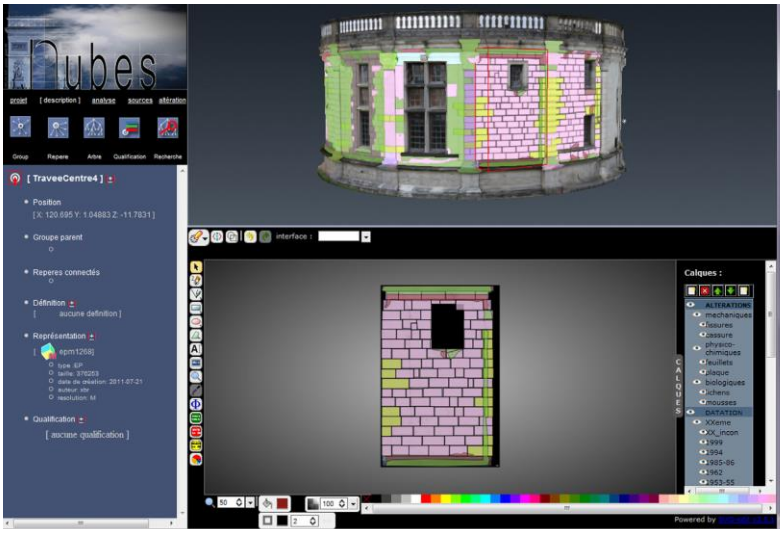


Figure 3.10: NUBES platform interface displaying stone degradation pattern documentation: Source; (Stefani et al, 2014).

3.6.2 Terrestrial Laser Scanning

Terrestrial Laser Scanners (TLS) are digital, remote sensing, metric survey data capture tools that calculate and image spatially relative measurements of a subject's surface (Kottke, 2009). Infra-red Laser light is emitted from the scanning instrument at equal angles which captures millions of data points on any surface detected referred to as "point clouds" in designated x, y, z description, which creates a 3D digital image of the environment, building or elevation scanned (Smits, 2011). In general, the higher the point cloud resolution or the smaller the distance between each point; the more surface information will be captured (Kottke, 2009). To exemplify the considerable value of TLS to historic building repair and maintenance survey, current 3D laser scanning technology can acquire hundreds of millions of points with a single-point accuracy of less than 1mm, in a few minutes (Valero et al, 2017). However, when collecting survey data, the level of detail of data required will inform the type of TLS method to be employed, as each technique provides differing levels of accuracy based on survey requirements (Smits, 2011) (Table 3.2). Furthermore, many factors affect the accuracy, reliability, and repeatability of the 3D scanning process, such as material patina, reflective surfaces, scanner resolution, proper selection of scanned historic building elements, etc. (Kottke, Matero and Hinchman, 2011).

Laser Scanner	**accuracy @ operating range**	**Operating Range**	**Stone Element**
Triangulation	0.05mm-1mm @ 0.1m - 25m	Close-range	Intricate architectural details
Terrestrial Phase Comparison	5mm @ 2-50m Mid-range	Mid-range	Facade surveying
Terrestrial Time of Flight	3-12mm @ 2-100m	Mid to long-range	General surveying

Table 3.2: Terrestrial Laser Scanner Types Source: Adapted from Smits (2011)

An ever-growing database of UK and international studies over the last decade (Arayici, 2007; Barber et al., 2006; Kottke, 2009; Laing and Scott, 2011; Pritchard, et al., 2017; Smits, 2011; Tapponi et al., 2015; Yajing and Cong, 2011; Xi et al., 2015; Bosché, Forster and Valero, 2017), have emphasised that 3D laser scanning can be a fundamental tool in surveying, measuring and monitoring historical building. The consensus indicates that the immediate uses from the captured data output are twofold. Firstly, more rapid and superior level of data accuracy expectancy when capturing measurements in comparison to undertaking manual surveys on site. Secondly, the potential of using such accurate surveys to identify and record the existing structure as part on a long-term digital documentation strategy to provide accurate information on the current condition and layout of the building. For example, when historic stone re-construction (recording, removing and re-positioning stones in the exact previous position) is required, laser scanning will be instrumental for visualising the required scale of maintenance (material and skill requirements) (Yajing and Cong, (2011) and Xi et al., (2015).

What is noticeable here, from these parallel studies is that despite these studies taking place in different locations around the globe, the results show a remarkable degree of correlation whilst providing similar invaluable results. They have all concluded that 3D laser scanning provides the ability for precise, structured, accurate digital data capture, stressing it was particularly relevant for a number of Project Management processes (see Table 3.3). As it provides a single accessible, reliable and objective as-built data comparison tool to help support a number of historic building repair and maintenance processes, such as; building condition monitoring, investigation and assessment, work planning and execution, structural analysis, Quality Assurance (QA) /Quality Control (QC), health and safety, based on generation of current/proposed 2D/3D models (BIM), by offering typical deliverables such as accurate measured surveys, and the production of 2D elevation and plan drawings in AutoCAD. Moreover, they suggested that it could; improve the efficacy and quality of construction projects by verifying that works had been carried out according to specifications; and also enable reverse and rapid prototyping modelling such as reverse engineering intricate historic building elements, for which a previous recorded data may not be available or never existed. Add the ability to use in structural and condition monitoring, thus reinforces the belief that 3D laser scanning can indeed provide new approaches to the practices and processes, both at a management level as well as at on-site operation level, far greater than current traditional practices. Another evident correlation between the studies is that they all employ case study research methodology and are centred on historic stone buildings, suggesting that to truly examine and investigate the possibilities of 3D laser scanning is the need to engage in applied research, whereby “live” projects provide not only a “real” perspective but also provide a scientific lens in which to investigate the technology’s potentialities.

Moreover, given the vast majority of historic building repair and maintenance in Scotland involves stonemasonry, when considering the use of 3D laser scanning for historic stone building repair and maintenance works, the greatest strength of laser scanning appears to be in the recording and representation of not only complex stone buildings and structures, but also the sculptural features and other intricate architectural elements, which make up these unique buildings, both externally and internally. Hence, the uptake of this rapidly developing technology with its non-destructive nature will provide new approaches to the traditional practices of stonemasonry, particularly stone replacement and stone carving. For example, the production of highly accurate 2D section drawings of individual stones from the TLS data will allow the creation of profile templates of the decayed stonework without the need to cut into the façade. Furthermore, 3D Models derived from the scan data will allow comparison of project specifications with as-built data, as part of an objective QA approach involving the development of a method statement and QC for on-site operations as opposed to a subjective quality check, which currently relies on the skill, knowledge, and experience of both the craftsman and the professional (González et al., 2010).

Yet laser scanning is not without its limitations as generating and manipulating point clouds, meshes, and models can be extremely complicated, time consuming, and can be very expensive (Kottke, Matero, and Hinchman, 2011; Scott, Laing & Hogg, 2013). However, recent research has centred on the automatic processing of captured point cloud data, albeit predominantly focused on the wider construction industry (Bosché, et al., 2015). In an attempt to address this, Bosché, Forster, and Valero (2017) in their comparative and evaluative efficacy study of two separate digital data capture processes (3D laser scanning and PG) incorporating five 3D reality capture technologies and tools (two types of (TLS); three PG technologies (a UAV with a solitary fixed camera system; and both a pole-mounted single-camera system as well as a stereo-camera system). Whereby, they digitally captured information on three sections of a 10m-high complex section of Craigmillar Castle, Edinburgh, and its random rubble masonry wall (Figure 3.11).

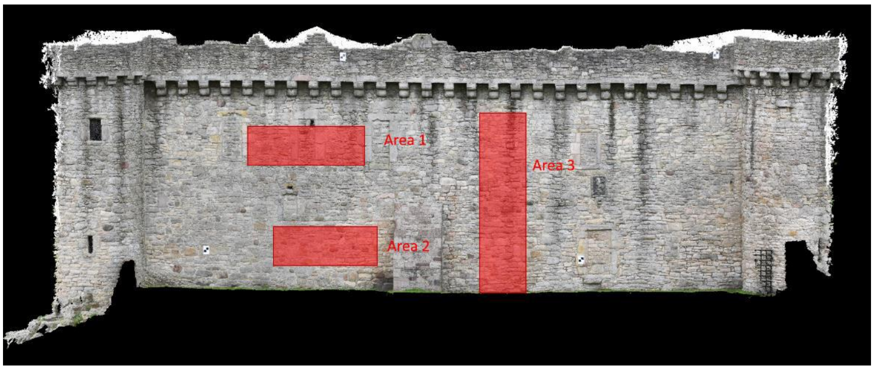


Figure 3.11: The three particular areas within the East rampart wall used for the performance assessment. Source; Bosché, Forster and Valero (2017)

In order to highlight the benefits and shortcomings of two separate digital data capture processes (3D laser scanning and Photogrammetry), the study illustrated the level of complexity of different reality data capture technologies for stone masonry practice and revealed that dependent on the stonework repair technique selected, will have different data capture expectancies and, therefore, contribute to different levels of accuracy acquisition. Thus, an interesting output from the Bosché, Forster, and Valero (2017) study, with regards historic building masonry R&M surveying, was the development of novel algorithms to automatically, extract information from the acquired survey data, to help support more complete, objective and efficient surveys, by labelling of individual stones, identifying and quantifying recessed mortar joints that require re-pointing, and ascertaining the volume of pinning stones to be rebuilt into the masonry (Forster et al., 2018) (Figure 3.12).

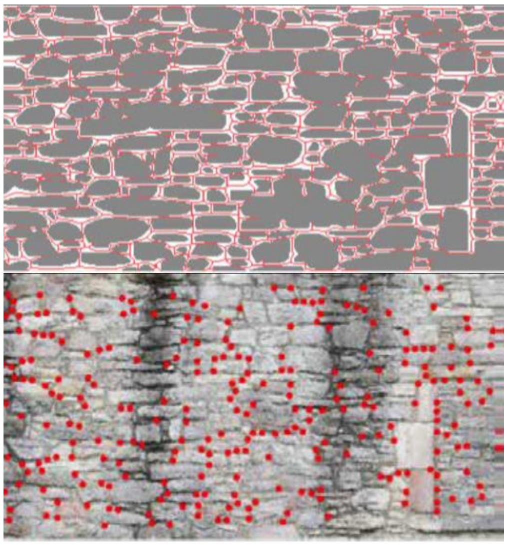


Figure 3.12: Identification and quantification of recessed mortar joints that require re-pointing and ascertaining the volume of pinning stones to be rebuilt into the masonry: Source; (Forster et al., 2018).

Despite, the undoubted value and benefits presented by laser scanning, the demographic make-up of the sector allied to the initial high costs of purchasing a 3D laser scanner and the need for automatic processing of captured point cloud data, presents a number of uptake challenges to the wholesale application of this type of digital technology; from project costs to workforce skills development to the need for changes in current processes and practices. Nonetheless, with today's increasing pace in technological change, the use of 3D laser scanners are becoming increasingly more affordable and user-friendly, this in turn will make 3D modelling faster, easier, and widely accessible (Sabrina and Wärmländer, 2013).

Indeed, exploring the possibilities of employing other disruptive technologies such as mobile technology has already begun, for example, combining a cheap line laser and a smart-phone into a fully portable 3D laser-scanning device (Kolev et al., 2014). Furthermore, the conceptual premise that employing ubiquitous computing tools (mobile technology and cloud computing), can provide the ability to capture relevant on-site activity and allow users to be aware of where more data capture needed during the survey process, is a valid proposition. As such Schops et al., (2015) presented a scalable interactive ubiquitous computing system for capturing and creating a complex 3D model of Aachen Townhall, Germany utilising a mobile device (Google Project Tango Tablet). Which allowed capturing the building and its environment "*on the go"* by simply walking around and digitally capturing the environment (Figure 3.13).

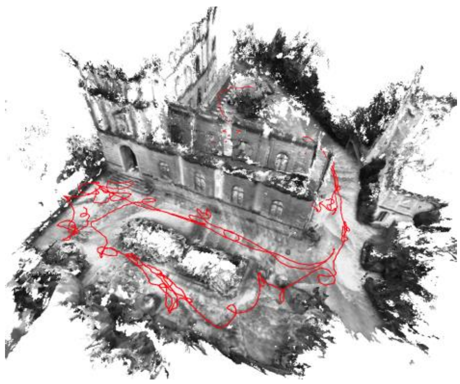


Figure 3.13: A reconstructed model of Aachen Town hall captured on a Google Project Tango Tablet, with the camera trajectory shown in red.

Although, Schops et al., (2015) study is part of a wider Google research project, the selection of a historic stone building as case study further advocates the use of 3D laser scanning technology for accurately capturing digital data to inform practice. It could provide both professionals and contractors with the ability to not only capture migratory data but also the ability for precise, structured, accurate digital data capture to be stored and disseminated successfully across the entire project team (from client to contractor to professional). Yet, what is more significant, is that over the past decade, whilst 3D laser scanning provides benefits in isolation, when incorporating 3D laser scanning technology as part of a development and adoption of BIM-based workflow processes and technologies, the data captured can be extrapolated and used for a number of processes, and vice versa.

3.6.3 Historic Building Information Modelling

With BIM defined by international standards as *"shared digital representation of physical and functional characteristics of any built object, which forms a reliable basis for decisions"* (Volk et al., 2014), BIM technology allows the constructing of an accurate digitally represented virtual building, provides the project team, efficacy improvements to the management and administration processes during the design and construction project phases, such as enhanced project communication and collaboration (Eastman et al., 2011). Therefore, in considering the use of BIM for historic buildings, given the lack of appropriate construction documentation for many historic buildings, with its ability to provide automated and fast data capture as well as intelligent modelling and documentation for effective maintenance management (Arayici, 2008). Researchers Murphy, McGovern and Pavia (2013) from the Dublin Institute of Technology, identified a new system for creating fully dimensioned drawings (2D along with 3D models) from the digitally captured data and proposed the term Historic Building Information Modelling (HBIM) to describe their new methodology of modelling historic structures (Figure 3.24) (Figure 3.14).

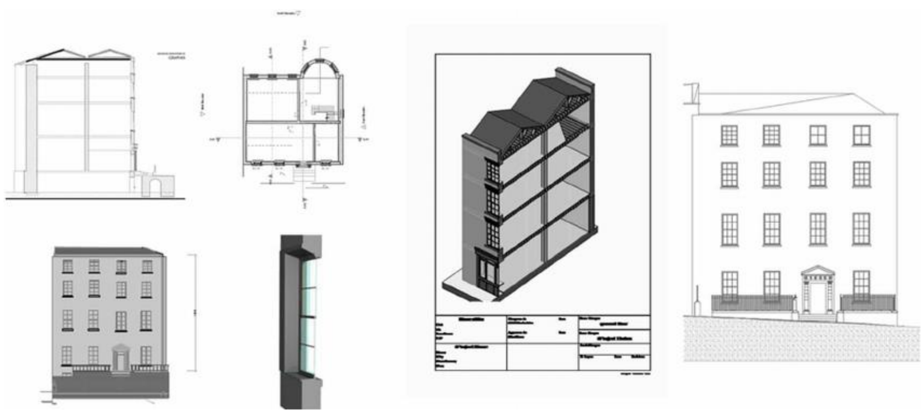


Figure 3.14: HBIM including automated documentation; Source, Murphy et al., (2013).

Similarly, a number of case studies worldwide have now adopted the term HBIM (Jordan-Palomar et al. 2018; Megahed, 2015; Quattrini et al., 2015; Wua et al., 2015; Baik et al., 2014; Oreni, 2014). Although, each study adopts a particular perspective for developing a HBIM, in practice these perspectives do not necessarily deviate significantly across the various conceptual and case studies research. HBIM allows a consequent gain of knowledge for all involved in the decision-making process, hence the concept is certainly applicable for historic building repair and maintenance (Murphy, McGovern and Pavia 2013; Logothetis et al., 2015). With its ability to; incorporate full engineering drawings and schedules (programme, cost, inspection, etc); add intelligence to point cloud data (construction methods and material makeup); provide relational database of spatial and non-spatial data such as, geo-referenced architectural elements and their inherent characteristics (material type, decay issues and cause, possible repair solutions, etc.); and to developing the HBIM model to simulate structural and energy behaviour for virtual analysis (Dore & Murphy, 2017; López et al., 2018). Arguably, the need for adopting a HBIM methodology in historic building repair and maintenance, is even greater; given not only the provision of a rich variety of information, but allied to accurate and precise documentation, being one of the central tenets of historic building conservation could be particularly useful during the design and construction processes (Dore and Murphy, 2017). However, this technology also brings some new challenges regarding the long-term preservation of digital data, for example, the processing, visualisation and storage of the information obtained from these various forms of digital reality capture technologies produce huge data sets (Logothetis, Delinasiou, and Stylianidis 2015), whilst the technology used (hardware and software) for creating, editing or viewing some files might become obsolete (Lourenço, Peña and Amado, 2010)., although an in depth discussion of this challenge is outside the scope of the research.

3.6.4 Infrared Thermography

Over the last decade, infrared thermography (IRT) tools have been used extensively for remote, rapid, and accurate imaging of historic masonry structures (Kylili et al., 2014). They can quickly provide relevant information, not only on the integrity and ageing of the structure but also on the condition of the building's material (Lim and Cao, 2013). With the advent of newer generations of infrared camera, IRT is increasingly becoming a more accurate, reliable, and cost-effective tool for historic buildings diagnostics, as investigations can be carried out without the need for sampling (Kylili et al., 2014). Numerous researchers (Paoletti et al., 2013; Bisenga et al., 2014) have advocated the use of IRT for historic building masonry repair and maintenance, citing that it offers several distinct, yet interrelated advantages. These advantages cover; evaluating the performance of various historic masonry interventions, as well as providing an effective monitoring tool for preventive diagnostics of historic masonry buildings (crack configurations, structural failures, and state of decay, residual moisture and humidity problems), which may not be evident from visual examination. Paoletti et al., (2013) and Bisenga et al., (2014) provide significant examples of IRT's capability, in their longitudinal studies of the well-known seismic area of Abruzzo, Italy, embarking on a series of thermographic surveys of historical buildings and monuments during 2003 and 2008. Then, in April 2009, the area was devastated by a major earthquake, resulting with most of the structures seriously damaged, leading to a series of post-earthquake IRT surveys (2009–2010). The subsequent comparative analysis of the before and after images, showed that the earthquake damages correlated to thermal imprints previously detected (Figure 3.15).

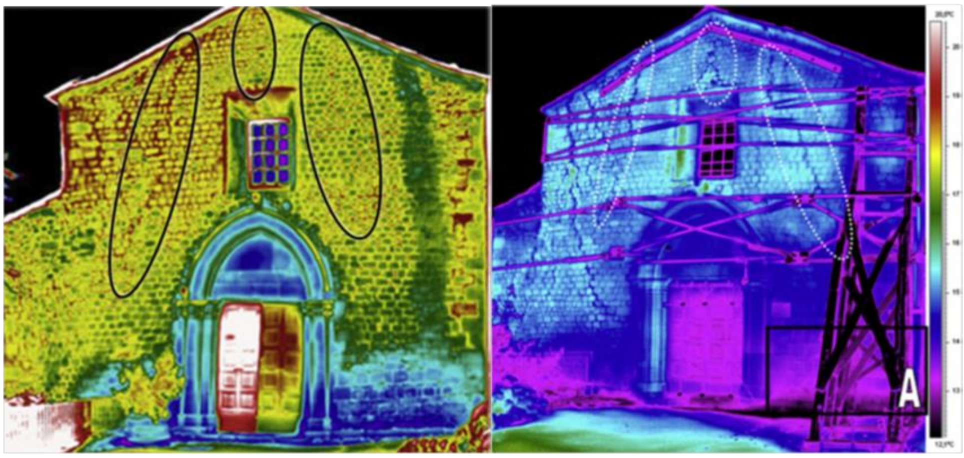


Figure 3.15: Before and after images showing damages pre and post-earthquake (Paoletti et al., 2013)

Nonetheless, despite these studies, undoubtedly demonstrating the effectiveness of IRT as a preventive diagnostic tool and given the increasing focus on historic buildings and the need to ensure they are energy efficient and thermally comfortable after repair interventions (Martínez-Molina et al., 2016). All the aforementioned studies stressed that the evaluation and mapping procedure of IRT data, relies heavily on the accurate assessment of thermal parameters, and a clear understanding of historic building construction technology and materials, in particular stone and mortar. Hence, on closer inspection, apart from Paoletti et al., (2013), who used a Qualitative (visually detected anomalies) method, all the studies analysed the thermal camera records of the selected case study buildings by employing Quantitative (numerically detected anomalies) methods: quantitative measurements produce more precise results as to the level of severity of the abnormality, as opposed to Qualitative IRT which can identify an anomaly, but it does not provide levels of severity (Kirimtat and Krejcar, 2018). Moreover, the integration of IRT with other techniques dramatically enhances the value of the investigation's results in the survey process, for example, the possibility of using TLS data and IRT images to provide a more accurate data set for monitoring residual damage is an area which is attracting attention (see Costanzo, et al., 2014; Kordatos et al. 2013, Maierhofer, 2011).

With thermal scanning of a structure, allowing data collection surrounding an elements technical properties, such as form, condition, and composition (Kylili et al., 2014); all fundamental elements of stone replacement practice, considering the qualitative method for detecting potential issues with historic buildings during the survey process, could be a very useful performance evaluation technique, particularly, as IRT's accessibility and capabilities continues to increase, both at a low level and high-level scale. For example, several studies (Spodek & Rosina, 2009; Kordatos et al. 2013; Moropoulou et al., 2013; highlight IRT is very useful in the evaluation of the performance of various historic masonry interventions, especially given the incompatibility issues of cement and stone (see Forster and Carter, 2011; Forster et al., 2014; Lott, 2013; Torney et al, 2012). Thus, realising the advantages of taking cost-effective and time-efficient precautions by qualitative methods, will present itself as an important tool in not only the condition monitoring of pre-1919 historic buildings but also within the survey process of stonework. For example, by employing an IRT survey, then subsequently exploiting the recorded images at the pre-planning stage of a project, may provide a more objective approach to masonry repair specification and application and facilitate a move away from the inherent subjectivity of stonework R&M, particularly, as such movements have the possibility to improve the specification of stone replacement, as it is far more likely to observe poor quality surrounding standards of workmanship and knowledge of masonry practices (Hyslop, 2004 and Torney et al, 2012).

3.6.4 Unmanned Aerial Vehicles (UAVs)

Several early systematic reviews on construction automation across the wider construction industry (Lu et al., 2011; Kim et al., 2015; Sun et al., 2013; Vähä et al., 2013;

Valero, et al., 2014), have provided a useful introductory step into the world of Unmanned Aerial Vehicles (UAVs), otherwise known as drones. Typically, UAVs are fitted with "image-based modelling" (either HDR digital camera/video device), to allow this precise data acquisition to occur (Colomina and Molina 2014). However, as outlined in previous sections, adopting an integrated data capture strategy can maximise the application of UAVs. For example, combining an UAV fitted with a HDR digital camera/video and IRT, combined with PG/3D modelling, would allow the obtaining of information about the geometry parameters and the deformations of the structure allied to 3D thermal profiling which allows a generated 3D model to be overlaid with the thermal data (Hallermann and Morgenthal, 2015).

Suggesting great potential, for the automation of Project Management data acquisition needs (surveying processes, material inventory management, and risk and safety analysis etc.) to actual construction practice application (progress monitoring, and quality assurance/ control) (Chabot, 2018), however, a lack of academic narrative exists on the use of UAVs in the historic building repair and maintenance field. Yet, despite this deficiency several studies (Colomina and Molina 2014; Eschmann et al., 2012; Hallermann and Morgenthal, 2015; Pajares, 2015) have highlighted that employing UAVs as an alternative survey and monitoring tool, can gain most traction, with their ability to remotely survey, inspect, monitor and capture high quality data; particularly being able to detect various masonry issues such as structural cracking and stone decay in hard-to-reach or inaccessible areas (Ellenberg, et al., 2014) (Figure 3.16). Furthermore, UAVs provide a number of benefits in comparison to traditional methods, such as reductions in logistical complexity, and reduction in costs of ensuring adherence to health and safety (Hallermann and Morgenthal, 2015).

Figure 3.16: 1200-year-old Masonry cathedral with Roof and façade inspections results: Source; Hallermann and Morgenthal (2015)

3.6.6 Ubiquitous Computing

Over the last decade, as ubiquitous construction mobile computing use (smart phones, mobile applications, and cloud computing and context-aware technology) is on an upward momentum towards critical mass; a plethora of studies have validated the consensus regarding the positive effects of utilising such mobile tools in construction projects for CPM and on-site practice (Azhar et al., 2015). Unsurprising as, they are capable of providing significant influence on project progress, quality, site logistics and co-ordination, material resource procurement, workforce management, which in turn can increase workforce productivity (Lu et al., 2014). With the ability to access "real-time" information, through digital document management platforms enables all project participants to access information "anytime, anywhere" using mobile devices, and in some cases access, view, manage, distribute, and collaborate in "real time" (Oesterreich and Teuteberg, 2016). The consensus within the literature perceive ubiquitous computing tools as part of a whole concept, for digital CPM, in the aim to create a "single source of truth" for the project team (Oesterreich and Teuteberg, 2016).

Whilst, there is a distinct lack of studies focusing on the use of ubiquitous computing within this field, the use and the benefits of these types of disruptive technologies, can be considered extremely suitable for the historic building repair and maintenance projects, given the highly fragmented Project Management structure (both horizontally and vertically). Hence, the ability to capture, communicate and collaborate within a unified platform digitally, represents a significant opportunity to create improved on-site and off-site management of complex historic building R&M processes, such as planning (logistics, site establishment etc.), R&M works (risk management, health and safety, progress monitoring, and quality control).

For example, Shaughnessy (2015) in her comparative analysis study of traditional system(s) and ubiquitous construction mobile computing being employed when documenting historic building restoration projects, specifically on-site stonemasonry unit data recording. The study examined six different case study projects across USA and Canada, which employed various ubiquitous computing technologies such as digital images, information databases, sensors (QR codes, bar codes), mobile Apps, and cloud computing. The study argued that the ability to harness such tools could enhance the documenting and monitoring of a historic building R&M project, throughout the project lifecycle, from survey to project closeout, through digital collaboration. However, on closer inspection, whilst providing some legitimacy, the study provided a number of anomalies in its conclusions; from a distinct lack of explanation of a recognised research methodology; to a lack of hard quantifiable evidence; the study did not provide a systematic comparative evaluation and analysis across the six case studies observed; in terms of potential benefits and challenges of each digital recording method, along with their individual advantages and disadvantages; to a lack of a definitive framework for guiding such processes as it read more like a promotional brochure, in places. resulting in a possible lack of the academic rigour, reliability and validity required for consideration as a valuable contribution to the debate on historic building R&M digitisation.

Nonetheless, the study does provide a possible valuable contribution to the debate on historic building R&M digitisation; in that, fundamentally, in terms of technological implementation, better to adopt incremental changes in practice rather than wholesale to allow an organic uptake of digital tools; in essence, keep things simple. Hence, it is safe to assume the implementation of cost-effective Project Management mobile application strategies by MSME and SMES could be a viable and scalable option (Clancy et al., 2012), and points towards creating a holistic, integrated, structured and unified approach to Project Management and onsite practice, through a dedicated platform as a network and repository for communication, collaboration, and project information distribution. Thus, providing a significant move towards the multi-disciplinary approach espoused on numerous occasions, by the literature.

3.7 Digitised Historic Building Repair and Maintenance Processes

Hence, with several studies having offered numerous applications relevant to repair and maintenance Project Management and onsite practice, utilising a varied range of 3D reality data capture fabrication and documentation technologies as well as mobile/cloud computing technologies for historic stone building R&M processes, can provide numerous enhancements to current process applications, from; new digital workflow methodology approaches to historic stonework R&M data capture (Ouimet, 2015; Shaughnessy, 2015; Bednarik et al., 2012; Sun, 2012); to quantifying and monitoring stone surface deterioration and material quantities surveying (Bosché, Forster and Valero, 2017; Ercoli, 2013; Kottke, 2009); to the integration of 3D reality data capture technologies, as vital tools for historic stone reconstruction purposes (Xi et al., 2015; Yajing and Cong, 2011); to the integration of 3D reality data capture technologies, mobile computing and web-based platforms to support and facilitate the production of a digital health record toolkit for historic masonry buildings, allowing the mapping and displaying of stone alterations and decay issues (Brunetaud et al., 2012; Oses et al., 2014; Stefani et al, 2014; Janvier-Badosa et al., 2015). Whilst, several studies by Ouimet et al. (2015) and Hayes et al. (2014) surrounding the restoration of Ontario's Parliament Hill buildings, explored the potential uses for 3D data, in terms of the development of a digitally assisted stone carving survey, manufacture and repair process, producing outputs such as; 3D digital model, 3D printed scale models, CNC carved maquettes, robotic stone carving and digitally designed replacement elements, resulting in the development of a digitally assisted stone carving process. Furthermore,

There are undoubtedly great benefits, in terms of enhancing process efficiency and performance. Yet, the re-occurring theme emerging across the majority of studies reviewed re-enforces the perspective that when employing digital data capture technologies, there is no single tool or methodology, which can support the execution of all the functions in the historic stonework R&M process. There is a need to identify the most appropriate technological mix to address the specific project challenges as illustrated Table, 3.2. Therefore, consideration and investment towards adopting an integrated approach is a pre-requisite to ensure capturing all relevant data and support a move towards a more coherent and comprehensive approach to varying degrees of historic building R&M project complexity.

Process improvement issue/ Onsite Causes of poor efficiency	**Relevant Digital Construction Technologies**	**Potential Application within a construction project lifecycle**	**Digital Construction tool**
Poor planning, control and supervision (Non-compliance with procedures, Human/ Judgement error etc.)	Reality Capture Visualisation (AR/VR) ICT Mobile Cloud Computing	Pre-project phase Planning phase Execution phase Fully engineered drawings	3D Laser scanner HBIM model Mobiles (smartphones/tablets) AR/VR readers
Poor data capture (surveying, logistics, dimensioning, QA/QC etc.)	Reality Capture IRT Visualisation (AR/VR) ICT Mobile Cloud Computing Sensing Photogrammetry Robotics	Data management and data transfer Procurement Scheduling Condition assessment and monitoring Quality control Building inspection Defect detection Surveying 3D reconstruction Fully engineered drawings	3D Laser scanner HBIM model IRT camera UAV Digital camera/video Mobiles (smartphones/tablets)
Poor logistics (Site congestion, material needs etc.)	Reality Capture Visualisation (AR/VR) ICT Mobile Cloud Computing Sensing Photogrammetry Additive manufacturing	Procurement Scheduling Calculating quantities and site representation 3D reconstruction Additive	3D Laser scanner HBIM model Digital camera/video 3D printer Mobiles (smartphones/tablets) AR/VR readers
Poor communication	Reality Capture Visualisation (AR/VR) ICT Mobile	Communication support and information consistency checking	3D Laser scanner HBIM model Digital camera/video AR/VR readers Mobiles (smartphones/tablets)
Health and Safety (access etc.)	Reality Capture Visualisation (AR/VR) Sensing	Communication support and information consistency checking Risk assessments/Method statements illustration	3D Laser scanner HBIM model Wearable Sensors UAV AR/VR readers Mobiles (smartphones/tablets)
On-site practice; Lack of knowledge and expertise	Reality Capture Visualisation (AR/VR) Additive manufacturing	On-site practice; Work methods illustration Off- site manufacturing of bespoke components	3D Laser scanner HBIM model AR/VR readers Mobiles (smartphones/tablets) Robotics

Table 3.3: Application of different combinations of technologies

Source: Table developed by the author based on Key Project Specific Challenges (Shenhar and Dvir, 2007)

With the application of new digital technologies (e.g. innovative 3D laser scanning surveying technology) and innovative PM practice (IPD), resulting in the need for investment in a structured effective data capture system, and a modernised workforce will help MSMEs and SMEs to rapidly, target emerging opportunities. Yet, there has been relatively little research into developing a process map, model or a management guide for historic building repair and maintenance digitisation, apart from a small number of studies investigating the development of a HBIM framework (Council on Training in Architectural Conservation (COTAC), 2016; Jordan-Palomar et al. 2018; Megahed, 2015). The following section provides discussion of the viability and suitability of developing a holistic, integrated, structured and unified CPMF (process model, map and tool) for sector projects, which informs digital technology application, and multi-disciplinary working. Such a tool would help support MSMEs and SMEs operating within the sector, as they will need to closely monitor and respond to the adaptive nature of repair and maintenance design solutions and invest in effective site practices and management options that reduce the reliance on siloed and individualistic procedures, to safeguard the timely and profitable delivery of projects.

3.8 Digitised Historic Building Construction Process Management Framework

Several studies (COTAC, 2016; Jordan-Palomar et al. 2018; Megahed, 2015) have attempted to address the concern of employing HBIM and the need to have a relevant process framework. All three studies and their developed frameworks, founded on the premise of encompassing and embedding people, technology, process, and policy, have attempted to bridge the knowledge gap in HBIM implementation. Their aim was to produce a fully relevant balanced approach to the overall introduction of digital documentation, HBIM, and simultaneously provide the ability to articulate issues regarding informational, technical, and organisational issues of HBIM.

Megahed (2015) developed a theoretical framework, as illustrated in Figure 3.16, as a methodology towards understanding the various processes of architectural conservation management through a smart open platform. Whilst the COTAC (2016) developed HBIM framework, overlaps the current wider construction industry frameworks; producing a fully relevant balanced approach to the overall introduction of digital documentation, HBIM, and simultaneously provide a cyclical arrangement framework with a series of overlapping ‘use-themed’ spirals, with the ability to insert a variety of related conservation issues, illustrated in Figure 3.17.

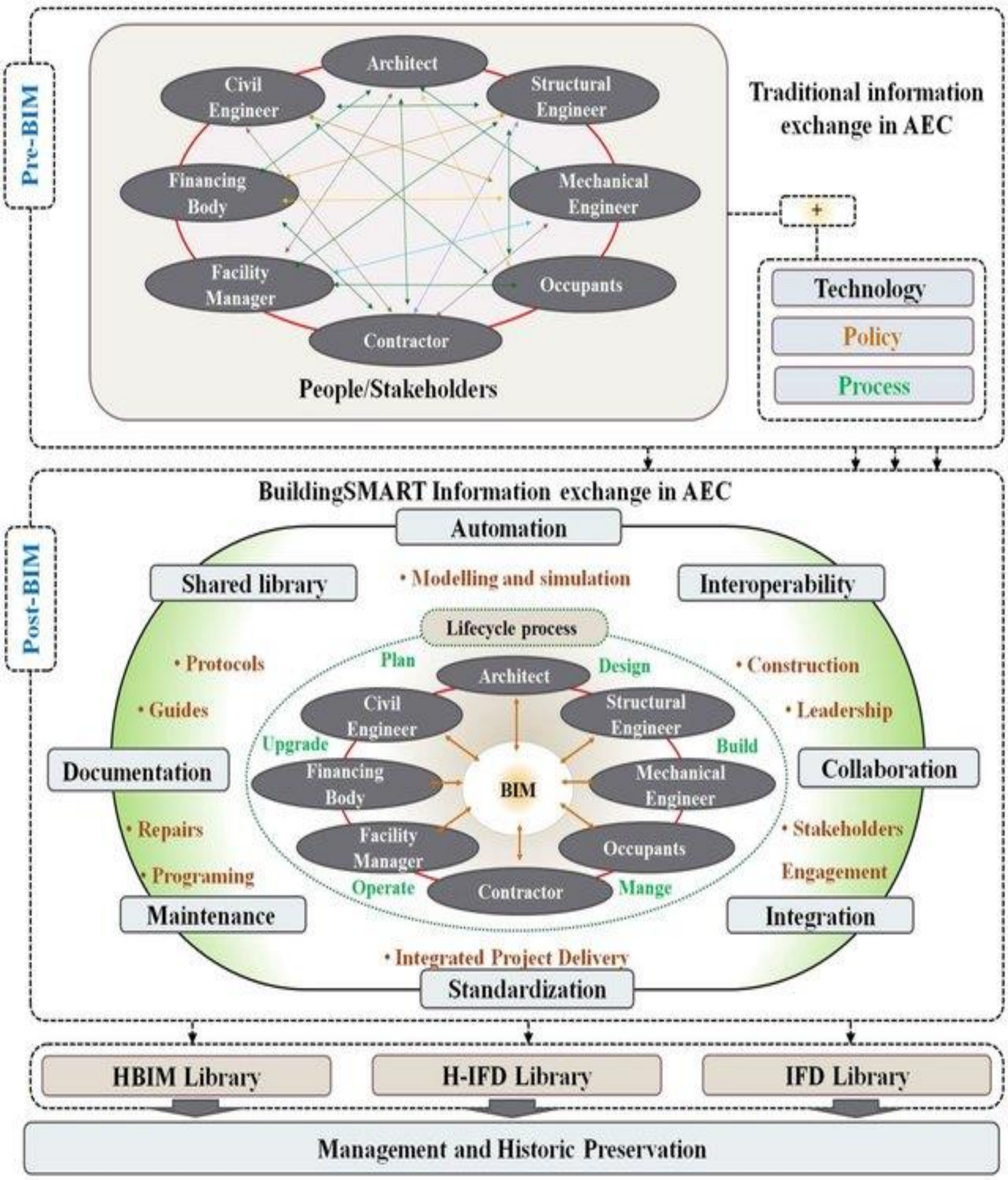


Figure 3.16: Theoretical Framework Visualisation: Source (Meghan, 2015)

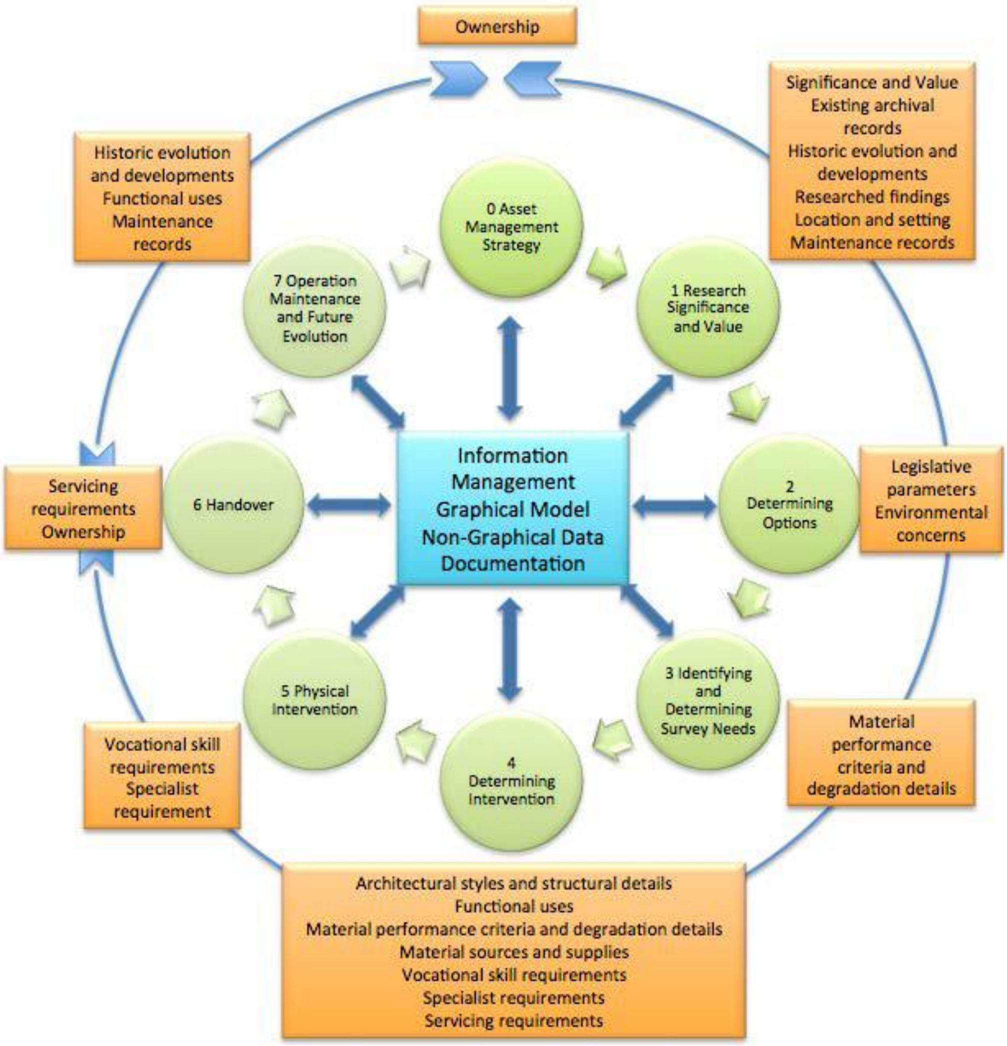


Figure 3.19: HBIM Framework (COTAC, 2016)

Whereas Jordan-Palomar et al. (2018) harnessing COTAC's (2016) HBIM framework, as a principal guiding element, reported they had developed a straightforward and accessible HBIM protocol. Naming it the *"BIM Legacy"* framework (Figure 3.18) and lauded their framework as original in terms of incorporation of a level of detail (LoD) definition for HBIM, which they remarked other protocols in the field had not addressed. Although there are serious weaknesses with Palomar et al.'s (2018) argument, as UK organisations such as HE and HES had remarked all prominent heritage organisations had been major influencers in the development of the COTAC (2016) framework., and also in providing established and recognised BIM metrics, such as; LoD, level of modelling definition (LoMD), level of information (LoI) and measurement classification (loIA) in HBIM (Antonopoulou and Bryan, 2017; Brookes, 2017).

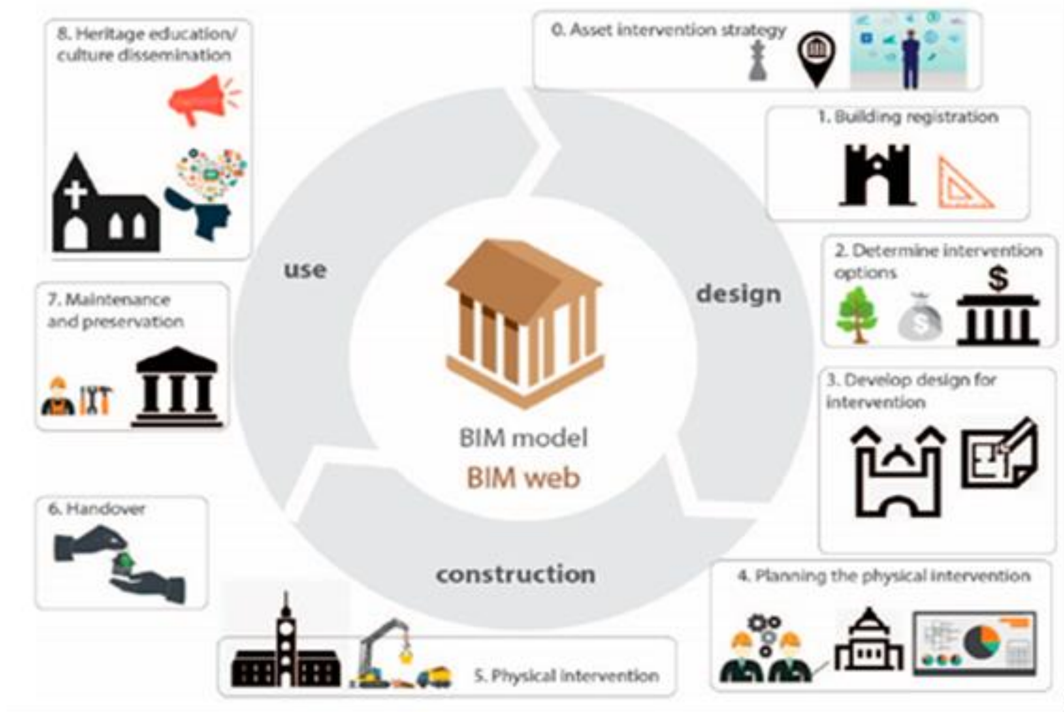


Figure 3.20: BIMlegacy Framework (Jordan-Palomar et al., 2018)

Whilst these HBIM frameworks are without a doubt a step forward in the right direction with regards the need for a relevant framework, they appear to mirror the wider construction industry's focus on BIM, rather than the concept of a holistic, integrated, structured and unified CPMF (process model, map and tool) for sector projects, which informs digital technology application, and multi-disciplinary working. Moreover, in terms of validity and applicability of the historic building R&M sector adopting a more industry relevant framework, that promotes not only a multi-disciplinary approach but also provides a defined delivery structure, which accurately reflects R&M practice for optimised project delivery. Hence, several limitations to these conceptual studies need acknowledged.

What is noticeable is that, all these studies concentrate within the high-level architectural conservation field (historic buildings with not only architectural significance but also cultural significance), focused solely on 3D laser scanning and its associated processes and methods for 3D model representation (data collection; data processing; and data fusion). This has resulted in the frameworks being directed towards Architects, researchers, built heritage organisations such as HES and HE, rather than MSME and SME practitioners. For example, Megahed (2015) concluded his framework would contribute to and highlight a shift in the future of architecture and its thinking; whilst, in COTAC's (2016) HBIM framework, the definition and naming of the work stages, does not reflect the terminology and work processes that are undertaken by the majority of historic building R&M MSME and SMEs, for example, describing the project appraisal stage in unfamiliar terms such as the identification, research, and options stage; whereas, congruently, Jordan-Palomar et al. (2018) echoed these perspectives, as they describe the project start up as the asset intervention strategy. Consequentially, this lack of correlation with the historic building repair and maintenance sector and its specialist MSME and SMEs, presents the potential of HBIM as a methodology to accomplish greater communication and collaboration, which is still far from transpiring in professional and contractor practice.

Yet, despite, the limitations within each of the three studies, they have provided useful direction towards the assumption; that a relevant framework to inform for historic building repair and maintenance digitisation, would help practitioners and researchers in the field, and also support establishing, to a greater degree, the importance that industry have a voice given the emergence of technological transformation. For example, Jordan-Palomar et al. (2018) concluded that an area for future research was that 3D models for repair and maintenance, should be as simplified as possible and only contain pertinent project data related to repair and maintenance work activities. More significantly, they suggested that given historic building repair and maintenance interventions are typically on small-scale projects, managed by specialist MSMEs and SMEs, there was a need to comprehend how to realise such frameworks in such small organisations.

Moreover, there is validity that adopting a holistic, structured and integrated based collaboration approach is essential to harness collaborative decision making for successful Project Management and on-site practice. For example, Megahed's (2015) study is the first to report by employing a model-based approach to collaboration between people, process, and practice, the potential of harnessing the concept of IPD, in order to support historic building protection and management. Yet, it is equally clear that; considering there is a knowledge and awareness deficiency concerning adopting IPD and its related benefits and challenges, suggests that for effective and efficient management of projects, they require managed with the application of a common structured collaborative process-standard framework to enable an integrated approach to the historic building repair and maintenance process. Moreover, SMEs need to not only look for new management paradigms that lead to real improvement but also not be aware of the benefits and advantages of such contemporary Project Management methodologies (Loforte and Fernandes, 2010).

3.9 The Need for the Development of a Common Structured Collaborative Industry Process-Standard Framework

In terms of highly capable Project Management and on-site practice for fostering performance improvement, much of the work and application of a process model, map, and a management tool that incorporates modern management practice, is focused on new projects within the construction sector (Mahdjoubi et al., 2013). Hence, there is a paucity of relevant frameworks for the historic building SME sector, to operate more effectively, more productively, provide value for money and to address not only the fragmented and adversarial nature of the industry but also reduce construction time, cost and increase quality. Yet, by drawing on the concept of Construction Process Management Frameworks (CPMF), several studies (Andújar-Montoya et al., 2015; Ansell et al., 2009) have indicated that customised sector specific CPMFs can positively influence project delivery. For example, Ansell et al., (2009) applied a customised CPMF in a highways maintenance project, in an attempt to optimise efforts and focus on the beneficial outputs of a holistic, structured and collective workflow approach, finding it allowed a more collaborative working environment, offering better informed decisions surrounding project change adoption, and identifying the number of specialist contractors needed during the project.

For the historic building repair and maintenance sector and its specialist organisations, the current Project Management frameworks, may include repair and maintenance as part of their agenda, however, they are not explicit and only infer that they can be adapted for the sector. Indeed, the current CPMF frameworks are in effect, not adaptable, flexible, and customisable to historic building repair and maintenance, whilst lack a reflection of sector practice is reciprocated within the previously discussed HBIM frameworks. Thus, the generation of a Construction Process Management Framework tailored towards historic building repair and maintenance MSME and SMEs is not only essential for shaping and informing practice but also future skills development needs. Furthermore, it would be reasonable to assume, given projects being inherently bespoke, unique and complex nature, serviced by a highly fragmented sector, comprised of a predominance of specialist MSMEs and SMEs, in the majority, they will have yet to embrace the application of digital technologies, never mind innovative approaches to project delivery such as IPD. Historic building repair and maintenance MSME and SMEs are not just in the embryonic stage regarding digital technology adoption, they are in danger of being marginalised as specialist businesses, that are unable (or unwilling) to engage with digitisation. By association, this infers that without the resources or capacity to embrace in the application of innovative approaches to project delivery such as IPD, never mind invest in digital technologies, would create not only a "digitally disenfranchised" sector, but also reduce opportunities to adopt contemporary management practice.

Hence, for those SMEs who are at the "coal face" and in need of support, the key challenge is to develop a SME tailored structured process-standard framework, in order to; enhance project delivery and performance as well as support work prioritisation; monitoring progress; specification; scheduling; programming; quality assurance; enhance workers' health and well-being; and to adapt to a constantly evolving wider technology-dependent environment, in a similar vein to the wider industry (see Dainty et al., 2017; Ghaffarianhoseini et al., 2016). Therefore, a simple yet appropriate and systematic methodology is needed, which is tailored to the specialist MSME and SMEs practice (Project management and onsite), designed to offer a process model, map and a management tool that supports an integrated working approach, which helps inform the use of digital technology. Furthermore, the development of such a structured and holistic approach would not only help support MSME and SME-led initiatives to manage change throughout project delivery, but also raise the awareness and highlighting the ROI and CBA potentials; of the efficient and effective use of available emerging technologies and innovative processes to help support the elimination of laborious, and inefficient construction processes. Especially as, when investing in contemporary management practice, new processes and digital technology, SMEs are inclined not to adopt such tools, that requires too much investment as they view this as too much risk (Sexton and Aouad, 2006).

3.7 Chapter Summary

This chapter examined the literature to provide an introductory overview of a construction process and CPMFs, centred on evaluating two relevant CPMFs (CIOB, 2014; RIBA, 2013), as well as a synopsis of currently developed theoretical HBIM frameworks, given that these frameworks share many similarities; in an attempt to identify the need for a specific framework, which is more suited and effective to the historic building repair and maintenance process and SMEs. Thus, the chapter provided a discussion and critique of these frameworks, in terms of validity and applicability, revealing that, the current CPMF's available, have several deficiencies (e.g. relevancy, definition, terminology, etc.). Whilst the available HBIM CPMFs suitability is directed towards architectural and building conservation practice within culturally important historic buildings and have a specific focus on BIM, rather than the concept of historic building repair and maintenance digitisation. Nonetheless, as a strategy for historic building "*process management and improvement"*, an integrated SME process standard CPMF remains a crucial component in the attempt to improve the overall Project Management process and project performance. Yet, the lack of research into "*process management and improvement"*, hinders effective and efficient SME management of historic building repair and maintenance projects, emphasising the primary focus of sector "*process management and improvement "* should be on the need to enable a structured approach to the historic building repair and maintenance process and form the basis for continuous improvement.

In addition, the chapter examined wider construction industry studies relating to IPD's, as it was identified that there was a lack of research on the application of IPD, never mind within historic building repair and maintenance projects, but across the wider R&M industry. Despite the extensive review identifying a lack of research on the historic building repair and maintenance and IPD, it was found its suitability to historic building repair and maintenance projects, is undoubtedly applicable, particularly given the inherent need for a multidisciplinary approach. For example, the principles of IPD can provide project stakeholders with the ability to effectively implement collaborative working practices and provide transparency and communication benefits.

The chapter also explored, the area of historic building digitisation, offering the key digital technologies available and suggesting areas that are relevant to historic building repair and maintenance projects, highlighting, that the digitisation benefits are numerous, such as; providing instruments for capturing and managing project data across a number of management and technical processes (e.g surveying, building diagnostics, monitoring and evaluation, project management, on-site operations etc.)

Moreover, it was postulated that a simple, yet appropriate and systematic methodology tailored to MSME and SME historic building R&M practice, designed to offer a process model, map and a management tool that supports an IPD approach and incorporates the use of digital technology, is essential to help support SME-led initiatives to manage change throughout the historic building repair and maintenance process. Thus, this research study is undertaken to develop such a structured and holistic approach, by building on industrial intelligence and existing studies, as well as provide direction and support to facilitate the employment of the framework. Moreover, to assist in evaluating the developed framework's relative effectiveness and demonstrate how the complexity of historic building repair and maintenance works can be dealt with, in terms of potential benefits, a demonstration project is presented. The next chapter will discuss the strategy, design, and adopted methods for the research study.

Chapter 4 – Research Design and Methodology

4.1 Introduction

Chapter 4 aims to provide an overview of the theoretical concepts that guided the adopted research strategy and methodology (methods and tools) and highlights their relevant strengths and weaknesses, to enable their critical evaluation, in relation to achieving the study's aim and its objectives. The chapter begins with a brief definition of research strategy and methodology, followed by a brief synopsis of Construction Management (CM) research. The chapter then provides an explanation of the theoretical model employed to inform and guide decisions on methodology, namely: Saunders et al., (2016) research "onion" model, as headings from the layered model, directs the discussion on the research strategy adopted and the reasoned rationale on the decisions made.

4.2 Research Design and Methodology Definition

A plethora of existing literature exists surrounding the subject of research design and methodology, hence, in turn; numerous researchers have offered a series of diverse explanations and definitions, regarding research design. For example, Saunders et al. (2016) state it is the process framework within which to conduct research, whilst relatively, Yin (2014) declared it as the logical procedural data collection plan, although Yin (2014), underscored that a research design deals with the logical issues of the problem investigated, whereas, Bryman (2012) provided a deeper characterisation and defined it as a coherent and logical overall strategy, which establishes the blueprint for data collection and analysis, to ensure research efficacy, in terms of effectively tackling the research problem. In summary, it is not just a work process plan or a scheme of works; it is a well-defined and rational structure, which holds the research together.

With regards research methodology, numerous researchers have offered several definitions: Dainty (2008) contended it embraces the research justification along with the theoretical philosophies, that motivate a study, whilst, Creswell (2013) expanded on this and defined it as the systematic and logical pathway of the selected research approaches, whilst integrating a theoretical explanation of the different research perspectives, considerations, limitations, characteristics, and significance of the adopted approach. Whereas, Saunders et al (2016), defined it as comprising the systematic collection and interpretation of data, based on logical relationships rather than researcher beliefs. Suggesting, in terms of reaching a central position, it was similar, to peeling back layers of an onion to reach the core. These layers represent, the questions fundamental to the decision-making process, in terms of data collection methods and analysis tools, establishing the principal factors in shaping a research methodology. To demonstrate this, they developed a theoretical research "onion" model, as illustrated in Figure 4.1; whose key components are identified, within the descending "onion" layers, from research philosophy on the outer layer to techniques and procedure in the innermost layer.

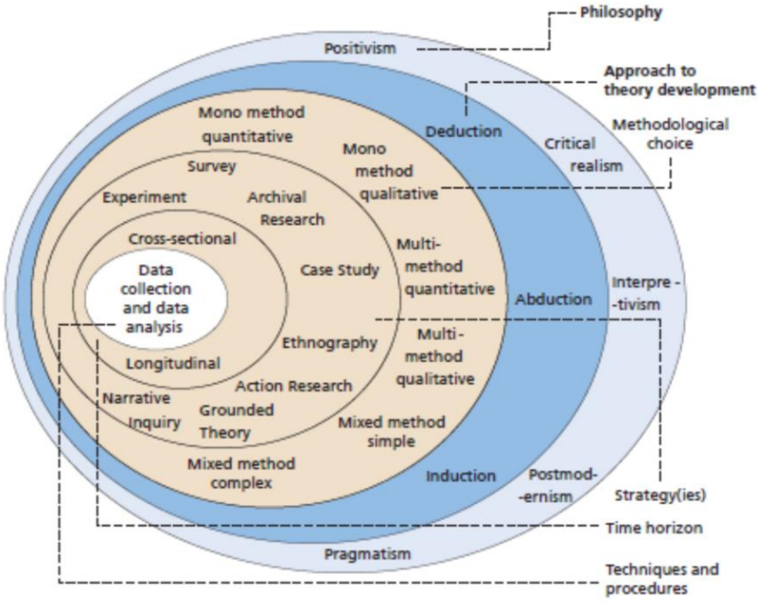


Figure 4.1: Research Onion (Source; Saunders et al., 2016).

As this study sits within the field of social sciences, and Construction Management (CM) research, the following section provides provide a brief synopsis of CM research.

4.3 Construction Management Research

Construction Management research is concerned with the potential external and internal benefits of augmenting Construction Management (CM) practices, improving the efficiency of site operations, and the need to employ new or improved materials and tools (Zou, Sunindijo, and Dainty, 2014). Furthermore, it is not only concerned with discovering objective facts, but also uncovering different subjective realities (Harty and Leiringer, 2017). Indeed, CM research has become an applied academic discipline in its own right, derived from three mainstream schools of thought: (1) social science; (2) a mixture of social and natural science; and (3) a technical science (Koskela, 2008). Therefore, in order to create scientific knowledge, whilst solving practical problems, to achieve valid research outcomes, and to address the identified research issue, CM researchers need to adopt a robust holistic research methodology, which not only provides methodological rigour, and comprehensiveness (Love, Holt, and Li., 2002). It also needs to consider the significant part, which the complex, project-based nature of the work, industry fragmentation, and the reliance on, site-based production, plays in employing an appropriately defined research design and methodology (Taylor and Jaselskis, 2010). Various CM researchers have demonstrated that there is a plethora of options at the researchers' disposal, whether that be qualitative ("soft" data) or quantitative ("hard" data) or a mixture of both (see Zou, Sunindijo, and Dainty, 2014; Taylor and Jaselskis, 2010; Dainty, 2008). Hence, there are a number of major theoretical frameworks available for informing and guiding CM research methodology (Zou, Sunindijo, and Dainty, 2014).

4.4 Research Study's Theoretical Model

To enable the research to be structured as a series of inter-connected steps in a specific sequence, whilst employing a simple, yet methodical comprehensive and instructive conceptual framework, in order to not rule out innovative thinking, but eliminate conjecture and suspicions in reaching research conclusions; two theoretical frameworks were selected for investigation, namely; Saunders, et al., (2016) six-component Research "onion" model (Figure 4.1) and Kagioglou, et al.,'s (1998) three-component "Nested" model (Figure 4.2). Whilst at first glance, from a research design perspective, both models appear arguably different, in paradigm, methodology, and methods comparison. Yet in reality, they are very similar in nature, as illustrated in Table 4.1, whereby it appears the choice of research design model is a case of semantics, particularly as the various authors use similar terms which are by essence; interchangeable dependant on the context. Based on the comparison, and to provide a comprehensive framework for the whole research process, it was decided to select and adopt Saunders et al., (2016) theoretical research "onion" model to; organise, inform, and guide the researcher decisions on the research design elements and methodologies applicable for this study.

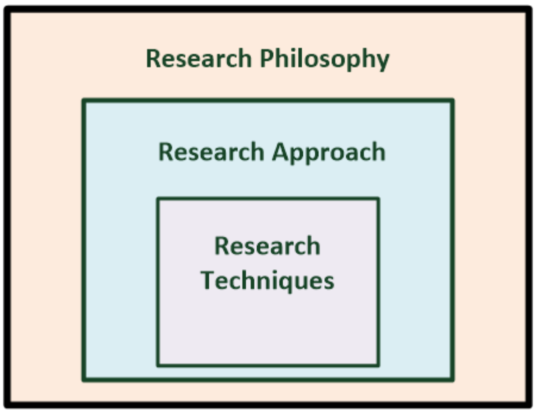


Figure 4.2: The Nested Model (Kaglioglou et al., 1998).

Nested Research Model	Research "Onion"
Philosophies	Philosophies
	Approaches
Approaches	Strategies
	Choices
	Time horizons
Techniques	Data collection and data analysis

Table 4.1: Nested Model and Research "Onion" Comparison; Source (Kaglioglou et al., 1998; Saunders et al., 2016)

The following sections provide an insight, discussion and justification into the selected and adopted research design elements and methodologies, based on Saunders et al., (2016) theoretical research "onion" model (Figure 4.2). Furthermore, it is necessary to appreciate and evaluate the philosophical position and direction of the proposed research focus i.e. the researcher's worldview and beliefs about knowledge generation (Saunders et al., 2016). As such, on the outside of the research "onion" model, an additional layer is provided, to help guide the significance of comprehending and selecting a philosophy, as an influential factor in research study planning and execution. Whereby, it includes the three main philosophies; Ontology (reality encountered in research), Epistemology (the study of knowledge and justified belief in research) and Axiology (the extent and ways values influence the research process) (Zou, Sunindijo, and Dainty, 2014).

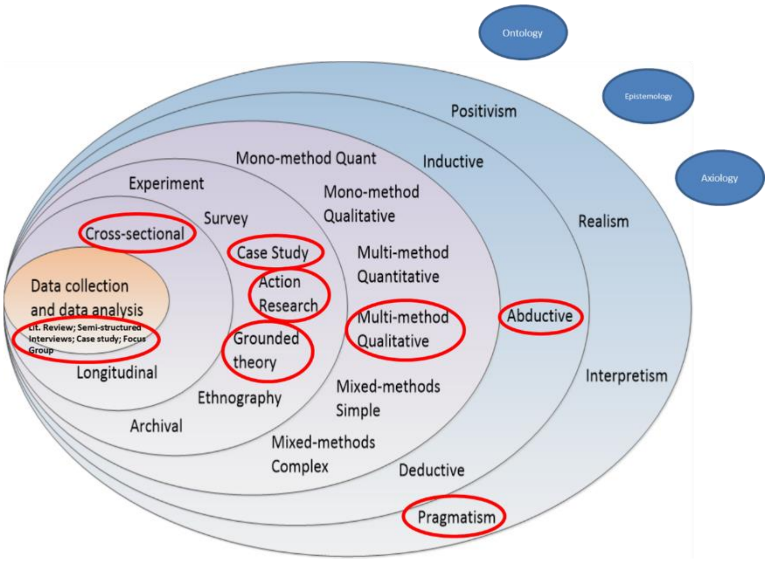


Figure 4.3: Research Theoretical Framework (Research Onion) as applied to this study (adapted from Saunders et al., (2016)

4.5 Research Philosophy

Adopting a particular research philosophy to underpin a selected research strategy and research methods, provides crucial explanations to the researcher's world view, the philosophical influences upon which their contributions are based, and determining suitable research methodologies (Creswell, 2013). These philosophical assumptions that underlie a research study known as "meta-theories" "paradigms", and even "traditions" are fundamental, a set of research practices, techniques, and tools that define a researcher's normal view of the world, and how the researcher determines the approach used to conduct research (questioning and discovery) (Fellows and Liu, 2015). These assumptions inevitably form the research questions comprehension, the methodology implemented, and the interpretation of the subsequent findings (Saunders et al, 2016; Creswell, 2013). Yet, in practice, seldom do research questions sit conveniently within one philosophical realm, nonetheless, establishing a rational and logical set of beliefs will form a plausible philosophical research viewpoint, which in turn strengthens the research background, and the methodological research choices and design (Saunders et al, 2016; Yin, 2013). Hence, to enhance the reader's understanding of this thesis, it is important to communicate the author's inherent beliefs, worldview and the research paradigm adopted.

4.6 Research Paradigm

A paradigm is a specific way of viewing reality that guides researchers towards their aim (Creswell, 2013; Fellow and Liu, 2008). Kuhn (1996) in his seminal work *"The Structure of Scientific Revolutions"* was the first to introduce the term paradigm. Such is the power of a researcher's paradigm, within the paradigm itself, Creswell (2013) stated there is a hierarchy relating paradigms to methods, specifically, these individualistic variances provide direction to the choice of adopting a qualitative, quantitative or mixed-method research approach. Considering the abstract nature of this connection, Lor (2017) provided a very useful analogy and visual metaphor of Hemingway's Iceberg Theory, to illustrate the relationship between paradigm, methodology and methods, (see Figure 4.4).

Figure 4.4: "Iceberg Model" of the dimensions of research (Lor ,2017)

It is widely known, only about 10% of a floating iceberg is above the surface of the sea, the huge mass of it remains below the surface, hence Lor (2017) assumed the tip of the iceberg is the research method (the specific procedures and techniques), then suggested the waterline is where the research methodology is located (e.g. research strategy decisions: the choice of quantitative, qualitative or mixed methods approaches allied to ethical considerations). Thus presuming, the larger, unseen underlying mass, related to the research philosophy, the paradigm and the subsequent philosophical dimensions, tends to be neglected, and is often left unexamined and unchallenged (Lor, 2017), as a consequence, four dominant ontological, epistemological, and axiological paradigms were investigated and compared; Positivism; Realism; Interpretivism/Constructivism; Pragmatism (Table 4.2).

Researchers view	Positivism (Myers, 2013; Saunders et al 2016)	Realism (Creswell 2013; Myers, 2013)	Interpretivism/ Constructivism (Myers, 2013)	Pragmatism (Creswell 2013; Saunders et al 2016)
Ontology:	External, quantifiable and unbiased	Viewed as objective; clarified and explained via social conditioning	Individual social construct susceptible to iterative alterations	Observable Phenomena (tangible and intangible) grounded in human conduct and perspective
Epistemology:	Founded in Simple observed phenomena which is fact based produces valid data, centred on cause and effect	Focussed context driven, fact based observed phenomena produces valid data. Data deficiency results in perception errors as phenomena is susceptible to misunderstanding	Focussed on subjective situational specifics and their authenticity implications	Focussed on applied research in practical contexts. Subjectively integrated observed phenomena values dependent on research question
Axiology:	Objective, unbiased perspective whereby research is not dependant on meaning	Objective, biased perspective whereby research is value laden	Subjective biased research value bound	Objective & subjective perspective High research value function
Data collection Techniques:	Significant substantially sized & organised quantitative data set although qualitative not to be discounted	Appropriate selection to fit research context (either quantitative or qualitative)	Small but deep and rich qualitative research	Mixed or multiple method designs, quantitative and qualitative

Table 4.2: Four Research Philosophies in Management Research Comparison; to enable the researcher's philosophy to emerge and be adopted for this study (Source; Creswell 2013; Myers, 2013; Saunders et al 2016)

From the initial comparison of philosophical perspectives, caution must be applied in decision-making, given in essence, it appears that one research philosophy is more "beneficial" than the others are. It was a question of deciding on the relative merits for each approach, whether one can benefit the research question(s) that require answering or one can be more "beneficial" for different things. One philosophy emerged; above all, as being directly connected to the researcher's world beliefs, in which consciousness, reality, experience, innovation, and the need for "real-life experience" interact. Hence, based on the researcher's world-view assumptions, their own experience, and evidence in real-life practice. Allied to the rationale: *the challenge of delivering quality R&M, confronted by the persistent skills shortages, project under-performance, poor communication, and lack of collaborative project practices, indicates a gap exists between theory and practice. Whereby, there is a distinct need for process management* *and improvement to historic building R&M PM and on-site practice processes, such as adopting a holistic, multi-disciplinary, structured, and integrated approach for optimised project delivery.*

The philosophy of pragmatism offered an approach, which is both multi-faceted and practical in nature, in terms of applied uses and successes, allowing the mixing of research strategies (Dainty, 2008; Love, Holt, and Li., 2002). Table 4.3, adapted from several well-known authors (Creswell 2013; Myers, 2013; Saunders et al 2016) provides a comparison of strength and weaknesses of the selected research paradigm, allowing substantiation, that this was a coherent methodological worldview for this study; to employ multiple research strategies and focusing on pragmatic, practical applied research. Thus, the following section identifies and clarifies all the necessary philosophies, tools and methods adopted for the research study, required for addressing the research problem.

Researchers Paradigms	Pragmatism
Strengths	Multiplicity of; qualitative research methods; data collection and analysis; varied beliefs and suppositions World view susceptible to change although grounded in current factuality Advocates robust valued practical applied research
Weaknesses	Difficult in negotiating value from instances of practical assumptions and unpractical beliefs Need for Explicit reasoning and meaning

Table 4.3: Pragmatic research paradigm strength and weakness (adapted from (Creswell 2013; Myers, 2013; Saunders et al 2016)

4.7 Research Approach

Various studies (Creswell 2013; Saunders et al 2016; Yin, 2013) have identified the three main traditional approaches to theory generation, testing, and elaboration, namely; deductive, inductive, and abductive. Yet, the continued discourse in the area (e.g. different views surrounding the order and connection of activities involved within a research approach), further complicates the already difficult task of having a clear understanding of these approaches, in terms of research design relevancy (Saunders et al, 2016). Interestingly, Bryman (2012) and Creswell (2013) suggest that many of the distinctions that separate the three traditions are a theoretical and philosophical mind-set, rather than found in research practice. Whilst, considering this perspective, is of value, for the purpose of this research; early career researcher and focused on the study's aim and objectives, it was necessary to consider all three approaches.

Concerning a deductive approach and its process, typically referred to as scientific approach and employed in research guided by a positivist worldview, involving quantitative data collection (Bryman, 2012; Saunders et al, 2016; Creswell, 2013). Thus, the deductive role is concerned with data generation to examine, substantiate, or widen theoretical concepts, initiated by data collection grounded in current theory, and then providing a research design to test the premise in the real world, as illustrated in Figure 4.5 (Saunders et al, 2016). In comparison, typically an inductive approach relates to varying qualitative research modes, in particular, grounded theory whereby, theory generation is *"grounded"* in data (Saunders et al, 2016; Creswell, 2013); whereby the key principal behind an inductive approach is to enable emergent research findings to rise from the initial unstructured raw data (Bryman, 2012) (Figure 4.7).

In terms of adopting an abductive approach, this process begins in similar fashion to a deductive approach, with data collection of data to explore observable phenomena, in order to generate or create a new theory (Saunders et al, 2016), as illustrated in Figure 4.7, whereby it involves s series of iterative movements, as the researcher alternates between theory and data (theory testing) and data and theory (theory creation), in effect an integration of both deduction and induction (Saunders et al 2016; Creswell 2013). Yet, caution must be taken, as an abductive approach is not a simple combination of deductive and inductive approaches, the iterative process requires creative reasoning and intent (Dubois & Gadde, 2002). Normally, an abductive approach concerns the adoption of either mixed or a multi-method research approach, given it can employ both quantitative and qualitative data, whereby it views data collection as a pragmatic breakthrough process, directing new aspects of the research problem (Saunders et al, 2016).

Figure 4.5: Research study deductive process (Source: Bryman 2012)

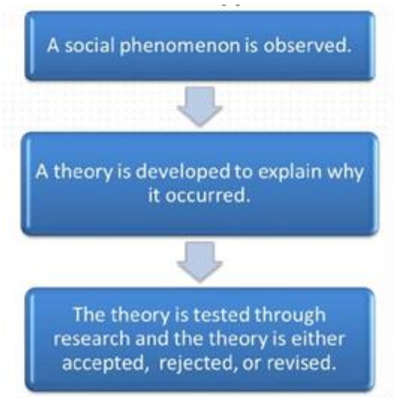


Figure 4.6: Research study inductive process (Source: Bryman 2012)

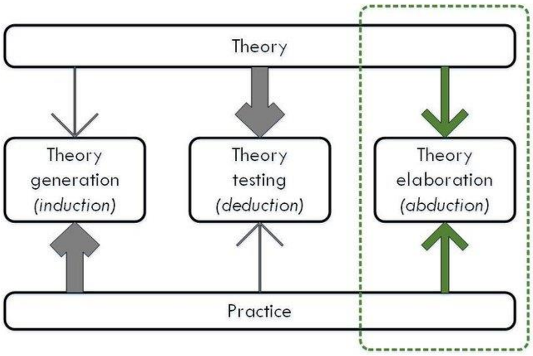


Figure 4.7: Visualisation of abduction approach (Source: Costa et al., 2017)

In order to clarify the decision on selection of the most suitable research approach, and address deficiencies in logic and reasoning, which places the satisfying of the research questions in jeopardy, the key differences in terms of logic, generalisability, uses of data and theory were investigated, as shown in table 4.4 (Saunders et al 2016).

	Deduction	Induction	Abduction
Logic	Suppositions and conclusions deemed true	Established suppositions generate unproven conclusions	Established suppositions generate proven conclusions
Generalisability	Generalising from to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Data Use	Evaluated data collection employed to assess current theoretical assumptions	Evaluated data collection employed to, classify themes and patterns within a phenomenon and create a conceptual framework	Evaluated data collection employed to classify themes and patterns within a phenomenon and examine within an iterative conceptual framework
Theory	Theory correction or corroboration	Theory generation and building	New Theory generation or alteration to existing theory

Table 4.4 Deduction, Induction and Abduction approach differences (source: Saunders et al 2016)

Thus, whilst there is wealth of information in one context on the topic (*historic building R&M*), there is far less in the context in which we are researching (*"process management and improvement"*). Both inductive and deductive approaches were considered, however, to support achievement of the research's aim and objectives and more relatively, as the study's intention was to modify existing theory. It was decided to adopt an abductive approach, employing the Generic Design and Construction Process Protocol (GDCCP) developed by the University of Salford, which will be discussed in detail later in the study, and based on the premise; there may be unexpected empirical findings; more specifically, gaining deeper theoretical insights could possibly be achieved during the abductive logic process of iteration between an overarching theoretical framework, data collection and examination (Dubois and Gadde 2002).

Various researchers use different terminologies to define the overall design of the research: Bryman (2012) refers to this as the research strategy, whilst Creswell (2013) uses the term research approaches, and Saunders et al, (2016) defines it as research methodologies. Therefore, an important consideration now for the research design, is selecting the most suitable research methodologies and their relevant procedures and tools, in order to support the coherent generation, collection, and analysis of the data, in relation to addressing the posited research questions (Saunders et al., 2016). As the lack of such consideration presents a distinct possibility of not realising the aim and objectives of the study, whilst also posing an even bigger risk towards employing the most suitable research methods; whether that be quantitative, qualitative or either mixed (combines qualitative and quantitative research) or multi-methods (combines two or more qualitative approaches or alternatively two or more quantitative approaches) (Bryman, 2012). As mentioned previously, given this research, is employing Saunders et al, (2016) research "onion" model, following section will now provide an insight into the various different termed research methodologies.

4.8 Research Methodology Choices

When deciding on which type of research methodologies at the study's disposal, broadly speaking, two research methodology modes were available, namely, qualitative and quantitative (Bryman, 2012). Yet, there is an on-going classical debate in relation to which research methodologies provides more value, although Creswell (2013) stressed such discourse, whilst important, should not cloud the significant consideration that the most appropriate should be based on; which methodology or methodologies has the ability to satisfy the research questions, the aim and the objectives more, based on the disposition of the phenomena being investigated and the type of data required, whether that be "hard and reliable" or "rich and deep" or a combination of both.

Hence, in actuality, there were four types of research methods available to select from, namely; quantitative, qualitative, mixed methods and multi-methods, to which, beneficially, Creswell (2013) provides a useful list of the four research methodologies summarising the differences between them as outlined in Table 4.5. For ease of comprehension rather than, individualising mixed and multi-method, Creswell (2013), combined these two research methodologies despite each having their own peculiarities, thus, the following sub-sections briefly discuss the four fundamental research methodologies in question.

Quantitative methods ⟶	Mixed/Multi methods	⟵ Qualitative methods
Fact-based documented evidence Pre-determined Statistical mechanism-based questioning, analysis and clarification Surveys and experiments (observable and performance related data)	Fact-based and perception documented evidence Multiplicity of research methods, tools and techniques Varied data sources (emergent and existing) Varied data analysis (statistical, transcript based) Employment of both open/closed-ended questions	Perception measured documented evidence and data (interview, observation etc..) generated through open-ended questioning Emergent research methods practised through grounded theory, case study and narrative Enables themes, patterns generation and interpretation

Table 4.5 Quantitative; Qualitative and Mixed Methods research strategies differences; (Source: Creswell, 2013)

4.8.1 Quantitative Research Methodology

Quantitative research is naturally "objective" in terms of data collection and analysis and inherently regarded as a scientific investigation (Creswell, 2013). Table 4.6 provides a tabular format of a quantitative research strategy's strengths and weaknesses, with its aim is to assess a hypothesis or theory and the variables, by statistically quantifying collected facts and statistically analysing the data in order to determine whether the hypothesis or theory holds true (Creswell, 2013; Saunders et al, 2016). With the numerical data typically generated and collated from various sources such as; questionnaires, interviews, and /or carrying our experiments allied to data gleaned from desktop studies (Fellow and Liu, 2015), the effectiveness of the selected types depends mainly on the nature of the social science research, although, to provide a quantitative explanation of a population's perceptions, trends and insights using statistical analysis; the questionnaire survey method technique tends to be employed the most.

Strengths	Weaknesses
Furnishes specified statistical data. Permits unbiased numerically driven outputs Relatively rapid data collection and analysis Suitable for investigating large populations Examination and corroboration of existing theories ("how" and to some extent "why")	Deficiency in ability to extrapolate subjective data (e.g. experience, tacit knowledge etc)

Table 4.6: Quantitative Research Strength and weaknesses (Source: Saunders et al, 2016; Creswell, 20013; Dainty, 2008)

4.8.2 Qualitative Research Methodology

Conversely, to quantitative research, a qualitative research methodology does not employ numerical measurement, but is preoccupied with investigating and describing a phenomena "subjectively" based on a real life situation, whereby it provides insightful narratives of experiences, the people involved, their actions and relationships with the issue (Creswell, 2013) (Figure 4.7). Fundamentally, a qualitative research methodology's aim is developing a detailed comprehension of the phenomena in question, in its native world (Saunders et al, 2016). In order to obtain a universal, innate, and valid view of the concept and capture the opinions and standpoints of research participants; qualitative data generation and collation are achieved through various data collection methods such as; case studies, focus groups, interviews, etc., along with data gathering through a desktop study (Saunders et al, 2016). Invariably, a precise examination and analysis of the subsequent generated data is required, whereby, adopting the analytical method of thematic analysis (descriptive in approach and analytical in practice) typically occurs (Vaismoradi, et al., 2013). Such a qualitative analysis tool is a flexible and valuable research method that facilitates the researcher to generate a deep and precise yet complex, account of the data (Braun and Clarke 2006). This analytical coding technique commences with a systematic process of categorising the data into packets of information, then analysing such data in order to provide meaning to these packets of data (Denzin and Lincoln, 2011). However, if there is a lack of research surrounding the concept or phenomenon within the area of focus, and to enable valid assumptions to a wider population, a suitable and relevant approach to adopt for qualitative research is to employ statistical procedures to evaluate data and produce findings (Creswell, 2013).

Dainty (2008) identified qualitative methods are becoming increasingly acceptable and attractive to CM researchers, despite quantitative methods remaining the established research archetype within the CM research field. Moreover, Dainty (2008) stressed it was a distinctive method that ought to provide a deeper comprehension of industry dynamics and the complex relational network between practitioners, which, in turn, presents opportunities for emerging theories to generate hypothesis formation and examination (Dainty, 2008). Highlighted in table 4.8 is a "snapshot" of this study's qualitative research's key strengths and weaknesses.

Strengths	Weaknesses
Valuable deep and rich investigation into a restricted number of complex phenomena in established settings	Susceptibility to researcher bias and beliefs Elongated data collection and analysis process Data findings may lack true objectivity

Table 4.7: Research study's Qualitative research strength and weakness (Source: Bryman, 2012; Saunders et al, 2016).

4.8.3 Mixed Methods Research Methodology

From the previous sections' discussion, both qualitative and quantitative research methodologies encompass different powers and limitations inherent in each method. Therefore, it is reasonable to assume, combining both methodologies allow focusing on their relevant strengths and weaknesses; Table 4.8 illustrates the strength and weaknesses of mixed methods research strategy. This type of research methodology referred to as mixed methods, whereby the integration of quantitative and qualitative research methods forms part of a research study, indeed, when either approach, in isolation, is inadequate, a mixed-method design is highly valuable (Creswell, 2013). Nonetheless, caution must be taken, as mixing research methods can increase research complexity, as the numerous research approaches and theories add supplementary complications (Fellow and Liu, 2015). For example, switching between qualitative and quantitative methods, in data collection and analysis, whilst allowing conversion of quantitative data into narrative based analysed qualitative data, and conversion of qualitative data into statistical measures and be analytically probed (Fellow and Liu, 2015).

Strengths	Weaknesses
Aids inferential conclusions Strength and weakness of each method balanced Assists answering a wider set of focused questions Provide deeper validity and reliability to findings Generate more comprehensive data complete knowledge to inform theory and practice	High degree of user experience required Costly and time laden

Table 4.8: Mixed methods strengths and weaknesses: (Source; Saunders et al, 2016)

Within a mixed methods research strategy, numerous combinations are available, however, typically, the three foremost mixed model approaches, are; concurrent (parallel) mixed methods (findings are independent of each other); sequential mixed methods (findings from one methodology inform the other); and transformative mixed methods (involves a sequential or concurrent data collection approach) (Creswell, 2013).

4.8.4 Multi-Methods Research Methodology

Multi-method research has emerged as an influential development, whereby a research study employs a solitary research methodology, either quantitative or qualitative, however the data collection and analysis processes harness a multitude of tools and techniques within the equivalent methodological framework (Creswell, 2013; Franco, 2011). Thus, care needs to be taken by the researcher to distinguish multi-method approach from a mixed-method approach and restrict themselves within one research methodology (Saunders et al., 2016). Nonetheless, this emergent research approach is increasingly employed to deal with the complexity of real-world problems (Henao and Franco 2016). Yet, widespread multi-methodology adoption, has not thus far occurred, due to the aforementioned quantitative research methodology ability to dominate CM research (San Cristóbal et. al, 2016). However, Dainty (2008) and Fellows (2010) advocated such a position for qualitative CM research, to present an alternative perspective on research design, by providing a more expansive outlook towards yielding deeper insights into CM management. At its heart, lies its abilities to integrate provide a multiplicity of methodologies bounded within a solitary framework, in order to enable triangulation of the research subject by addressing it from multiple viewpoints (Dainty, 2008). Multi-methods research allows the ability and capacity to provide varying measures of a variable from diversified methods, which in turn suggests improved validity, in terms of the rigour and robustness of research findings (Saunders et al., 2016). Furthermore, unlike mixed-method research, where to make sense of the data; all aspects of the data need published, a significant attribute of multi-methods research methodology is findings from each approach has the ability to publish as stand-alone studies.

4.8.5 Selected Research Methodology

With this Construction Management research, concerned with historic building repair and maintenance "*process management and improvement",* and discovering from the literature review there being a distinct lack of discussion surrounding this research area, resulting in a neglected area in the field of CM. Allied to the research having a number of correlated but specific objectives, an important contribution of this research work is investigating and analysing of first-hand data; on how key stakeholders view the current challenges and project-specific issues facing modernising historic building R&M. Particularly, the focus on a deeper understanding of perceptions and interpretation, in order to raise key issues and their variables (see section 1.6), although this was supported by the testing of experimental data (i.e. piloting of the developed framework).

This signifies the research to be qualitative in nature, not quantitative, by attempting to raise appreciation and interpret the phenomena in its accepted locations (Denzin and Lincoln, 2011). Therefore, the methodological choice adopted is qualitative and precisely the type of approach required; given the inherent industry complexity and problem-focused orientation of Construction Management research and the need to comprehend deeper the project practice and processes (Dainty, 2008). Whereby, moving from qualitative data collection measures, to moving to detecting themes and patterns in the data (Saunders et al, 2016), was deemed a rigorous approach to obtaining answers to the research questions. Furthermore, influenced by the researcher's pragmatic worldview and need to support establishing meaningful data, grounded in the use of the theory, existing data, and anecdotal experience, a single quantitative methodology was employed, incorporated in an overarching coherent multi-method qualitative methodology. In addition, to this strategy justification, the supplementary value adopting such an approach can bring, includes exploring in more detail, the effective and specific information that obtained from specialised population groups about their industry perspectives, values, practices, and environment (Bryman, 2012). Indeed, the historic building repair and maintenance sector with its unique, bespoke, and complex field, undoubtedly falls under this umbrella.

4.9 Research Strategy

Research strategy typically denotes the research's general orientation (Bryman, 2012), however, in this instance, as the research study employs Saunders et al, (2016) theoretical layered "onion" framework; research strategy refers to the different sets of strategies of inquiry available to the study (Saunders et al., 2016). Various researchers (Popper, 1963 and Saunders et al, 2016) claimed for success, it is fundamental that the research strategy, relates to the disposition of the field of study enabling to furnish the hypothesis with equal probabilities of misrepresentation or corroboration. In considering, that Historic Building repair and maintenance Project Management is about the effective and efficient control of complex and specialist processes and practice, on and off-site. Yet, sector instability and the conflicts arise make Project Management efficacy become even more difficult, driven by the in-built industry fragmentation and the lack of appropriately and suitably qualified workforce.

Therefore, the following question was posed; what strategies of inquiry within this theoretical model should be adopted to meet the five research objectives, whilst considering the research constraints, scope and align with the research methodology adopted (pragmatic qualitative exploratory multi-methods approach)? Thus, various authors have characterised these as distinctive research strategies; Denzin and Lincoln (2011) recognised eight main approaches, whereas Saunders et al., (2016) acknowledged seven main approaches, whilst Creswell (2013) identified five main approaches (Table 4.9).

Author	Creswell (2013)	Denzin and Lincoln (2011)	Saunders et al., 2016
Research strategies	grounded theory ethnography case study narrative phenomenology	action and applied research clinical research case study; ethnography phenomenology/ethnomethodology grounded theory life history historical method	case study action research grounded theory experiment survey ethnography archival research

Table 4.9: Qualitative research strategies comparison; (source-Creswell, 2013; Denzin and Lincoln, 2011)

Each research strategy, although similar in nature, each has its own distinct advantages and disadvantages, yet, more importantly, the selection and use of the most appropriate, is not confined to a single research strategy adoption. Rather, the tendency is to adopt a multiplicity of combinations dependent on the research question, its aim and objectives exclusive, although, it is necessary the decisions are guided by the additional following factors: (i) extent of existing knowledge; (iii) resource limitations (time, budget, access etc.); and (iii) the researcher's worldview. However, providing a deeper insight into all these available methods is out with the scope of the research.

Hence, as already highlighted, the research study is more concerned with theory formulation than theory testing, thus, the following selected strategies of inquiry were adopted, then employed; primarily, a survey research strategy (semi-structured interviews along with focus groups) to allow the collection of empirical practitioner data (data based on real-world observations) to ensure obtaining reliable data all within a limited timescale and resources (i.e. PhD study see section 4.10) (Saunders et al., 2016). Whilst, secondly the research, adopted Grounded theory; Case study; and Action research strategies. Pertinently, a brief discussion to highlight the reasoning behind these three additional qualitative research inquiry strategies follows.

Grounded Theory first described over 50 years ago, which has since been refined and expanded, is an abductive approach to qualitative data (Glaser and Strauss in 1967; Creswell, 2013). According to Denscombe (2003) and Saunders et al., (2016) it allows the realisation of an emergent research design, as the aim is to develop a theory "grounded" in the data, achieved through an iterative process of data collection and analysis during various phase of the research study, enabling the gradual construction of a theoretical data set comprehension via combining various data collection techniques (e.g., interviews, observations, documents, etc.). In relation to adopting a Grounded theory approach to investigating *"process management and improvement"* within Historic Building repair and maintenance Project Management research. It resonates as a suitable selection for this study, as it tends to be associated with; exploratory investigations, small-scale studies in specific settings (Saunders et al., 2016), and has the ability to produce recognisable rationalisations, based on immediate evidence (Denscombe, 2003). Moreover, adopting a Grounded theory approach enabled identifying and contrasting against current wider Construction Project Management (CPM)Theory, such as the Generic Design and Construction Process Protocol, as well as, process improvement and architectural conservation theory. Furthermore, this strategy of inquiry, forms a useful basis for not only this research study but also for future research, given the complex, bespoke and multi-disciplinary patterns of communication and behaviour that emerge in response to Historic Building repair and maintenance Project Management and onsite practice.

In terms of an action research (AR) strategy, it draws strength from its explicit focus on action, as it adopts a pragmatic philosophical position, advocating combining of philosophies and methods to address social problems (Denscombe, 2010). Whereby the focus is on change and the need to involve practitioners throughout the research process to identify, develop, implement and evaluate the data findings and results (Fellows and Liu, 2015; Saunders et al., 2016). Indeed, at its core, is the epistemological paradigm that the "truth", is based upon the effectiveness of the research (Azhar et al., 2010). Thus, various Construction Management researchers (Azhar et al., 2010; Denscombe 2010;

Sexton and Lu, 2010) have identified AR as a valuable research methodology for construction; to reduce disparities between theory and practice, by cultivating academic research applicability and influence, through its pragmatic nature. Moreover, AR is a powerful tool for researchers who are interested in finding out about the interplay of humans, information, social-cultural contexts, and technology (Denscombe 2010), as is the case for this research. For example, Sexton and Lu (2010), argued AR is particularly valuable when studies are focused on small firms, specific sectors, and orientated towards change, collaboration and process, whilst, Azhar et al. (2010) indicated that AR is a rigorous, structured, and meticulous applied research method that is very beneficial to stimulate and develop construction practices such as CPM, on-site operations, as well as new product, materials, and tool development (Sexton and Lu, 2010). Hence, given the focus of the research being upon a specialist sector of construction; the historic building repair and maintenance sector, prevalence of MSME and SMEs (professionals and contractors), and the unique, bespoke and complex project environment. Indeed, adopting an AR strategy, was intended to support the solving of an industry practice problem and to produce guidelines for best practice (Denscombe, 2010); in this case a contemporary process model, map and management tool. Hence, AR allowed the research study to investigate practice, undertaken by those involved in that practice, with an aim to change and improve it and produce practical, useful knowledge (Connaughton and Weller, 2013). In this context, AR allowed the systematic collaboration among participants to address both MSME and SMEs practical apprehensions and concerns, as well as supporting the research goals by working collaboratively with stakeholders on a selected project (Love et al., 2011).

With regards, the third strategy of inquiry adopted for the research study; the research study sought out a case study approach, which would enable the research study to answer fundamental questions such as; “why”, “who”, “what” and (Denzin and Lincoln, 2011; Yin,2013), as the literature review exposed a paucity of research within the domain of; *“process management and improvement”* for Historic Building repair and maintenance Project Management research. Although, more often than not, case study is employed across not just exploratory research, as is the case here but across three other types of approaches, namely; descriptive, explanatory, and interpretive (Denzin and Lincoln, 2011). Furthermore, as with any research study and its iterative nature, it does not sit within one sole category, as in reality, research is iterative in nature and susceptible to change and develop over time, leading to identification of more than one purpose (Gray, 2013). Therefore, as initially, the study adopted and employed an exploratory approach, and to determine the study needed to combine an explanatory and interpretive approach as the research evolved. Hence, to provide the study with an evaluation of the numerous data collection methods, techniques and tools available, a comparative table was generated to support the decision-making process, as illustrated in Table 4.10, as each one has its own particular merit and justification (Yin, 2013). Thus, the study adopted and employed a combination of exploratory, explanatory and interpretive approaches as the research progressed.

exploratory	descriptive	explanatory	interpretive
Explore relatively unknown phenomenon and seek to pose probing questions	Describes a naturally occurring phenomenon	Explain and provide reasoning	Interpretation of tacit knowledge, experience and perceptions
Literature review. Interview key experts face to face and in focus groups	Depict a situational and relational portrayal of a phenomenon	Seek to discover cause and effect correlation	Interrogation of tacit knowledge, experience and perceptions
Seeks to ask 'what' questions	Seeks to ask 'what' questions	Seeks to ask 'why' and 'how' questions	Seeks to ask 'what', 'why' and 'how' questions

Table 4.10: Fundamental differences between research purpose classification strategies; adapted from; *Doing Research in the Real World (Gray, 2013)*

Moreover, at a research study's disposal were two types of case studies; single case or multiple cases, which themselves can be further categorised and challenged by their focus; be it a holistic case or embedded case or a case considered, on its significance, uniqueness or even scarcity or extremity (Yin, 2013). However, for case study research, the biggest challenges surround; scope determination; the unit of analysis, be that "a bounded system" (for one case) or "multiple bounded systems" (for more than one), which are wholly dependent on the focus and the extent of the research; and determining the many points of interest and variables which intersect and overlap in case study research (Creswell, 2013). Moreover, when investigating a whole case study as one unit, either by providing a "helicopter view", or focussing direction on a precise facet of the case (Yin, 2013), the data collection methodology needs to be structured, and systematic to allow for substantiated evidence (Harrison, 2017), whilst the subsequent analysis methods, and tools such as thematic analysis, require to provide triangulated data, which is fundamental to ensuring the holistic quality of a study (Creswell, 2013). In summary, due to the value, validity, capability and efficacy of adopting a case study approach as powerful forms of qualitative research (Yin, 2013), in terms of, *"process management* *and improvement"* for Historic Building repair and maintenance Project Management research, its use suggests the applicability of this strategy of inquiry, as an effective methodology to examine and comprehend the bespoke and complex issues facing the sector and its projects in a real-world setting. In fact, arguably, a case study strategy suits the study of diverse, distinctive historic building R&M SMEs (projects, processes, people) and their idiosyncratic, specialist nature, due to inherent sector difficulties such as fragmentation, disposition of siloed working practices that exist between different professional and contractor SMEs.

Therefore, with the aim, to develop a common structured collaborative industry framework which informs digital technology use for supporting a multi-disciplinary PM and on-site practice, in order to satisfy objectives; 3, 4, and 5 of the research, and constrained by limited resources. A single case study AR strategy was selected, with a view, to illustrate the framework's impact and value, in terms of performance and productivity, in comparison to current practice used in historic building R&M projects in Scotland and evaluate the framework effectiveness. Based on the use semi-structured interviews, allied to the demonstration and observation of the framework in terms of a basic cost benefit analysis (CBA) (time, cost, quality and health and safety), and the subsequent research questions, directed towards the mutual development of "know-why", "know-that" and "know-how". Furthermore, given the unique setting of the case study: *"process management and improvement"* for Historic Building repair and maintenance Project Management. The research study was keen to exploit the benefits of a multi-faceted study to explore the phenomenon in question (Sexton and Lu, 2010), whereby, the correlated intention of the case study was exploratory, explanatory and interpretive in characteristics. Hence, positioning the study within the scope of a multi-dimensional case study methodology and analysis of historic building repair and maintenance project stakeholder views, in order to evaluate theory with practice. This ought to contribute significantly to not only this study's quest to secure a deeper understanding of the challenges and issues, such as the difficulty in adopting a truly multi-disciplinary collaborative integrated Project Management and on-site practice process approach; but be beneficial to secure a multi-layered perception of the need for historic building repair and maintenance Project Management modernisation and enhancement; suggesting it ought to be beneficial in contributing valuable knowledge to; *"process management and improvement"*, as well as future research of the historic building repair and maintenance sector, in general.

4.10 Time Horizons

In terms of this PhD study, time considerations were investigated, within the context of Saunders et al., (2016) research "onion", however, due to the constraints of PhD studies and their relevant timescale limitations of delivering a successful PhD within a set time period. Allied to working in the field of Construction Management research, whereby, the research timescale will be significantly influenced by numerous other factors, as shown in Figure 4.8 (Mukherjee, Hoare, and Hoare, 2000). For example, in terms of this research study's secondary influences, they appeared in the form of; the study's philosophical standpoint; the lack of existing knowledge on the subject; and given the developed framework was to be piloted, the sectors propensity to adopt siloed working practices that exist between different project stakeholders and project implications, bounded by available financial budgets or lack of. Therefore, grounded in these boundaries, it was decided to omit this layer of the theoretical model, based on the logical reasoning that the research undertaken was simply a *"snapshot"* of the phenomenon and its associated occurrences, taken at a single juncture in time.

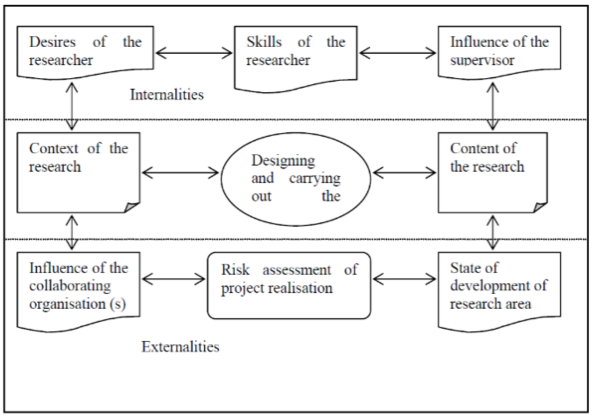


Figure 4.8: The influences on selection of research length strategy (*Reproduced from Mukherjee, Hoare, and Hoare, 2000*)

As the research study has adopted several research strategies (case study, survey, and action research), it is necessary to discuss the research data collection and analysis methods selected. However, before providing a discussion and clarity on the techniques and procedures employed. First, it is appropriate to discuss the ethical factors pertaining to the study, as well as the concepts of validity and reliability, in the context of this qualitative research study.

4.11 Research Ethical Considerations

As part of the research study's strategy, it was imperative that deliberating the ethical factors influencing the study, particularly as they are integral considerations and elements of any research study, in particular the collection of data in the field (Bryman, 2012). In relation, as part of the multi-methodology research design, three models of qualitative field research were undertaken, namely: (1) a preliminary pilot study; (2) an AR case study; and (3) a focus group validation study. Given, the main qualitative data collection technique employed, was in the form of semi-structured interviews, administered through one to one discussion and as part of a focus group discussion, there was an inherent need to safeguard the participants and their organisations, (Creswell 2013). Hence, the three core ethical matters considered were; (i) *informed consent*; (ii) *confidentiality/privacy*; and (iii) *accuracy and authenticity,* in order to address participants concerns surrounding trust, protection, and integrity. Prior to participant agreement, each study contributor was resolutely introduced to the research study, provided with clarification of the research's purpose (its aim, objectives and rational), and informed their participation was voluntary; which could be withdrawn at any point of the study, should they so wish. Furthermore, to ensure scientifically and ethically that the qualitative reporting methods selected (interviews, case study and focus group), were performed to ensure participants confidentiality and integrity were respected, ethical approval was sought and obtained from the Heriot-Watt University Ethics Committee in May 2016 (see Appendix A).

4.12 Research Validity and Reliability

Imperative beliefs in research design are validity and reliability, regarded as singular diagnostic concepts (Dainty, 2008). Validity refers to the accuracy of the research measure; whereas, research reliability is the degree to which a research method produces stable and consistent results (Bernard et al., 2016). However, outside of statistical research, reliability and validity are interchangeable concepts, hence in terms of qualitative research; there exists a number of different types of validity and reliability models, although a further concept that adds rigour to the research design is the generalisability of the data results (Bernard et al., 2016; Gray, 2013). Hence, collectively, validity, reliability, and generalisability are influential tools, in the evaluation of the quality and the truthfulness of the data findings presented (Bernard et al., 2016). However, various qualitative researchers (Guba and Lincoln, 1985: Nowell et al., 2017; Tobin and Begley, 2004) have questioned the applicability of these nomenclatures, as being completely apt for qualitative research. Instead, they offered the alternative terminology. Suggesting the following; *credibility, dependability, confirmability*, and *transferability* (Table 4.11).

Intriguingly, Bernard et al., (2016) added *trustworthiness;* the quality of qualitative influence research design, to the mix, whilst; Dainty (2008) suggested for qualitative CM research the need to adopt *"ecological validity"*; the extent and pertinence, to the generalisation of findings, within settings typical of "real-life" environments. For the purpose of this PhD study, the content and constructs whilst viewed as significant parts of the research study (Dainty, 2008); the validity and reliability discourse surrounding this topic is out with the scope of the study. Nonetheless, decisively adopting the terminology, as illustrated in Table 4.11, would provide the key aspects and strategies of the verification of the study's qualitative research data; the process and mechanisms of checking, confirming, and affirming, by incrementally contributing to ensuring the study's validity, reliability and rigour.

Aspect	**Strategy**	**Strategy used in this study**
Credibility; Providing an accurate depiction of area of study	Long-standing and varied experience Establishing the authority of the researcher Triangulation	Researcher has over 30 years of experience, in historic building R&M practice, (contractor, consultant, lecturer) Researcher developed and documented ideas/concepts The results from the interviews/focus groups were triangulated by comparing them to current literature
Transferability; Can findings be applied to a different setting	Purposeful sample Rich description of the research setting Data saturation	Indicative representation sample of historic building R&M practitioners and data collection methods; pilot interviews, case study selected, case study interviews, 2 no, validation focus groups
Dependability/ Reliability	Review Triangulation Peer Review	An iterative research audit process adoption Allow cross comparison between qualitative and quantitative data collection and analysis Publication of early research findings in academic journals. PHD supervisor provided peer review through questioning, challenging of research direction
Confirmability; Direct emerging data	Review Triangulation Peer review	An iterative research audit process adoption to confirm rigourness of findings. Findings whilst could be generalised, bespoke nature of historic building R&M, allowed context specific issues to arise. PHD supervisor provided peer review through questioning, challenging of research findings

Table 4.11: Verification strategies used in the research adapted from Nowell et al., (2017)

4.13 Data Collection and Analysis Techniques and Procedures

Adopting appropriate data collection and analysis techniques and procedures, researchers need to factor in decisions that fit in with the philosophical stances, strategies, methodological approaches and choices already fixed upon, if valid results creation can withstand criticism (Saunders et al., 2016). At the researcher's disposal, lay two principal data sources available; primary and secondary, to address the research question(s), its aim and objectives (Saunders et al, 2016). Primary data correlates to original data, sourced, collected and analysed by the researcher for a specific purpose, either quantitatively (numeric) and qualitatively (non-numeric), employing varying data collection methods such as interviews, case studies or focus groups (Saunders et al., 2016), as employed in this research study, grounded in qualitative strategies, approaches and methods. Furthermore, when selecting primary data analysis techniques and tools, decisions on sample groups, case study selection, and interview content, requires careful development and structure; in order to provide valuable data that can be explored either thematically or statistically to harvest a result that can be generalised to the wider populace (Bryman 2012). Contrastingly, secondary data and its data sets, relate to already undertaken preliminary work; previously published academic journals, books, industry reports, online platforms, and other documentary sources (Saunders et al., 2016). Despite the considerable advantages of secondary data analysis, particularly the benefit of having already collected data, the suitability towards all research studies may not be appropriate in addressing the researchers need, given the lack of control over the sample, and how and what was measured (Greenhoot and Dowsett, 2012). Nonetheless, for this CM research study, beneficially utilising primary and secondary data and its sets, particularly, interviews, case study, focus groups, and industry intelligence reports, provided resourceful, authoritative, valid, and readily available resources for addressing the Construction Management questions.

4.13.1 Data Collection Method

A multi-method qualitative four-stage data collection methodology, along with a single quantitative methodology was employed; further clarified, and summarised by the conceptual research strategy, as illustrated in Figure 4.9. The first stage consisted of two parts and covered research objectives 1, 2 and 3, which involved reviewing previous research on the key sector-wide and project-specific level challenges and issues; with the aim to identify research gaps and define the focus of the study; *"process management and improvement"* for Historic Building repair and maintenance Project Management. This was further supplemented by harnessing the researcher's 30 years' plus knowledge, experience and anecdotal observation of industry practice as a consultant, contractor and latterly as a CM lecturer, whilst from the outcome of this initial part of stage one;

generated the need to review related topics such as, historic building digitisation, Integrated Project Delivery, and Construction Process Management Frameworks.

Moving on to the second stage, which covered research objectives 1 and 4, this stage of the study investigated current practice of Project Management and on-site process operation, as well as exploring the key project specific level issues facing MSME and SME's. Also, in the absence of SME specific Project Management guidance and standards targeted for carrying-out and managing on-site operations, in order to determine a high-level generic SME generated historic building repair and maintenance process diagram, which involved process mapping of existing processes. The initial anecdotal generic map was shown iteratively to the interviewees, during the interview process, who assessed and amended the graphical schema, and resulted in a generated best practice process map containing four process levels (level 0, 1, 2, and 3) to determine *"process management and improvement"* areas within key project areas. The outcome of this process mapping supported the development of the common structured collaborative industry framework for process management and improvement to support a collaborative, multidisciplinary approach for facilitating an integrated approach, whilst inform digital technology application.

Thus, the third stage piloted the developed framework on one demonstration project, in order to relate it impact and value, particularly through digital technology use in process performance and productivity (time, cost, quality).

The fourth stage of the study was to review, evaluate, and validate the developed framework by experts and practitioners, using focus groups and further interviews. The formulated research strategy embraces a predominantly qualitative triangulation study approach, whereby, it employed several qualitative data collection techniques and tools to gather data (Dainty, 2008). Although, it can be argued that psychological measurement, such as measurement of opinions, through a non-dichotomous data set on the ordinal scale, has no validity (Saunders et al, 2016). Therefore, it was prudent to provide a statistical opinion survey technique during the focus groups, in order to provide a descriptive statistical analysis, to gain information from the focus group sample to draw conclusions/inferences about the overall effectiveness of the framework, hence, the choice of quantitative-based questionnaire was considered appropriate. Thus, the following sub-sections outline the various qualitative and quantitative data collection techniques and procedures adopted (see table 4.12).

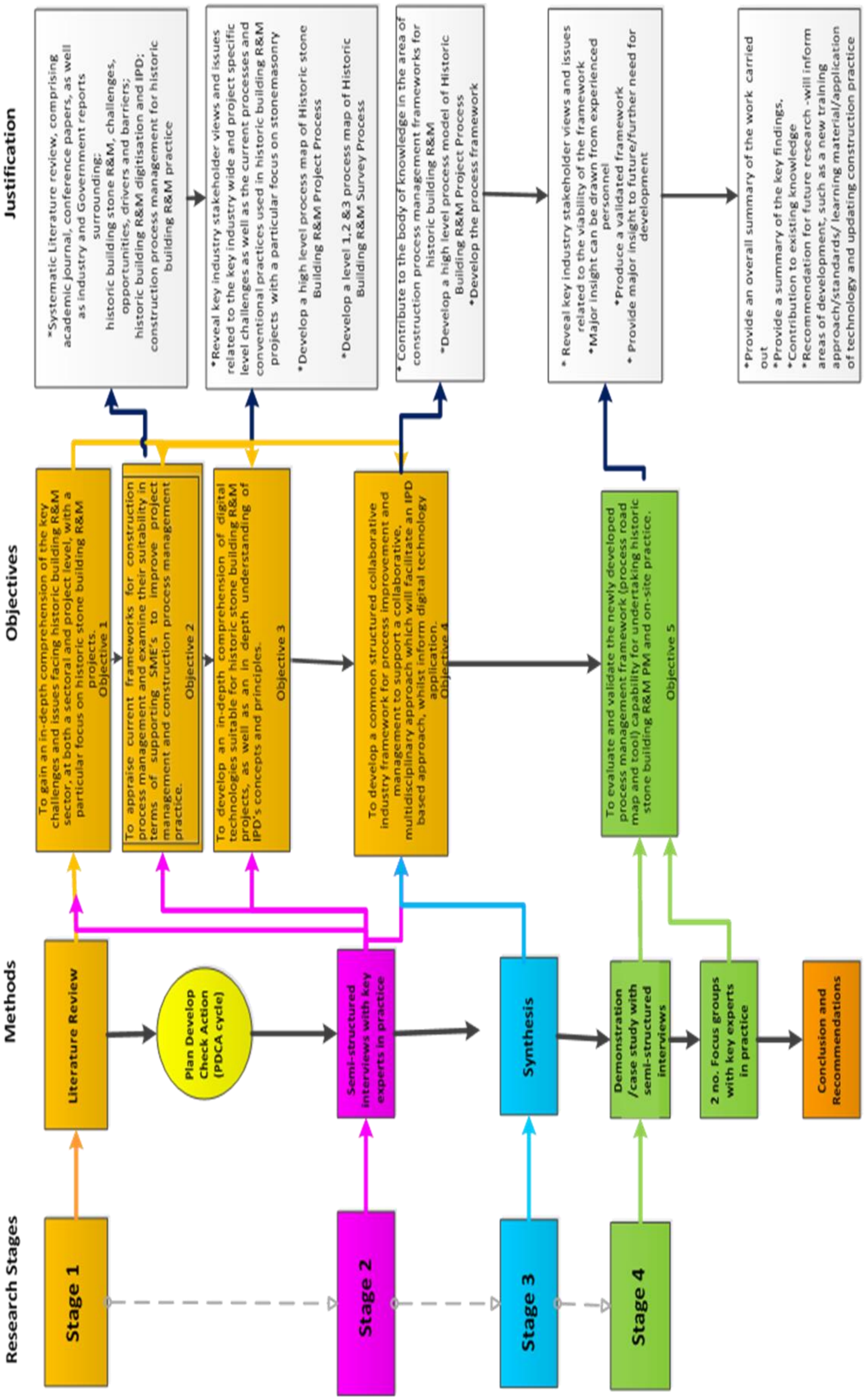


Figure 4.9: Research Methodology Process adopted for the study

Objectives	Qualitative/Quantitative Methodologies
To gain an in-depth comprehension of the key challenges and issues facing historic R&M sector, at both a sectoral and project level, with a particular focus on historic stone building R&M projects.	Qualitative data-Literature review- Semi-structured interviews
To appraise current frameworks for construction process management and examine their suitability in terms of supporting and enhancing PM and on-site construction process management practice.	Qualitative data-Literature review- Semi-structured interviews -
To develop an in-depth comprehension of digital technologies suitable for historic stone building R&M projects, as well as an in depth understanding of IPD's concepts and principles.	Qualitative data-Literature review- Semi-structured interviews -
To develop a common structured collaborative industry framework for process improvement and management to support a collaborative, multidisciplinary approach which will facilitate an IPD based approach, whilst inform digital technology application.	Qualitative data- - Case study Semi-structured interviews
To evaluate and validate the newly developed process management framework (process road map and tool) capability for undertaking historic stone building R&M PM and on-site practice.	Qualitative data- - Case study; Semi-structured interviews; 2no.Focus Group Quantitative data-Questionnaire

Table 4.12: Research Objectives, Qualitative and Quantitative Data Collection Methods used

4.13.2 Literature Review

Performing a literature review is a fundamental part of the research process, as it allows the researcher to demonstrate that they acquired an in-depth exploration of the background theory, equipping them with a professional command of the area of study, in order to justify an original contribution to scholarship as opposed to reiterating existing knowledge (Naoum, 2013). Hence, the literature review (Chapter 2 and 3) forms a significant influence, as it provides the research study's theoretical foundation, rationale, and justification (Saunders et al, 2016). Particularly, given, the key outcome from the literature review was the dual need; to modernise and innovate; and to develop a tailored project management and on-site practice process delivery framework/model, in order to manage project success with better processes and operations. From these outcomes, the focus of the research was established and a set of semi-structured interview questions, were generated to address the succeeding objectives of the study.

4.13.3 Semi- Structured Interviews

Initially, due to the time constraints of the study, the study contemplated employing a qualitative based questionnaire study, however, due to their inherent poor response rate and simplification (Bryman, 2012). The conclusion was that interviews would provide the most effectual and valuable data collection method, at the research study's disposal, for the assembling deep and rich opinions relating to the complex phenomena under study; as they have a number of reasons, disadvantages, and advantages, as noted in Table 4.13. Primarily, they provide a notable opportunity to obtain high quality, detailed, and in-depth information from respondents (Naoum 2013).

Reason	**Advantages**	**Disadvantages**
Divergent subjective data, although fosters constructive discussions resulting in a more holistic viewpoint	Prompt Data availability	In depth organisation, Escalated costs
Deeper richer data analysis due to fundamental question probing	Responses centred on a singular event.	Data insight difficulty due to topic sensitivity and inherent biases
Research topic nurturing	Deeper richer individual interviews realise opportunity for further research	Study sample limitation and constraints (e.g. scope, population size etc.)

Table 4.13: Reasons, advantages, and disadvantages of interviews; Source (Creswell, 2013; Naoum, 2013)

Given this research had an exploratory, explanatory, and interpretive nature, three types of interview format were available; unstructured, semi-structured, or structured (Bryman, 2012). The interview style decided upon was *"semi-structured interview"*, as they offer the flexibility and adaptability required by the researcher, in the study's attempt to gauge the specific, yet potentially wide general nature of this study. Furthermore, adopting a *"semi-structured interview"* approach would allow the respondent to develop ideas and discuss them in-depth, whilst giving the opportunity to express their views, experiences, beliefs, values, as the emergence of additional subjective and qualitative data information may be expected and easier achieved from these types of interviews. Moreover, to enable a successful interview to take place, it was fundamental, to the design and employ standard best practice guidelines, in terms of control and how the interview took place, making the data collection systematic, ensuring that topics and issues of interest were covered (Bryman, 2012). Hence, an interview guide was prepared, mainly consisting of short experience and opinion questions (one overarching parent question and several sub-questions to act as prompts or guides, if needed to assist and promote a free-flowing discussion), scheduled into four sections for the semi-structured interviews conducted (see Appendix C).

4.13.4 Semi- Structured Interview Design

A significant part of designing the interview process is correlating with existing academic and industry knowledge; therefore, it was first necessary to establish the parameters and boundaries regarding the sample of interviewees, and the types of selected organisations (see section 4.8.6.2). The reasoning was twofold; (i) ensuring the most appropriate respondents (relevant expertise and knowledge) had been targeted; and (ii) to provide data collection integrity, validity, and reliability. Once established, it was necessary to consider the number of interviews believed to be satisfactory and sufficient for this research area. Therefore, within each individual stage of the research, semi-structured interviews were employed to collect data, hence, it was deemed necessary to view them as separate elements: for the second stage, as part of the preliminary investigation, 14 interviews conducted; for the third stage, 4 case study interviews; and for stage four, 12 focus group interviews. This was deemed to be satisfactory and proportionate given the specialist nature of the historic building sector. The finalised 30 semi-structured interviews (pilot study, case study, and focus groups) lasted between sixty and ninety minutes.

Despite, the interviews viewed as separate elements, in order to address the research aim, the research objectives and satisfy the qualitative data type required, they were all held face-to-face with MSME and SMEs employed contractors and professionals in the historic building repair and maintenance sector, selected through purposeful sampling (see section 4.8.6.2). Thus, participants were recruited from different private organisations, working in two management levels (middle and top) within the historic building R&M sector, resulting in all having wide experience and held managerial positions (each having a minimum of 15 years' experience), which confirmed all participants had the necessary relevant expertise, skills, and knowledge in the research area, and supported the validity and reliability of the data collected.

Consideration was afforded to providing a unprejudiced evaluation of the framework, therefore participants in the preliminary investigation, were not invited to return and participate either as part of the case study project stakeholders, nor in the focus group sessions, considering they could provide possible biased feedback. Instead, relatively, 4 and 12 new respondents, from a professional and contractor background, participated in the case study interviews and focus group sessions, as they would provide valuable alternative feedback. This tactical approach enabled the study to provide a balanced evaluation of the credibility, dependability, confirmability, trustworthiness, verification, and transferability of the findings to the wider population (Nowell et al., 2017).

4.13.5 Case Study Design

Based on the overarching need to use single case study design, compelled by the fact there are no other cases available for replication (Eckstein, 1975). In essence, the use of a common structured collaborative industry framework, the second qualitative method, to address objectives 3, 4, and 5, adopted was an exploratory, explanatory and interpretative, action research single case study approach. Furthermore, the single case study design methodology being employed, would provide an empirically rich, context-specific, and offer a holistic account, whilst contributing to both theory building and theory testing (Flyvbjerg, 2006; Yin, 2013). This inferential logic is rooted in Eckstein's (1975) influential single case study investigation into the potential advantages of this type of research method, arguing selecting such a unit of analysis, can provide a *"Sinatra inference";* if a theory can make it here, it can make it anywhere (Levy, 2008). Yet, it could be argued, that this is inappropriate and insufficiently generalisable to the wider sector, given a common misunderstanding about single case-study research and its findings: single case generalisation cannot contribute to scientific development (Flyvbjerg, 2006). However, previous studies (Flyvbjerg, 2006; Yin, 2013) on qualitative single case study research, suggested an exploratory, explanatory and interpretive, practitioner-based study, can undoubtedly provide scientific value and support the pathway to scientific innovation. Moreover, the apparent gap in existing knowledge of *"process management and improvement"* for Historic Building repair and maintenance Project Management, suggests the identified paucity of research, would allow this study to seek a wider discovering of theoretical evolution and future research questions, and indeed invoke the *"Sinatra inference"* is at play.

Furthermore, to alleviate the limitations and subsequent concerns of restricted resources, and time, providing, a single case study, as a vehicle to pilot, demonstrate and validate the effectiveness of the developed framework within the bespoke and unique historic sector substantiates the selection. Additionally, with a view, to illustrate its impact and value, in terms of performance and productivity in comparison to current practice and the need to access a well-suited and relevant single case study, it was necessary to posit some first-order selection criteria (Table 4.14). Furthermore, the research study utilised the researcher's extensive industry experience, knowledge and connections., given normally, this would involve an elongated process of searching and identification, followed by a series of continual communications to gain appropriate access. In summary, an exploratory and explanatory, action research single case study, carefully and rigidly selected ensured that the researcher obtained sufficient information, in order to generate research conclusions and recommendation.

Requirements of case study	Purpose
Sufficiently Simplistic without unnecessary historic building R&M complexity	Perform as a clear example (good or bad practice) to preclude avoidable complication
Appropriately focused without being overtly specialised in one technical area (e.g. stonemasonry etc.)	Assessment clarity of varying issues
Literature review findings checked.	To support generalisation in conclusion as opposed to "specific case study conclusion '.
Provide academic level yet easy to present and understand	Founded in substantiated data

Table 4.14: Requirements and purpose of case study (source; Creswell, 2013)

4.13.6 Focus Group

The third qualitative method selected, the focus group data collection method, allowed the achievement of the sixth research objective. Focus groups as a discussion and validation approach to qualitative research are a valuable approach and are a more extensive technique than interviews (Fellows and Lui, 2015). They are regarded as a highly collaborative process, whereby, communication and openness among participants, permits the free interaction, creation and exchanging of ideas and opinions (Lucko and Rojas, 2009; Stewart and Shamdasani, 2014). Moreover, they can lead to insightful information sharing; rapid information generation and gathering; and a consensus of perspectives, about a defined area of interest among experts, however, they need carefully orchestrated, in order to not diverge into conflicting conversations (Lucko and Rojas, 2009). Adding to this strength, various studies (Krueger 1994; Morgan, 1997; Lucko and Rojas, 2009; Stewart and Shamdasani, 2014) have discussed focus groups, in comparison to other qualitative strategies, identifying a key strength, is their ability to collect data about similarities and differences across a number of participants' opinions and preferences simultaneously. Moreover, these studies discussed the optimum focus group number, in terms of focus group sessions and participation, observing that the optimal number, in relation to focus group sessions, for the majority of studies, ranges from one to ten sessions. Although it was noted, that the literature stressed, was wholly dependent upon the investigatory complexity and current subject landscape, allied to the generated data intention application and determining whether additional sessions will simply replicate existing data (Stewart and Shamdasani, 2014). In terms of participant numbers and composition, the consensus in the literature, is that between six and eight participants as the optimal number (Krueger 1994; Morgan, 1997). With regards composition, there is a need to make sure it is homogeneous in constituents, with members sharing similar background and experience (Lucko and Rojas, 2009; Stewart and Shamdasani, 2014), which allows, as the group dynamic emerges, for; sufficiently different viewpoint representation to facilitate opportunities for each participant to exchange comments freely; support the generation of novel proposals and concepts, thereby opening up fresh lines of investigation; and discussion management and moderation efficacy of the discussions and more importantly, (Lucko and Rojas, 2009).

Thus, as this qualitative research study, situated within the bespoke, complex, siloed, and fragmented nature of historic building repair and maintenance; two focus group sessions with 6 professional practitioners and experts from the historic building R&M sector were held. Initially, each participant received an e-mail, inviting attendance at a scheduled focus group session, two months prior to the pre-organised session taking place. On confirmation, an additional email with an official Heriot-Watt University (HWU) attachment was issued; an official form outlining the focus group etiquette, and the newly developed process management framework (process road map and tool) (See appendix D). A week prior to the focus group session discussions, all confirmed invitees, received an e-mail notification, for them to confirm attendance. Two separate focus group sessions (FGS) were held in Edinburgh and Glasgow, respectively, whilst each group comprised of six different participants attending, although in reality eight were invited, but invariably in each group there were a couple of non-attendees. The FGS took place in a board meeting room at City of Glasgow's Riverside campus, a contemporary FE learning centre, whilst the second focus group was held at the researcher's own university (HWU) at its Edinburgh campus situated on the outskirts of Edinburgh (see chapter 9). As due diligence towards good practice, the focus groups were limited to two and half hours in length, since lethargy is a risk among participants, hence they were digitally recorded (Stewart and Shamdasani, 2014). During both sessions, the researcher assumed the role of moderator, and initiated each session by asking each participant for a brief introduction to themselves, then provided an overall synopsis of the research study and issued the relevant focus group documentation.

4.13.7 Questionnaire

Questionnaires are commonly used in Construction Management research (Akintoye, 2000, Dainty, 2008) and tend to be in closed question form (defined bounded responses) or opened question form (no defined bounded responses). Thus, to achieve the quantitative data set, as previously outlined (see section 4.8.5) employing a statistical questionnaire as a secondary data collection method, whereby, the questionnaire comprised of eleven close-ended questions (see Chapter 9, Table 9.5) allowed assessing the overall effectiveness of the framework. The questionnaire, distributed to the FGPs at the end of focus group sessions, who then returned the questionnaire once completed before leaving the session, allowing the researcher to monitor participants who had completed the survey and remind those that had not. Employing a questionnaire also enabled the researcher to relatively quickly, draw conclusions during the subsequent analysis

4.13.8 Qualitative Data Analysis Method

When using qualitative methods, crucially imperative is that robust methods are in place for handling and analysing the data, as, a difficulty may be encountered in corroborating the validity and reliability of resultant findings (Bryman, 2012). Unfortunately, unlike quantitative analysis, qualitative analysis is faced with several obstacles, in selecting the most suitable procedure, such as; lack of a standard communal theoretical framework, model or indeed method; and lack of best practice analysis guidelines (Bryman, 2012). Therefore, it is vital the researcher correlates the theoretical framework with their decisions on methods adoption (Braun and Wilkinson 2003), as undoubtedly, employing both focus groups and interviews directs the research towards substantial amounts of data set collection, invariably in the form of transcripts (digital or written), which can be, both laborious and arduous, in terms of analysis, (Bryman, 2012).

Therefore, for the study's qualitative data analysis method, the adoption of a combination of Braun and Clarke's (2006) and Maguire and Delahunt (2015) procedural guidelines and processes occurred (outlined in Table 4.15). This analysis approach is used frequently, as it is fundamentally an independent and reliable qualitative approach to analysis, given analysing such data is regarded as an ambiguous and multifaceted procedure, especially when employed within alternative analytical strategies such as grounded theory analysis (Denzin and Lincoln, 2011). Moreover, Braun and Clarke (2006) and Maguire and Delahunt (2015), argued that its ability to analytically examine and break qualitative data text into relatively small units of content, through; data familiarisation and transcription; key pattern identification; code generation; theme search; theme review, definition and naming, to allow it to be grouped in a systematic way, permitting different themes and sub-themes to emerge from data, indicates that absolutely it can be considered a wholly independent qualitative data analysis method.

Thematic Analysis Procedures	**Purpose**
Data familiarisation	Exploration of research issues, areas of interest and connections documented formally
Data transcription	Data transcripts rigorously transcribed, in depth data familiarisation fundamental for an effective thematic analysis (Braun and Clarke 2006).
Meaningful pattern identification of issues and patterns	An iterative pattern and theme generation process identifying potential meaning, significance, relations and relevance to research problem
Code generation	Developed codes identify relation to theme and patterns spread across transcripts. Codes assigned to transcript extracts
Collated Extracts	Extracts coded and grouped in relational themes which reflected interview process; minimal personal interpretation to obtain a in-depth discussion on emergent themes, ideas or issues
Theme review, definition and naming	Themes generated from common re-occurring transcript words/phrases, as well related literature review findings to highlight contribution to knowledge and improve the framework.

Table 4.15: Qualitative Thematic Analysis Processes and Purpose used in study (source; Braun and Clarke, 2006; Maguire and Delahunt 2015)

Hence, on reflection, as this PhD thesis involves, an early career researcher with the need to develop core research skills, adopting established procedural guidelines and processes (Braun and Clarke’s 2006; Maguire and Delahunt, 2015) occurred not only support this study but would provide a future vehicle to conducting other forms of qualitative analysis. Yet, fundamentally, due to thematic analysis being suitable for undertaking exploratory, explanatory and interpretative work surrounding a phenomenon, which lacks similar studies, this enabled to provide a flexible and valuable research method that facilitates the generation of deep and rich, yet complex data (Braun and Clarke 2006), whilst allowing the simple reporting of inherent issues reported in the current literature (Braun and Clarke, 2006; Vaismoradi, et al., 2013). Hence, as part of the process, interview and the focus group data was digitally recorded, then transcribed and based on interview/ focus group feedback, qualitative thematic analysis was used to identify, analyse, and report topics arising from both data sets (Denzin and Lincoln, 2011). To aid and assist with the thematic analysis of the responses; all the interviews were categorised and grouped together, then examined using in NVivo 11 for Windows (qualitative analysis software package) for analytical purposes, by allowing the researcher to classify the data as verbatim transcripts. Especially, as various researchers have described such types of data as “the undigested complexity of reality”, needing classification to make sense of the collected data, and concurrently facilitating patter emergence and analysis of recurrent phenomena (Braun and Clarke, 2006; Denzin and Lincoln, 2011; Saldaña, 2013). This process permitted data comparison, contrasting and synthesising, which allowed cross-interview comparison, enabling four key themes to emerge. In essence, allowing the complete thematic analysis procedure to invoke increasingly higher data abstraction intensities.

4.13.9 Quantitative Data Analysis Method

From the focus group questionnaire, the quantitative data collection and analysis, employed was the process of descriptive statistics, in order to discover the patterns within the sampled data, in order to draw conclusions (or “make inferences”) (Denscombe, 2010). Based on the disposition of the variables and the questionnaire being univariate in nature, a frequency distribution analysis methodology was employed (Denscombe, 2010), whereby, each question surrounding the overall effectiveness of the framework, was ranked on a five-point Likert scale: 1 represents “Poor”, 2 represents “Fair”, 3 represents “Satisfactory”, 4 represents “Good” and 5 represents “Excellent”, (see Chapter 9, Table 9.5). In terms of frequency distribution, it refers to the measurement of each scale’s distribution, among the respondents and provides an insight into the data spread; very beneficial in the identification of recurrent scores, known as “measures of central tendency” (Saunders et al, 2016). This expression, refers to the calculation of the collected and analysed data’s mean, median, and mode, whereby; the mean relates to the statistical average of all the scores, whilst the median relates to the statistical flection point, as 50% of scores are either above or below the mean value, whereas the mode relates to the most frequently recurrent distributed score (Creswell, 2013). However, sole reliance on “measures of central tendency”, is conceivably an ambiguous perspective to take (Lucko and Rojas, 2009), given observation of these measures (mean, median, and mode) could occur across several distributions of scores, yet offer variability across the dispersion of scores (Denscombe, 2010). In essence, distribution scores in one instance, could be clustered more around the vicinity of “the measures of central tendency”, as opposed to other distributed scores (Creswell, 2013). Therefore, to define and exhibit the level of variability in the distributions, referred to as the "measure of dispersion" (Creswell, 2013), and based on logical reasoning and anticipated interpretation of the results, whereby the symmetrical distribution of the statistical data, deemed adopting the statistical quantification tool standard deviation would be more interpretable (Denscombe, 2010). Typically, calculating the standard deviation, the tendency is to use a Statistical Package for the Social Sciences (SPSS). However, it was decided to calculate these measurements by hand using standard formulaic expressions (see Figure 4.10), due to two overriding reasons; (i) the mean is the only one that requires a formula, and (ii) the small population size of the combined focus groups (12 FGPs in total).

$$\frac{\sum_{i=1}^{N} x_i}{N} \qquad \frac{n+1}{2} \qquad \sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}}$$

Figure 4.10: Standard formulaic expressions used in research study to calculate; Left-hand side; the mean; Σ means to sum things up, *N* relates to the number of data points, whilst *Xi* represents each of the value of the data. Middle; the median; n relates to the number of data points divided by 2; Right-hand side; the standard deviation; achieved by calculating the square root of the mean and all its values (μ is the mean of all values)

4.14 Summary of Chapter

In this chapter, the theoretical research design model adopted; Saunders, et al., (2016) "Research Onion", the strategy and the methodology adopted for the study were discussed, which provided a structured and systematic guide through the research process, demonstrating the study's informed decisions, illustrating that pragmatism is the underlying philosophical perspective. A comprehensive justification was presented, in relation to the selected data collection and analysis strategies, methodologies and subsequent methods, and the precise ways in which the corresponding research strategies (conducting data triangulation through qualitative multi-method strategies) and the research validity and reliability criteria concepts ensured the quality of the current research, were explained. To provide the reader with a coherent description of the outcomes of Stage 2, the data analysis results, findings and discussion are presented in Chapter 5 and 6.

Chapter 5: Understanding the Challenges facing Modernising and Enhancing Historic Building R&M; Study on Industry Practitioners Perceptions

5.1 Introduction

Chapter 5 presents the qualitative data analysis findings from the pilot study; stage 2 of the research study, focussing on the discussion surrounding, the following two main areas: (1) Key challenges facing historic building repair and maintenance in Scotland (Sector wide & Project Specific); and (2) the typical project delivery phases and processes used by MSME and SMEs in current practice. Fourteen individual semi-structured interviews with key sector practitioners were undertaken, thus, to enable relevant themes and emerging concepts to materialise during the interview process; an interview guide was produced which provided a roadmap of questions, located in Appendix D.

The main aim was twofold, to validate the literature review and construct more robust evidence, as to whether: (1), the challenges and issues identified were perceived to be the same by historic building R&M sector practitioners; and (2) based on literature and the author's empirical and anecdotal experience within the sector, a draft high level process map of the Historic Building R&M project delivery process (key phases and processes) was presented, which was re-iterated through the interview process. Based on the interview data, the challenges/issues identified were classified under three themes: technical, human resource and senior management. The chapter begins with illustrating the background details of the interview participants (see Table 5.2). Furthermore, parts of Chapter 5 findings are published in the following Academic journals: International Journal of Building Pathology and Adaptation (formerly Structural Survey) (McGibbon and Abdel-Wahab, M., 2016), and Journal of Cultural Heritage Management and Sustainable Development (McGibbon, Abdel-Wahab & Sun, 2018) (Appendix G).

5.2 Pilot Study on Industry Practitioners Perceptions

5.2.1 Interview Participants

Taking into consideration, both contractor and professional MSME and SMEs, are widely acknowledged, as fundamental components within the transient and specialist historic building repair and maintenance eco-system, it was decided to focus on providing a combination of these industry practitioners (Table 5.1).

Respondent	*Interviewee Position*	*Role*	*Experience Qualification*	*Industry*	*Area of practice*
RA	Managing Director (MD)	Contractor	25 Yrs (RICS)	Private sector	All trades
RB	MD	Contractor	25 Yrs SVQ	Private sector	Stonemasonry
RC	MD	Contractor	25 Yrs SVQ	Private sector	Stonemasonry
RD	MD	Supplier	25 Yrs SVQ	Private sector	Stonemasonry
RF	MD	Design Professional	35 Yrs (RIBA)	Private sector	All trades
RG	MD	Design Professional	25 Yrs (RIBA)	Private/Public sector	All trades
RH	Building Surveyor	Consultant	25 Yrs (RICS)	Private sector	All trades
RI	Building Surveyor	Consultant	15 Yrs (RICS)	Private/Public sector	All trades
RJ	MD	Contractor	25 Yrs SVQ	Private sector	Stonemasonry
RK	MD	Contractor	15 Years (RICS)	Private sector	Stonemasonry
RL	Project Manager	Contractor	25 Yrs Bsc.	Private sector	All trades
RM	Project Manager	Contractor	25 Yrs SVQ	Private sector	Stonemasonry
RN	MD	Consultant	25 Yrs (RICS)	Private/Public sector	Stonemasonry
RP	MD (Building Surveyor)	Consultant	20 Yrs CA (RICS)	Private/ Public sector	All trades

Table 5.1: Background and Profile of Interviewees

The focus centred on industry practitioners who had direct project and diverse professional experience (a minimum 15 years' experience); held industry recognised occupational qualifications and/or professional body membership (CIOB/RICS/RIBA conservation accredited) (Table 5.2); and occupied middle/top-level management positions within their organisations. Hence, the interviewees' encapsulated the full spectrum of historic building repair and maintenance practice experience and knowledge, ranging from; technical practice level to senior management processes. The interview findings are concurrently organised, whereby, the thematic identification of the prominent key challenges are substantiated by interview extracts. The contribution of this strategy supported the development of a high-level Historic Building R&M project delivery process map of phases and processes currently used in practice in Scotland, assisted in highlighting the common process issues related to project under-performance, discussed in Chapter 6.

5.3 Identification of the key challenges facing the Historic Building R&M Sector in Scotland

5.3.1 Interviews Findings and Discussion

The literature review, primarily surrounding the Scottish historic building repair and maintenance sector, at a strategic and project specific level, had highlighted a number of significant correlating industry challenges, which reflected the desire to improve the quality, performance and efficacy of R&M, all within the background of the Government's strategies and targets for preserving the built heritage (HS 2012; SHEP, 2011; and Scottish Government, 2014a). Hence, the fourteen respondents were posed a series of questions, as to whether the strategic and project specific challenges identified within the literature review were perceived to be the same by the practitioners, as well as being asked to identify, what they considered were the possible causes and impacts.

The interviewees were initially posed the following open-ended question; ***"In your opinion, what are the key challenges facing historic building R&M practice, at an industry wide and project specific level?"***

In total, nineteen specific different challenges, were identified, as illustrated in Figure 5.1, ranging from; regulatory to project funding to skills, which were classified under three key themes, deemed the broader cross-cutting strategic sector and project level challenges, namely: (1) Senior management; which impact MSME and SMEs in their aim to help meet their business and project objectives; (2) Human resource; which impact MSME and SME practice and their aim to deliver high quality works; and (3) Technical;

which impact the sectors knowledge, skills, and abilities and the aim to deliver high quality works.

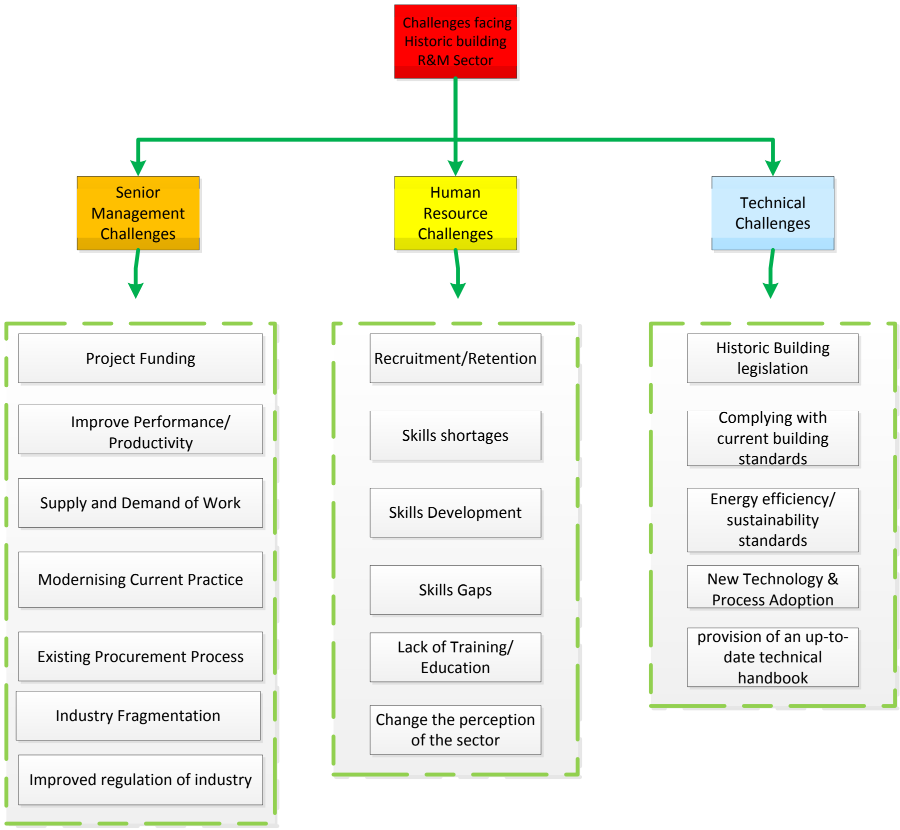


Figure 5.1: Themes of Key Challenges Facing the Historic Building R&M Sector

The replies from the respondents, suggest that they had a consistent idea amongst their own group of the key challenges facing R&M of historic buildings, and were homogeneous in their view that six of these challenges were major issues. Yet, the importance of each challenge seems to have been driven by the respondent's current role and background, however, in reality the amount of key challenges offered by respondents indicates the recurring mantra that at an industry-wide and project-specific level, these challenges are not only inextricably linked, but also multi-faceted and technical. When viewed within the context of historic building repair and maintenance practice, it is easy to appreciate why the subject is considered a complex, unique, and bespoke landscape. Hence, in essence, the replies resonated with the literature (Abdel-Wahab and Bennadji 2013; COTAC, 2014; Deloitte, 2014; Dyson, Matthews, and Love, 2016; ECORYS; 2013; Forster and Kayan, 2009; Forster et al, 2011; Forster et al, 2013; Kayan, 2015; Kayan et al., 2016; Kayan, Forster, & Banfill; 2016; HS, 2010, 2012; IHBC, 2014;

Mohamad et al., 2015; NHTG 2007, 2008; Pye Tait, 2013; SSLG, 2006; SHEA, 2018; SCHS, 2016), as they surrounded the topics of: *education and training, recruitment, supply and demand, disrepair levels, economics, technology, sustainability, modernisation, process improvement and performance measurement.* Within each theme, the relevant sub-category challenges, were then analysed based on the number of respondents who voiced each challenge, to allow the key challenges to be identified, as illustrated in Table 5.3 – 5.5. Hence, the following sub-sections, presents and discusses the key challenges identified, whilst providing brief examples of responses.

5.3.2 Theme 1: Senior Management Challenges

Findings and Discussion

In the first theme, respondents discussed a range of senior management challenges facing historic building R&M practice, and echoed the literature (Abdel-Wahab and Bennadji 2013; Bullen and Love, 2011 a&b; Deloitte, 2014; Dyson, Matthews, and Love, 2016; ECORYS; 2013; Forster and Kayan, 2009; Forster et al, 2011; Gillespie and Tracey, 2016; HS, 2010; Hyslop, 2004; NHTG 2007, 2008; NHTG 2007, 2008; Pye Tait, 2013; Shipley et al., 2006; Smith, 2005), revealing a range of similar important strategic challenges, namely; *project funding, awarding of local contracts to local contractors, supply and demand (work and the workforce), modernising current practice, existing procurement processes, improve performance/productivity, industry fragmentation, and improve industry regulation,* as illustrated in table 5.2.

However, despite this range of senior management issues, there were two key fundamental challenges, in one form or another, which consistently scored the highest, during both the interview session with the respondents and during the thematic analysis process, namely; ***Project Funding and Supply and Demand.*** Unanimously, they all stressed the challenge of *supply and demand* was inextricably linked to the key challenge of *project funding* and from their perspective both were of equal standing, as such, these two key fundamental challenges are discussed.

All fourteen respondents muted that the key challenge of *project funding* was a continual issue within historic building R&M projects. For example, respondent RF, based on 35 years' worth of PM experience remarked, *"there is a tendency to apportion insufficient monies to the project"* commenting further, this was *"very typical when dealing with historic buildings".* This brings into question if there is enough funding to support the repair and maintenance activities of historic buildings. Yet, when investigated further on this issue, the majority of respondents conceded it was not the amount of project funding needed. This concurs with current official statistics estimating pre-1919 non-housing and housing private sector investment at around £0.72 billion per annum (ECORYS (Firm), 2013; SHEA, 2016;2018).

Response	**SME; Contractors in agreement**	**SME; Professionals in agreement**	**Total no. of stakeholders in agreement from**	**SME Interview total**
Project funding	8	6	**14**	**14**
Supply and demand	8	6	**14**	**14**
procurement	8	2	**10**	**14**
Improve performance/productivity	5	5	**10**	**14**
Modernising practice	5	4	**9**	**14**
Industry Fragmentation	4	4	**8**	**14**
Industry Regulation	4	4	**8**	**14**

Table 5.2: Senior Management Challenges

Respondents (RN; RP) both suggested it was a need to have a, *"more effective use of funds, derived from the private and public sector"* ; and "*that part of an effective use of funds, was the need to evenly spread the market share of contracts".* When asked what they meant by this, they proposed that there was a need to observe, *"an increase in the steady release of smaller R&M projects, across both public and private funded projects, as opposed to a release of larger projects instantaneously, which would help competition at SME level, as projects would hopefully be contractually less complex allowing an ease to procuring funding.".* Such comments highlights the challenge and subsequent solution of project funding, requires to be approached holistically, although, when investigated further regarding their understanding of the current funding frameworks and who was responsible for ensuring sufficient funding is available. The feelings surrounding this problem were highly emotive, with several contractor SMEs (RA,RB, RC, RD, RK) raising, the interconnected project challenge of late payment, with RA concernedly reported, *"when this happens, I stop work on the project, whether the Main contractor or the client's consultant's defaults on payment according to the terms agreed. I am a* *specialist so they just can't go get someone else easily".* Furthermore, RK proclaiming, *"Many main contractors will use specialist sub-contractors to bank roll projects",* stressing, "*if you don't have the cash flow to finance a project, large organisations should never win at tender stage".* Several respondents candidly admitted, from a SME business capacity, *"it is not my business or responsibility, as in reality, I am more concerned with if the money is there, not where it came from".* Adding to the debate, given a large majority of projects are self–funded, respondent RL, echoed the literature, (Dyson, Matthews and Love, 2016; Bullen and Love, 2011 a&b; Shipley et al., 2006), that, "*finding extra monies from private sources is difficult, as most people (funders, banks, private building owners etc.) perceive projects to have numerous inherent threats such as the probability of cost overruns".* Moreover, a number of respondents, who procure, a majority of their work within the private domestic sector, suggested the reasoning behind this was, *"budgeting for historic building R&M is viewed as a subsidiary responsibility, resulting in insufficient budget allocation at the time of the decision to carry out repair works".* Although this perspective in essence appears justifiable, the literature whilst, echoing this viewpoint, remarked many prospective clients struggle with the realities of budgeting and the possibilities of fund raising, regardless, whether in public or private realms (Smith, 2005).

With regards, the second key challenge identified; *supply and demand*, *a*ll fourteen respondents were in agreement, mirroring the literature, raising it, as not only a fundamental issue but a complex subject, connected to a myriad of correlated issues (skills shortages, bespoke and specialist sector nature, current disrepair levels etc.). Respondent RD remarked that supply and demand was suffering from "*a contradiction driven by an amalgamation of poor client confidence and lack of investment in potential future projects".* Yet, several funding schemes exist, which are designed to create a demand, such as the UK wide Heritage Lottery Fund (HLF) and its subsidiary Townscape Heritage Initiatives (THI), whilst the Traditional Building Health Check (TBHC) scheme, is initiated to promote and stimulate quality proactive repair and maintenance (Historic Scotland, 2012c). Whilst undoubtedly a forward move, in terms of; demand uptake and subsequent condition improvements in historic buildings, many of the respondents (n=9) praised these schemes, as invaluable, although there seems to be a focus caveat, observing that, *"the schemes are excellent; however they tend to be focused on restoring, revitalising and regenerating of key buildings within town centres".*

Reinforcing the earlier position of a sector contradiction, RH and RI, in their roles as independent historic building inspectors, stressed "*It's a bit of a chicken and egg situation; there is no end of need for repair in this country, given the current alarming level of statistics of buildings, requiring work within the private and public sector, yet neither the money nor is the skills there, available to service the demand".* Moreover, the eight industry experts from a contractor capacity (RA, RB, RC, RD, RJ, RK, RL, and RM) and the remaining four professional respondents (RF, RG, RN and RP) resonated that the demand is there, observing in general *"combatting the current alarming disrepair levels is a given"*, Yet they questioned it was not only a case of *"generating more work"* it was also *"the need for a flexible and integrated response to the skills supply and demand issue".* Re-iterating the earlier point raised in the discussion on the key challenge of project funding, whereby various studies have highlighted the demand is not enshrined in Scotland's town and city centres, but across all areas of a locale (SCHS, 2015; Historic Scotland 2012c; SSLG, 2006).

On reflection, the consensus was that the two key senior management challenges, that arose from the data analysis were not only inextricably linked but in reality, were of equal standing, in terms of business growth as well as delivering improvements in project works quality, efficiency and value. Unsurprising, as all respondents underscored this perspective, explaining it from a business capacity; RF provided a succinct commentary, remarking *"without an increase in project funding, the issues of supply and demand surrounding the amount of work and the lack of availability of the appropriate skill set at contractor and professional level will continue, much like the continuing constraints provided by existing tendering approaches, leading to the perpetuation of not only a lack of a multi-disciplinary approach but also a lack of structured and collaborative approach will result in a continuation of poor project delivery and performance".*

Within the mix of SME contractors and professional practitioners, philosophically, it was suggested to alleviate these problems, that there is potential and a belief that by adopting a stronger perspective on promoting quality proactive R&M, will in turn create an increase in the supply and demand arena. For such an evolution, the need is to transform the demand into a continual workflow. This in part could explain why it was not an increase in demand that was required but a raising of a steady workflow for SME's which according to one reply will in turn provide *"the opportunity for an SME to have steady stream of work for the next 5-10 years and look to pro-actively plug the skill supply and* *demand".* This comment further emphasises that if a holistic, integrated, structured and unified approach was adopted to projects, more work would be delivered successfully, which would increase the desire to provide more funding, and the required supply, and demand needed to service current disrepair levels (HS, 2012).

5.3.3 Theme 2 Human Resource Challenges:

Findings and Discussion

Numerous industry specific intelligence reports (NHTG Research Report; 2005; 2007; 2008; 2009 and UK Built Heritage Sector Professionals NHTG Report, 2008; Pye Tait, 2013; SSLG, 2006), have illustrated the continual challenge of human resourcing (HR) facing the sector, again echoing the literature and revealed a number of significant challenges such as; *skills development, skills shortages/gaps, changing the perception of the sector, recruitment/retention of the workforce,* and *lack of training/education,* evidenced with the continual decline in workforce numbers and training up take, coupled with limited trainee and apprentice opportunities. From the aforementioned human resource challenges, two fundamental challenges stood above all the rest, namely: *skills shortages and skills gaps* (see table 5.3).

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of SMEs in agreement from	SME Interview total
skills shortages	8	6	14	14
skills gaps	8	6	14	14
skills development	5	5	10	14
Recruitment/retention	3	5	9	14
lack of training/education	4	4	8	14
changing the perception of the sector	5	4	8	14

Table 5.3: Human Resource Challenges

In terms of profession, all respondents agreed that, there was no boundary, with major issues at both contractor and professional level within each key challenge, re-iterating the literature. With regards *skills shortages,* respondents (RF; RG) based on their professional background pointed out, most of the issues in these reports, could be transposed into the professional field, commenting, *"most skills shortage surveys focus on the craft level, however within the professional realm the issues are the same"*, further adding, *"a shortage of expertise in the design team for historic building R&M projects (Architect; Structural Engineer; Building surveyor)".* Contrastingly, several SME contractor background respondents (RA, RB, and RC), whilst agreeing that *skills shortages* was a key issue, remarked, "*genuinely from a company perspective it is not an issue",* part in fact, to being pro-active employers regarding the interrelated challenges of workforce recruitment/retention and skills development. All three, similarly enthused, they endeavour to employ at least two apprentices a year, as a way to recruit new blood into the sector. They see skills development as a, *"lifeblood of the company"* believing there was a dual opportunity to not only, *"promote the craft as a valued alternative to academia"* much like the highly regarded dual apprenticeship scheme training found in Germany, Austria and Switzerland (Fuller and Unwin, 2008), but provide in-house training for their already qualified workforce (craftsman and professional) staff, in order to support performance and business growth. However, they did remark that they were aware that this might not be the case for the rest of the industry, with RA offering, *"the expensive and time consuming nature of historic building training and education presents barriers to the industry",* whilst RB and RC both cited, *"industry fragmentation and the prevalence of specialist sub-contracting"* as further possible barriers to addressing the industry skills shortages.

Indeed, respondent RF, a highly experienced conservation accredited architect and also an industry renowned stone consultant, warned that ultimately, "*without an adequate supply of quality of craftsman and professionals with the necessary skills and knowledge, regardless of demand, the building will suffer*". Which gives rise to the question; how can demand be satisfied, when the number of suitably qualified professionals and contractors is unknown specifically by industry, which in turn informs the public sphere? This ambiguity is further fuelled by the construction industry's fragmented nature (Dainty et al., 2005), which is symptomatic of UK construction as whole, with opportunities for apprentices and craftsmen tending to not be advertised (Clarke and Hermann, 2007).

The second central HR challenge; *Skills gaps* was unsurprising, given the intrinsic link to *skills shortages*, evidenced by the plethora of literature highlighting poor practice at contractor and professional level with the ever increasing number of studies into the inappropriate use of lime and stone (see Forster 2010a; 2010b; Forster and Carter, 2011; Forster et al., 2011; Henry and Stewart, 2012; Hughes, 2012; Hyslop, 2004; Lott, 2013; Odgers and Henry, 2012; Snow and Torney, 2015; Torney et al., 2012; 2014; Torney and

Hyslop, 2015). For example, a number of contractor SME respondents (n=8) remarked in one form or another that *"building professionals when specifying stone repairs, lack the knowledge of the complexities involved with R&M. of a historic building"*. They attributed this to the lack of professionals with *"hands-on technical knowledge"*, a perspective that is borne out in reality; the majority of higher education curricula has an inadequate coverage of traditional building materials and techniques and lack practical learning elements (NHTG, 2008). This could explain why they also remarked that an often-typical inference from the building professional was that they tend to have "*an over-inflated expectation of what the project budget can deliver"*. Giving credence to this perspective, the SME professionals respondents (RF, RG, and RP), concurred, by drawing on their typical experience of the planning phase of a project, stating that "*they would consider defining the scope to be the most difficult component of the project*." Rationally explained by, Respondent RH who indicated there needs to be *"an educational shift not only from a contractor viewpoint but also from a consultant/professional perspective"* further adding *"it's the whole education factor, from gaining a better understanding of the reliance of continual upkeep to the existing building stock to an improved approach to the complexities involved with Project Management of historic building repair".*

Moreover, the dual challenges of; *skills shortages and skills gaps,* are further compounded by legislation (SHEP, 2011) and guidelines (Historic Scotland, 2015; BS 7913; Urquhart, 2007; Knight, 1995). As, currently, they do not stipulate that specific qualification levels and skills, which are a pre-requisite to working on historic buildings, as there are distinct skills and knowledge, attributed to the bespoke practice of historic building repair (PYE Tait, 2013). Hence, much like the complex and fragmented landscape of historic building repair sector, *skills shortages and gaps* cannot be solely *"plugged*" as described by several contractor and professional respondents alike, by an increase in the workforce or an increase in training, individually. Suggesting, in reality, to truly realise a suitably skilled workforce and long-term planning of resources to meet industry requirements; perhaps adopting a holistic interdisciplinary approach to practice and training, is a way of providing a pathway for the workforce to not only gain the necessary skills and knowledge needed to achieve successful historic building repair, but also circumvent the existing deficiencies in the workforce shortages, in order to support improvements in project performance. Although, to accurately reflect, given the lack of official demographic data surrounding the sector, there is an urgent need for project-based data on historic building skills, in a similar vein to SSLG (2006) city study of |Glasgow's stone-built heritage needs

5.3.4 Theme 3: Technical Challenges:

Findings and Discussion

From the literature, a number of technical challenges were raised, within the overarching areas of; energy efficiency to sustainability to adhering to building standards (Baker, 2010; Forster et al., 2011;2013; Kayan, 2013; Kayan et al., 2016; Naeeda, et al, 2010; STBA 2012; HES, 2012-2019). Hence, given the practical background of the sector, and the various SMEs interviewed, similar challenges were raised; namely; *historic building legislation; energy efficiency/sustainability standards; current building standards; hidden/latent defects; an up-to-date technical handbook; new technology & process adoption.* However, similarly, to the theme of senior management, the importance of each challenge seems to have been driven by the respondents' background; as over 60% of the respondents (RA; RB; RC; RD; RJ; RL; RM; RN) tended to discuss the management of the technical elements, relating these to carrying out site processes and work practices (discussed further in 5.3.2), whereas the remaining 40% of respondents (RF; RG; RH; RI; RK; RP) were more focused, on the managing of on-site operations and processes, in part to their professional background, as having more day to day dealings with the Project Management process and seeing the impact these challenges delivered (table 5.4). Nonetheless, despite, each respondent having their own perspectives and raising a number of pertinent perspectives, two key challenges surfaced universally, namely; *current building/energy efficiency/sustainability standards; and hidden/latent Defects.*

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Building; energy efficiency; sustainability standards	8	6	14	14
Hidden/Latent Defects	8	6	14	14
Historic Building legislation	4	6	10	14
up-to-date technical handbook	5	5	10	14
New Technology & Process Adoption	4	4	8	14

Table 5.4: Five Key Technical Challenges

In terms of, the first key challenge; *current building/energy efficiency/sustainability standards*, despite, an apparent paradox; respondents from a SME contractor capacity, in general viewed this challenge as being prohibitive in nature, encapsulated by RA, lamenting *"meeting the requirements of Historic Building standards can be time consuming and creates difficulty from a business perspective when trying to schedule and/or programme the intended works".* Whilst SMEs from a professional capacity viewed it as a tool to drive quality historic building repair works, stressing "*a lot of additional Project Management activities, in not only the design process but also the construction process, are needed to achieve compliance with standards and provide quality outcomes".* Yet, despite this apparent contradiction, the consensus of the mix of contractors and professionals agreed, when dealing with such technical requirements, that a lack of understanding of the intricacies of current building/energy efficiency/sustainability standards, was on of the main reasons behind the lengthy project timescales highlighting, *"a considerably greater level of consultation is required, as there are significantly more people, procedures and processes to consider".*

In terms of the second key technical challenge, overwhelmingly, *hidden/latent defects,* was seen as the second key technical challenge facing the historic building R&M, inferring this was *"the biggest one"* with several echoing *"unknown conditions"* are one of the main causes of project delays, and increase in costs. A recurrent reaction to this challenge was the common view, that it had a direct result on historic building processes, particularly within the planning and execution phase of a project. Summarised by respondent RG, who reflected on their own project experience, observing "*hidden defects on previous projects had impacted a number of processes such as planning/programming/scheduling which had squeezed the project budget".* There was a sense amongst the respondents that this was an inherent part of historic building R&M projects, inferring *"in actuality you have to design and document projects without knowing fully enough about the building".*

They alluded, despite their extensive project experience; they had been continually surprised as to the actual extent of hidden/latent defects that were not apparent at first inspection, reinforcing the bespoke complex and specialist nature of historic building R&M. Moreover, when the number of possible hidden defects and latent conditions is unknown, specifically at the planning/design phase which in turn informs the construction process sphere, gives rise to a further question; how can quality, performance and effectiveness be achieved in the repair of the stone-built heritage? This could explain why eight respondents (RC, RD, RF, RH, RJ, RK, RL, and RP) declared that further significant challenges were to; *incorporate technology into historic building R&M and create an up-to-date technical handbook*.

Yet, it remains to be seen how far historic building repair projects, are conforming to current technical and quality standards, and where the conflicts might be between education/training and application. Although recent research (HS, 2010) offered a possible conflict identifying a distinct lack of relevancy towards historic building repair within current apprenticeship training content, despite governed by National Occupational Standards: (NOS), whilst within the realms of historic building repair specification and scoping of works creates a dichotomy between the tension of appropriate repair vs. the most sustainable in terms of whole life expenditure (Forster et al, 2011), an issue which is further complicated by the substantial errors in the way that traditional buildings are treated in building standards, regulations and assessment systems (STBA, 2012). This demonstrates, that deciphering technical challenges into their individual areas was indeed difficult in itself, as repair and maintenance, ought not to be viewed as a straightforward and simple process. On the contrary, the project's technical challenges ought to be viewed as a natural part of a holistic and integrated approach, based on a triple partite philosophy (quality, performance, and effectiveness) combined with firm action and advanced deployment of expertise and skills.

5.4 Key Phases and Processes used by SMEs in Historic Building repair and maintenance Project Management and On-site Practice

5.4.1. Development of Conceptual Historic Building R&M Process Diagram

Based on research objectives 1, 2, and 5 (see chapter 1; section 1.5), the study now sought to collect data concerning the typical project delivery phases and processes used by MSME and SMEs in practice. Based on the literature (British Standard 70913:2013; RIBA, 2013; RICS, 2009) and the researcher's experience within the sector; a draft high-level process map of the key phases and processes was developed, then subsequently presented to the interview participants, whereby, they were asked to evaluate and modify the diagram, if needed. This enabled the researcher to develop a collectively generated generic process map, thus embedding the PhD research within an industrial context, whereby, utilising action research is essential towards ensuring greater collaboration between academia and industry and preparing players in the field for process improvement through appropriately designed support tools. Thus, the hypothesis was such a strategy would support the development of a high-level generic map, as illustrated in Figure 5.3, in order to inform the development of a SME focused common structured collaborative industry framework to improve the management of Scottish historic stone-built repair and maintenance projects.

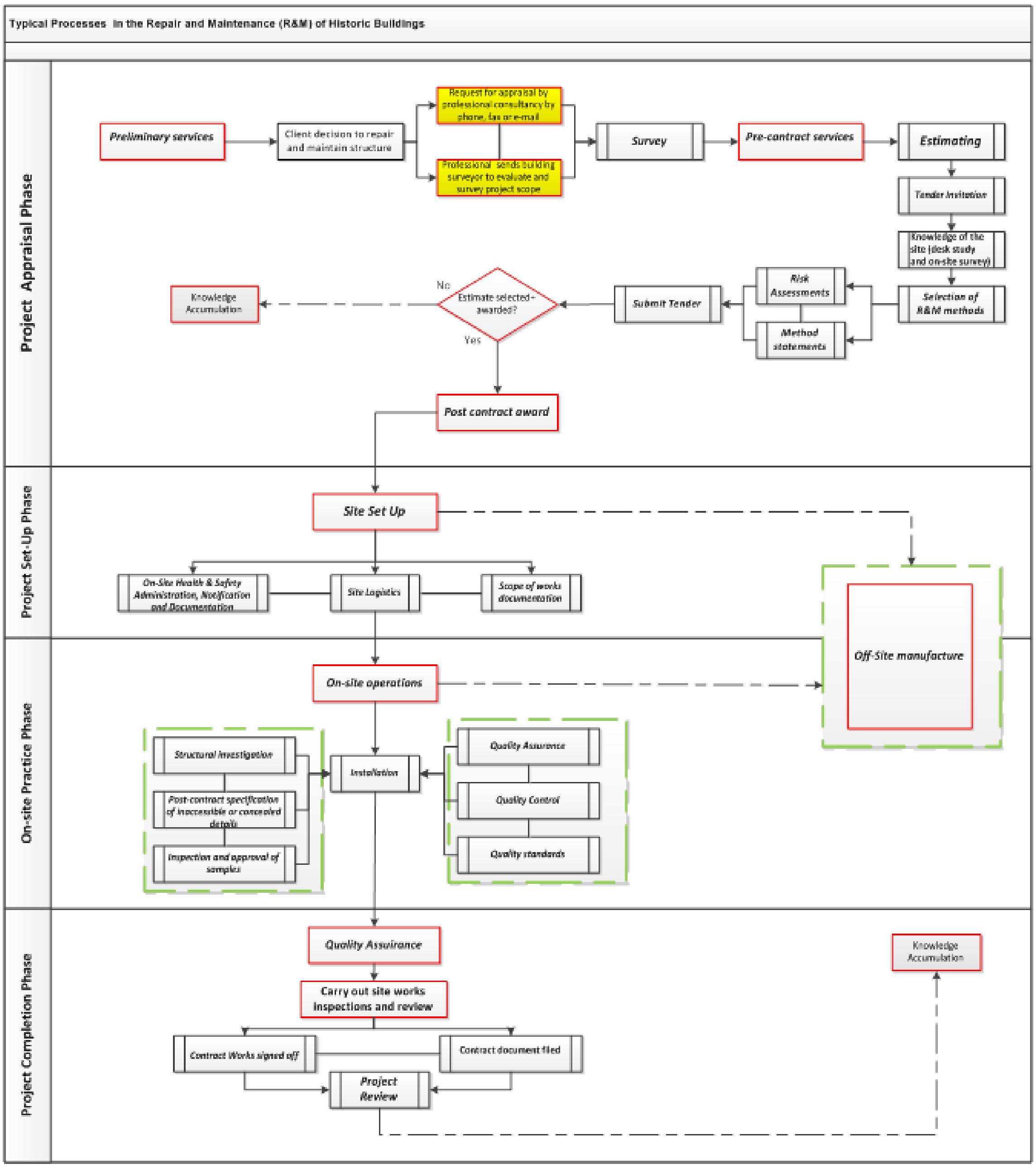


Figure 5.2: Conceptual Diagram of Generic Historic Building R&M Process: See Appendix E for full illustration

As an initial starting point the fourteen industry experts were primarily posed the following open-ended question: ***"Based on of your knowledge, expertise and responsibility; what are the key phases and processes used in historic building R&M project delivery from start to end?"***

Influenced by their backgrounds whilst in a Project Management capacity, as well as a business function, in response to the initial open-ended question, several interviewees summarised the process generally, whilst others debated individual parts of the process. Although the consensus was to discuss specific phases of the entire process, dependant on their day to day practice, for example, SME contractor respondents unsurprisingly placed more emphasis on the construction process, pronouncing "*project delivery has a number of phases, however, the focus for us as a contractor, is without a doubt at the coal face and the actual physical doing of on-site operations"*. Whereas the SME professional respondents reciprocated the inclination towards their area of preference, viewing the design process with a greater sense of focus, articulating, "*the design process, whether that be specifying or generating drawings drives everything that occurs on a project".* Nonetheless, despite each respondent having a coherent idea as to their own organisation's evaluation of the importance of their area of focus, they did concede the Project Management of the design and construction processes, requires to be viewed in equal measure, proclaiming, *"the responsibility is ultimately to assess, investigate, specify, schedule, construct and maintain the program".*

Thus, all 14 interviewees concurred; that they tended to adopt a four-phase model. However, as revealed by the interview results, the naming of each phase of the 4-phase historic building repair and maintenance process is not uniform across all 14 respondents; Table 5.5 illustrates the exported Node Matrix (Nvivo output) of the key phases and processes. Whilst in essence, the varying terminology used describes similar processes, the disparity in terminology could be due to varying technical backgrounds across the various 14 SMEs; for example, professional SME practitioners (RF, RG, RH, RI, RN RP) tended to switch between the terminology used within their areas of expertise, whether they were either an Architect, Surveyor or Project Manager and what professional organisation they allied themselves to (RIBA; RICS; CIOB), such as; *project planning or project inception* or *project feasibility*.

Response: Key phase	SME: Contractors in agreement	SME: Professionals in agreement	Total no. of stakeholders in agreement	SME Interview total
Project Completion	8	6	14	14
Project Set-Up.	6	2	8	14
Project On-site Practice	6	2	8	14
Project Appraisal	6	1	7	14
Project Planning	2	3	5	14
Project Design	0	2	2	14
Project Execution	0	2	2	14
Project Construction	0	4	2	14
Project Feasibility	0	2	2	14
Project Inception	1	1	1	14

Table 5.5: Key Phases and Processes used in the Management of Historic Building repair and maintenance Projects

Although, intriguingly, RF (a conservation accredited Architect; MD of a design consultancy and a member of RIBA) subscribed with the vast majority of contractor background SME respondents (RB, RC, RD, RJ, RK, RL, RM), naming the start of a project, the *appraisal* phase. Relatedly, contractor SME; RA and RL, reciprocated the professional SME response and referred to this stage in the project lifecycle as the *planning* phase. Similar situations arose regarding the naming of the other three phases of the generically agreed 4-phase project model, for example; for project organising and administering they imparted three distinct terms; *project planning or project inception or project set-up*; whilst for the actual works stage of a project they again offered three separate terms, however, they were more correlated; *execution, construction and on-site practice*, and finally for the end of a project they were unanimous in their selection, advocating; the *project completion phase.*

Furthermore, when explored deeper regarding the validity of a generic 4 phase model, they highlighted, within each phase, there are sub-phases that are associated with specific activities and tasks, which are linked to distinct historic building repair and maintenance processes. Moreover, a plethora of sub-phase terminology was suggested by the 14 respondents, such as; *pre-planning, pre-construction, estimating, tendering, survey, scope of works, logistics, health and safety, on-site administration, notification and documentation, site preparation, etc.* Regardless of the numerous sub-phase terminology provided, two divergent and often conflicting discourses emerged; the complexity of the historic building repair and maintenance Project Management, is clear; and that during the four main phases of a generic model, each phase contains a sub-phase, which contains main processes, which itself contains several sub-processes and within each sub-process, there are a number of operational activities.

Unsurprisingly, a collective perspective emerged, with the majority of the SMEs (n=12) commenting, that "*siloed workflows and team interaction gaps between professionals and contractors are generating inconsistency in work route dialogue and communication; and as a contractor, no longer feel like I have valid input to a project".* When prompted further, the majority reflected, that indeed this was the case not just for SME contractors, with RP, a MD of building surveying SME, commenting, "*the typical scenario is to work in isolation, particularly at the beginning of a project",* although arguing that *"current procurement strategies such as traditional contracting prohibited them from adopting a multi-disciplinary approach throughout the project".* Despite this characteristic paradox, with current procurement practice, which is out with the scope of this research study; the identification of the outline generic Historic Building repair and maintenance process, whereby four main phases and eight key sub-phases, presented in Table 5.6, were generated based on the respondents' answers to the initial question, which in turn, supports both a common comprehension and possible develop of sector specific process standard framework.

Main Phase	Sub - phase
Project Appraisal	preliminary appraisal services
	pre-contract services
	Post – contract award
Project Set-Up	Site Set-Up
	Off-site manufacturing
Project On-site Practice	Off-site manufacturing
	On-site operations
Project Completion	Quality Assurance
	Project Review

Table 5.6: Generic Historic Building R&M Key Process and Sub-process Phases.

The perspectives of the fourteen industry experts demonstrate they have a coherent idea amongst their own organisation's evaluation of the importance of the various project phases and processes. Yet, from the responses given, which provides evidence, to the belief, that there is potential and opportunity, to adopt a stronger perspective on existing inefficiencies and costly rework, by promoting pro-active communication and collaboration, will in turn create a better appreciation of accessing, updating and sharing of critical project data. Hence, for high-quality historic building repair practice and process improvement there must be a move towards a multi-disciplinary led system, yet, for such an evolution one respondent proposed "*cultural shift in how the historic building repair process is approached, not only from a contractor and professional viewpoint but also from a building owner perspective*".

Based on the comments and attitude from the 14 semi-structured interviews, the emergent discourse illustrated that most SME contractors and professionals within the historic building repair and maintenance sector, currently lack a dedicated process map that specifically identifies the full spectrum of historic building repair and maintenance processes, or how employing such a map can support improvements in historic building R&M project delivery. Thus, Table 5.7 serves to illustrate the complexity of the historic building repair and maintenance processes, whilst it also needs to be considered, that each project phase relies on being supported from outputs and data, from the previous phase.

Main Phase	Sub- Phase	Main process	Sub-process	Activity
Project appraisal phase	Preliminary services (P1-1)	Identify R&M Project Brief/Requirements; Identify Integrated Project Scope of works approach & Collaborative Environment Implement Integrated Project Scope of works Approach & Create Collaborative Environment Identify Integrated Project Delivery Approach & Initiate Collaborative Environment	Desk study; • Identify project description; functionality; • Identify if building requires either informal/formal protective measures/constraints (Desk study) On-site survey; • Identify + Define Project Scope of works; (Comprehensive on-site survey: site environment investigation; Building Diagnostics/Condition Survey; Structural Investigation; Building Dimensioning; Repair Strategy) • Identify the equipment and special services/requirements (i.e. Contractors) • Identify how a collaborative relationship with other professionals and or specialist contractors could impact on the project • Generate specific information regarding project • Identify General Outline for Collaboration • Identify communication and data exchange, sharing, management, and storage protocols • Identify roles and responsibilities	• Define R&M Project Brief/Requirements; Provide a comprehensive statement of the objectives and parameters for the project based on close consultation between the client and selected organisation in line with the local authority requirements. • Generate Scope of works (Comprehensive on-site survey; site environment investigation; Building Diagnostics/Condition Survey; Structural Investigation; Building Dimensioning; Repair strategy; project specific pre-construction health and safety plan) • Provide an agreed document on project specifications, levels of details and processes for the development and utilisation of digital technologies. • Define Integrated Project Scope of works approach & Collaborative Environment Implementation Plan and Requirements • Define Integrated Project Delivery Approach & Initiate Collaborative Environment; Identify: how a collaborative relationship with other professionals and or specialist contractors could impact on the project; General Outline for Collaboration; communication and data exchange, sharing, management, and storage protocols; roles and responsibilities • Identify the most appropriate procurement strategy

Table 5.7: Contents of Proposed Operational Historic Building R&M Processes and Sub-processes for the Project Appraisal Phase

For example, in the course of the project appraisal phase, in the first of its sub-phases; preliminary appraisal services, there are four main processes, which themselves have a number of sub–processes, such as, desktop survey and on-site survey, which relate to a range of operational activities, activities such as inspection of building and site environment; building condition survey; possible structural investigation survey; generate general project information; and produce tender documents information; administration, notification and documentation.

This in part, could explain why it was not an increase in the amount of phases or processes that were required but a raising of the co-ordinated and standardised flow of the sequence of activities/works performed, to achieve the collective, combined delivery performance objectives of time, cost, safety, technical and quality on projects, all within a context of a centralised and streamlined workflow. Hence, with the increasing complexity and multidisciplinary nature of historic building repair and maintenance allied to the findings from the literature review and the pilot study interviews; a SME focused common structured collaborative industry process model/framework map would be beneficial to improving the efficiency of the process itself, but to date investigating *"process management and improvement"*, in particular surrounding guiding Project Management processes and on-site practice, has received limited attention. Therefore, in this sense, such a process model, map, and framework explaining the workflow, would help all stakeholders to not only better understand their own position but also other project team roles in the process, thereby, improving the efficiency of the process itself.

Consequently, to determine a better understanding and provide a clearer picture of historic building repair and maintenance processes, whilst also seeking to provide a collectively, and standardised generated approach. It was necessary to first develop a conceptual generic Historic Building repair and maintenance diagram, on which to base the development of common structured collaborative industry process model/framework map, designed to improve industry performance of historic building repair and maintenance Project Management and on-site operations management. Hence, as process mapping was undertaken, and to provide context to the process of developing the conceptual generic Historic Building repair and maintenance diagram, the following sections; first provide a summary of the concept of process mapping followed by the selected process mapping approach, and features of the process diagram are presented along with a chapter summary. the optimum process improvement areas

5.5 Mapping the Historic Building R&M Project Process

5.5.1 Process Mapping

Process mapping and/or modelling is a mechanism that provides effective design of business processes into a process map to aid the visualisation of linkages between inputs, outputs and tasks (Vom Brocke and Rosemann, 2015). It is recognised as a valuable tool for Construction Management (Anjard, 1998); enabling complex organisational processes to be communicated more easily in a structured format; understandable to both management and the workforce; depicts the roles, activities, and interactions of all participants (people, technology, roles, etc.) in a process; and ultimately allows for more efficient work practices (Vom Brocke and Rosemann, 2015). Hence, various types of developed tools are available such as flowcharts, process-relationship maps, and cross-functional process maps, complete with frequently used symbols to clarify and managing work processes (Figure 5.3).

Broadly speaking, for process mapping, the literature identifies two types: high-level and detail specific maps. For high-level (generic) maps, they provide a "helicopter" overview of the whole process, describing its main stages and activities, typically use a flowchart methodology; whilst maps which illustrate detailed level processes are typically developed using structured modelling approaches, e.g. Integration Definition Function Modelling (IDEFØ) or Business Process Model and Notation (BPMN) which focus on defining information flows (Awadid and Nurcan, 2016).

Five process-modelling methods deemed appropriate for construction management process modelling were evaluated (Dave, 2017) and, it was concluded, the modelling technique selected is dependent on the LoD required and is wholly situation reliant (Tangkawarow and Waworuntu, 2016). Hence, in order to support the generation of a best practice historic building R&M process map, the Business Process Model and Notation (BPMN) technique was employed to support the creation of the generic historic building R&M process map.

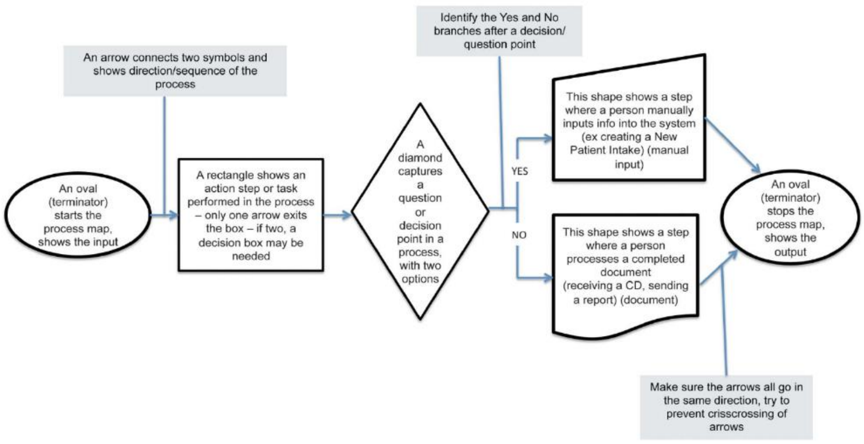


Figure 5.3: Summary of most frequently used symbols used for process mapping. Modified from http://www.fpm.iastate.edu/worldclass/process_mapping.asp

5.5.2 Business Process Model and Notation (BPMN)

Business Process Model and Notation (BPMN), in recent years has become the de-facto process modelling standard and graphical representation specifying business processes, as the technique, allows, the start and end of a business process workflow, to be illustrated as a system (Smith and Tardif, 2012). BPMN offers a simple, yet, homogeneous visual communication tool and schema to enable users to: provide a clear overview of the whole process; easily understand the workflow process; concurrently bridges the gap between management, technical staff, and non-technical staff; is suitable for a range of projects and their activities (from small scale to highly complex); does not need any specialist skills; and interestingly, for BIM-related business process modelling, it has been acknowledged as the preferential option, as it creates a standardised methodology between process design and application (Smith and Tardif, 2012).

Although, conversely BPMN, can be nebulous, creating misperceptions when sharing BPMN models, as no standardised file format, yet exists for importing and exporting BPMN models between the various modelling tools available (Tangkawarow and Waworuntu, 2016). Nonetheless, for the purposes of this study, BPMN is a relatively straightforward and standardised methodology to map out historic building repair and maintenance project flows, the process relationships and support documenting and communicating process performance; positively or negatively. The five basic categories of elements are as follows (White, 2004); (1) Flow Objects; (2) Connecting Objects; (3) Swim lanes; (4) Artefacts; (5) Data (see table 5.8 and Figure 5.4).

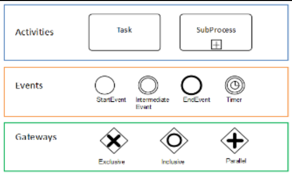
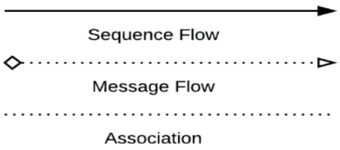
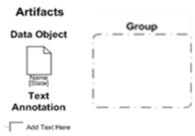
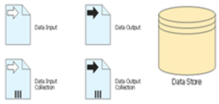
Categories of elements	Description
Flow Elements: These are the three key actions which occur during a process; (1) an Event, symbolised by a circle; (2) an Activity symbolised by a rounded-corner rectangle; and (3) a Gateway symbolised by a diamond shape.	
Connectors: These are the three key line connectors, which help form a process structure; (1) Sequence Flow denoted by a solid line and a closed arrowhead; (2) Message Flow denoted by a dashed line with an open arrowhead; and (3) Association denoted by a dotted line.	
Swim lanes; There are two types of swimlanes, either represented vertically or horizontally; (1) a contained Pool which signifies a Participant in a Process and their activity; and (2) a Pool with lanes which act as diagrammatic containers for delineating a set of activities and allows sub-division of pool	
Artefacts: These are object tools, which provide a mechanism to allow additional notational context to be inputed to a specific process modelling condition.	
Data: Denoted by 4 BPMN Data element forms: (1) Objects; (2) Inputs: (3) Outputs; and (4) Stores.	

Table 5.8: Business Process Model and Notation (BPMN) (Saluja, 2009)

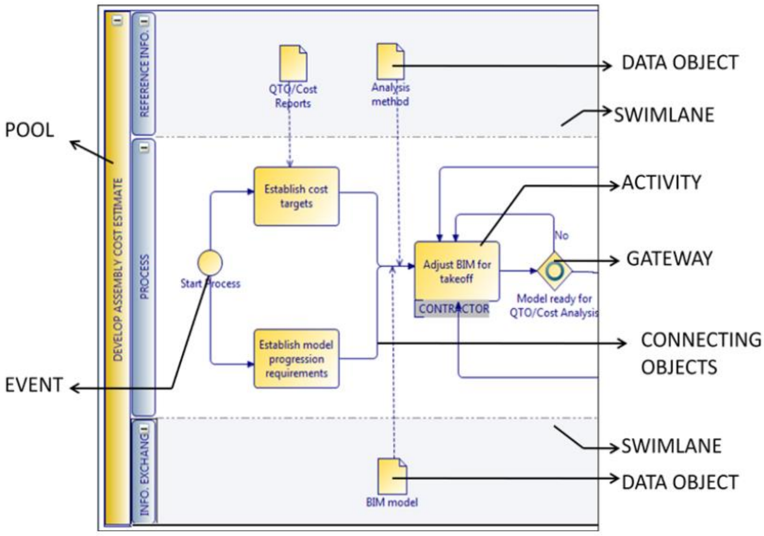


Figure 5.4: Business Process Model and Notation (BPMN) (Saluja, 2009, p. 47)

5.5.3 Features of the Generic Process Map

Based on the literature (British Standard 70913:2013; RIBA, 2013; RICS, 2009) and the researcher's experience within the sector. Within the 4-phase generic model (*Phase 1, Project Appraisal; 2, Project Set-Up; 3, Project On-site Practice; 4, Project Completion*) eight key sub-phases were identified. Hence, to provide an insight into the features within the high-level generic SME historic building R&M process diagram (Table 5.5; Figure 5.3), an overview is presented.

Phase 1, Project Appraisal: A Historic Building R&M project begins when the client, whether in the public or private realm, decides to embark on a campaign of repair and maintenance works and requests a project appraisal (Phase 1). However, within the overall process for Phase 1, it encompasses three individual stages; (1) *preliminary services;* (2) *pre-contract services, and* (3) *post contract award.*

The *Preliminary services* sub-phase begins in one of two ways:

(1) the client contacts a professional Architectural or Building Surveying SME practice; submits an appraisal request along with a brief description of possible requirements (normally by phone or e-mail), which allows a pre-cursor activity to take place; in essence, an initial desktop scope of works, in order to determine resources required for the proposed site visit. From this activity, once an appropriate date has been arranged, the professional SME then carries out a ground level project survey (building condition, site environment/logistics, dimensional etc.) in order to support the development of a more detailed scope of works. Concurrently, an initial desk study is implemented to determine the level of historic building legislation (listed building; conservation area; or not within a conservation area) that will need to be adhered to;

(2) alternatively, the client contacts a specialist SME contractor and /or sub-contractor practice such as stonemasonry or roofing contractor and proceeds to go through a similar sub-process as above. However, at this point typically, a specialist SME contractor and /or sub-contractor only implements a very brief desk study in comparison to the desk study executed by the professional practice, highlighted by the responses during the interviews (see section 5.3.4). Regardless of the route taken, fundamental to a project is

gaining a full and comprehensive understanding of the building, essential for correctly advising clients, and providing the most appropriate repair and maintenance solutions. From the ground level survey, a more detailed scope of works is compiled allowing the devising of an appropriate repair strategy. Once the repair strategy has been generated, several activities can now be engaged such as determining approximate quantities of work and materials, calculating estimated costs, compiling of drawings, specifications, and if needed obtaining the necessary historic building consents. Once this stage of the Project appraisal phase is complete and a full suite of project documents are compiled for dissemination, an invitation to tender is sent either by post or e-mail to a series of specialist historic building contractors.

From this point the other two main stages, within Phase 1 can start taking place: *(2) pre-contract services; and (3) post contract award;*

(2) *Pre- contract services*; the aim is to provide, the tendering SME main contractor and/or specialist sub-contractor, with the ability to generate a comprehensive, competitive and accurate tender quote. In order to support this, SMEs will carry out a series of document verification and site inspection processes, surrounding: (i) *Identification of scope of works, project drawings and/or the specification discrepancies (ii) the building and the site environment; and (iii) foreseeable site risks (generic H&S, work method statements and risk assessments, existing services and structural risks).* Once these activities have been completed and a subsequent tender compiled, the next stage within Phase 1 is the third sub-phase, acknowledged as;

(3) *Post contractor award;* a main contractor is selected by the client's representatives, initiating the appointment of the successful contractor as the principal contractor, governed by Construction Design and Management regulations (CDM, 2015). Whereby the selected contractor is obligated to compile a Pre-construction health and safety plan, inclusive of extensive risk analysis and assessments, covering work practices and materials (COSHH, 2012) together with detailed work methods and their scheduling in order to minimise the risk to those involved in the construction works being undertaken on the project (CDM, 2015). In addition, it is imperative specialist SME contractors, in particular stonemasonry SMEs, engage early with the supply chain and place orders for the material requirements, due to the extensive timescales of the manufacture and delivery of bespoke material requirements.

Phase 2, Project Appraisal: Upon completion of these interconnected sub-phases of the Project Appraisal phase (Phase 1). This phase can now be executed, and so begins the site setup processes, which fall into four categories: (*1) Site Logistics; (2) On-Site Health & Safety Administration, Notification and Documentation; (3) Scope of works documentation; (4) Off-site Manufacturing requirements.* Within each of these key processes are a number of tasks and activities, which are driven by CDM (2015), for example, within *(3) Scope of works documentation*; the contractor must provide accessible on-site Contract Documents (architects/structural engineer drawings, specification, scope of works, etc.), as well as provide a procedure to update documentation during the works. Once confirmation that the activities within all four categories of the site setup processes (Phase 2) are either completed or near to completion, all project safety issues have been addressed and all specific hazards and risks have been investigated and incorporated in work method statements and risk assessments.

Phase 3, Project On-site Practice; this phase commences, however dependant on the project scale, size, and complexity, a core on-site management team can be established. During Phase 3, in tandem with the sub-phases of Off-site manufacturing and On-site operations commencing concurrently. The following activities will be initiated and continued during these sub-phases: *(i) Inspection and approval of samples; (ii) Additional Structural investigation; (iii) Post-contract specification of inaccessible or concealed details; (iv) Quality control of appropriate R&M interventions; and (v)* a continual regime of pollution minimisation (noise, dust, and disturbance levels) (RICS, 2009).

Phase 4, Project Completion; this final phase surrounds ensuring satisfactory completion of the works and involves the processes of; Quality Assurance (QA) inspection and Project Review. QA is colloquially referred to, within the industry, as “snagging”; which involves compiling a rectification list of work defects or omissions, whilst the Project Review, surrounds the evaluation and assessment of projects, measured, in terms of management and performance success (e.g. time, cost, quality etc.), as much of the literature, recognises the benefits of identifying any lessons learned and taking these forward to future projects, by spreading good practice across the design and construction team, as well as ways of avoiding the repetition of mistakes (Carrillo, 2005; Eleyan and Loucopoulos, 2011). Hence , like the previous phases and their related sub-phases a number of work activities will be involved, for example, during the QA sub-phase, the verification and assessment of completed work against project specifications and industry standards, where ‘final construction issue’ on-site drawings can be marked up supplemented by as-built surveys (comparison of exact measurements, location and dimension of each and all elements of the work), in order to produce as-built drawings and record drawings.

5.7 Summary

This chapter has provided the qualitative data findings and analysis of the 14 executed semi-structured interviews, with Scottish historic building repair and maintenance sector practitioners, from contractor and professional SMEs. The interview results validated the literature review findings, categorising the numerous challenges facing historic building R&M industry practitioners into three key classifications: (1) Senior management; (2) Human resource; and (3) Technical, whilst within these three classifications, various sub-issues have been identified as illustrated in figure 5.1. Moreover, given the research study has adopted an action research strategy, and is concerned with *“process management and improvement”*, in particular surrounding guiding Project Management processes and on-site practice; as an outcome of the 14 semi-structured interviews responses provided; an iterative generated generic common practice historic building repair and maintenance process map was produced (Figure 5.2), in order to assist highlighting, the common approach adopted by the sector and to support the generation of the development of common structured collaborative industry process model/framework map. Yet, the comments and attitude from the 14 semi-structured interviews, illustrated that most SMEs, professionals, and contractors within the sector, lack such a common process map, that precisely illustrates the main phases and sub-phases within historic building repair and maintenance projects, or in what way utilising such maps can improve the delivery of historic building R&M projects and their process issues, related to project under-performance. Hence, the next chapter discusses the efficacies related to the management of current on-site processes and conventional practices used in historic building R&M projects, as well as exploring industry practitioners’ current awareness of; Construction Process Management Frameworks (CPMFs), digital technologies and Integrated Project Delivery. (see Figure 5.2).

Chapter 6: Investigating the Efficacy of the Project Management and On-site Processes used in Historic Building R&M Projects

6.1 Introduction

Chapter 6 provides the second part of the pilot study and discusses the findings from the identification and exploration of the key industry practitioners' views and issues related to the management of current on-site processes and conventional practices used in historic building R&M projects, in terms of, *"process management and improvement"*. Based on the iterated generic best practice Historic Building R&M project process map, the first section explores the respondents' perspectives on the efficacy of the Project Management and On-site Processes used in the historic building R&M Process, in order to highlight the key issues and difficulties that might surface during individual phases of projects. The second section explores industry practitioners' awareness and applicability of Construction Process Management Frameworks (focusing on the RIBA Plan of Work, 2013, CIOB Code of Practice, 2014), and their relevancy to; MSMEs and SMEs, small to medium scale sized projects and their specialist settings, as well as their perspectives on digital technologies and Integrated Project Delivery (IPD) (see Table 5.1), however, within this 2nd section there was no demarcation of the issues raised into categories, when analysing the responses. Furthermore, parts of Chapter 6 findings are published in the following Academic journal: Journal of Cultural Heritage Management and Sustainable Development (McGibbon, S., Abdel-Wahab, M., & Sun, M., 2018) (Appendix G).

6.2 Efficacy of the Current On-site processes and practice used in the Historic Building R&M Process

Based on the generic best practice process map, respondents were initially posed an open-ended question; ***"In your opinion, do you think that the current processes and conventional practices used in the historic building R&M process delivery are efficient?"***

The fourteen industry experts were, then further probed with a series of sub-questions to identify and establish, the key process and practice management issues, and to comment not only on what they considered were the possible causes and impacts, but also potential ways and opportunities, to help meet the project's management and execution objectives successfully. Similar to section 5.3.1; the key issues were identified, and, in line with the thematic analysis methodology, the key category issues, which emerged from the data analysis, required to help meet the project's management and execution objectives (Figure 6.1): (1) Senior Management; the supervision; planning and administrative processes; (2) Human resource; the specific practical project knowledge, skills and abilities issues; (3) Technical; the on-site technical activities and processes.

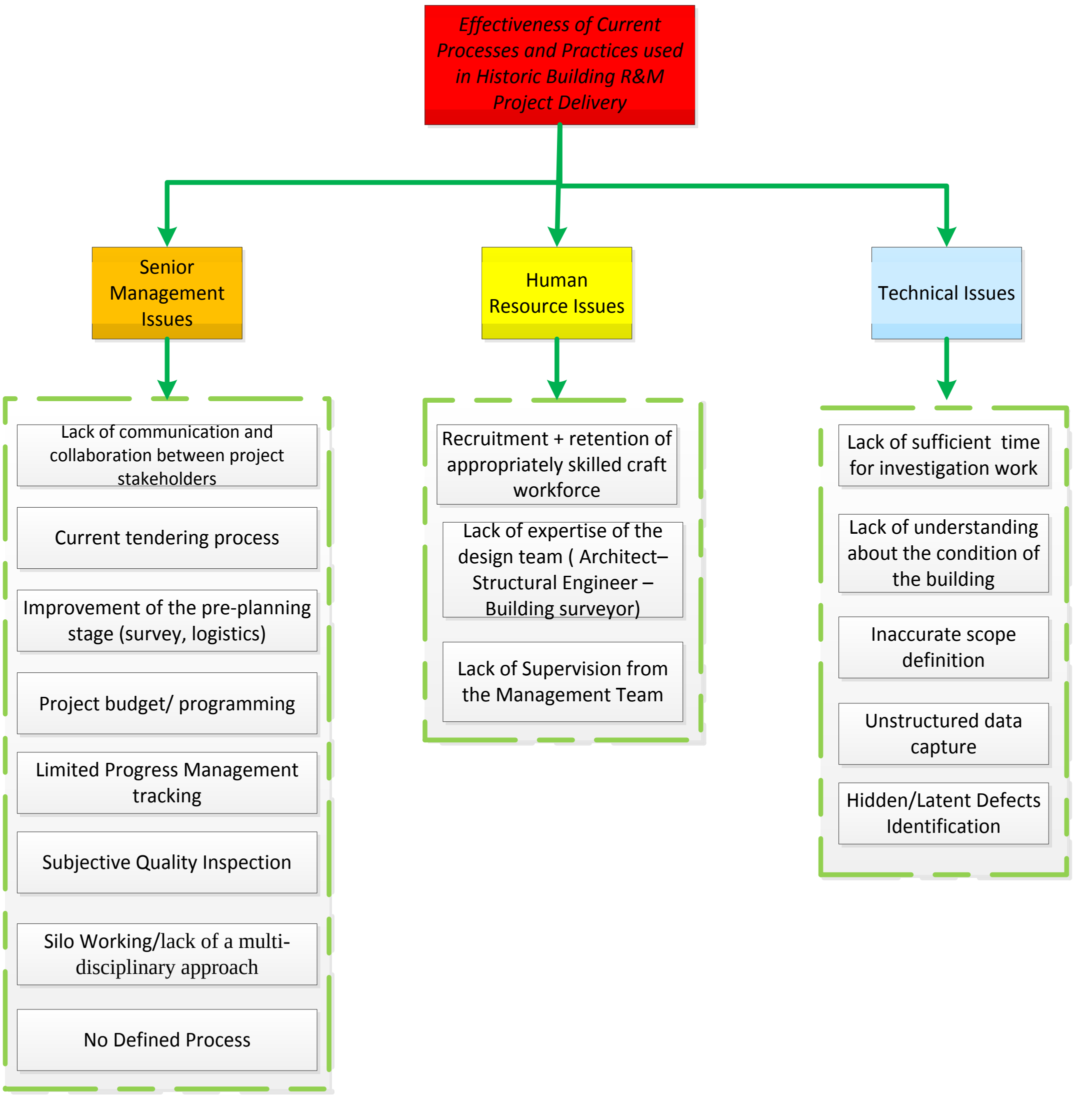


Figure 6.1: Themes of Key Issues affecting the efficacy of current on-site processes and practices

6.2.1 Theme 1: Senior Management Issues

Findings

The literature review (BS 7913, 2013; Bullen and Love, 2011a&b; Deloitte, 2014; Dyson, Matthews and Love, 2016; Forster and Kayan, 2009; Forster et al., 2011; Kayan, 2013 RIBA, 2013; RICS, 2009; Shipley et al., 2006; Shenhar and Dvir 2007; Smith, 2005; Torney et al., 2012; 2014) revealed several wide-ranging, yet comparable process and practice management efficacy issues, which can potentially affect project performance. Influenced by their backgrounds in a Project Management capacity as well as a business function (either/or consultant and contractor purpose); seven main senior management issues were constantly raised, namely; *no defined tailored MSME/SME process standard; siloed approaches; improvement of project pre-planning (project survey & logistics), programming/scheduling, current tendering processes, subjective quality inspection/assurance, and limited progress management tracking* (see Table 6.1).

Response	**SME; Contractors in agreement**	**SME; Professionals in agreement**	**Total no. of stakeholders in agreement from**	**SME Interview total**
No Defined Process	8	6	14	14
Silo working/lack of a multi-disciplinary approach/ Lack of communication and collaboration between project stakeholders	8	6	14	14
Improvement of project pre-planning (survey & logistics), programming/scheduling	6	6	12	14
Current tendering processes.	8	2	10	14
Subjective Quality Inspection/Assurance	4	6	10	14
Limited Progress Management tracking	4	6	10	14

Table 6.1: Main Senior Management Issues

They did offer a reason as to why this might be, to which, respondent RF, summed up succinctly, that given the unique, complex and interrelated nature of projects, *" it was a dynamic environment, where it not only makes it difficult to differentiate completely as to what the key issues really are, but also the processes and practices involved are closely linked, making it even more difficult to separate"* (see Figure 6.2).

Main Phase	Sub- Phase	Main process	Sub-process	Activity
Project appraisal phase	Preliminary services (P1-1)	Survey (P1-1-1)	Desk study; (P1-1-1-1) On-site survey; (P1-1-1-2)	* Client decision to repair and maintain structure * Request for appraisal by professional consultancy * Request for appraisal by specialist SME contractor * Inspection of building * Inspection of site environment * Condition survey * Structural Investigation survey * Generate general information regarding project * Generate tender documents information; Administration, Notification and Documentation
	Pre-contract services (P1-2)	Estimating (P1-2-1)	Tender Invitation; (P1-2-1-1)	* General information regarding project; Administration, Notification and Documentation * Contract conditions (type, payment, risks, liabilities etc.)
			Knowledge of the site; (P1-2-1-2)	* Desk study and on-site survey * Inspection of building * Inspection of site environment * Generate general information regarding project * Study R&M design data * Study R&M construction data
			Selection of R&M methods; (P1-2-1-3)	* Specification * Extent of R&M * Location and Accessibility constraints * Structural Engineer requirements * Health and Safety requirement/consideration * Environmental requirement/consideration * Identify suitably skilled personnel
			Risk Assessments; (P1-2-1-4)	* Identify Health and Safety risks * Identify Environmental risks * Identify Workforce risks * Identify Temporary structures risks
			Method statements; (P1-2-1-5)	* Describe the steps involved in selected R&M method in accordance with approved drawings, specification, ensuring safety, quality and durability. *Scope and method of work *Project organization for health and safety control *Health and safety risk control / Assessment *Workplace access and egress *Workplace lighting *Plant and equipment *Personnel training certification *Hazardous materials and substances *Waste management *Special control measures *Communication of Method Statement
			Cost Estimate; (P1-2-1-6)	* Site overhead cost (Welfare, accommodation etc) * General overhead cost (Administration, Insurance , Transportation etc) * Selected R&M method cost (Health and Safety, Labour, plant and material) * Waste removal cost * Temporary structure cost
			Bid Submission; (P1-2-1-7)	* Contractors qualifications; Competence, experience and management
	Post contract award (P1-3)	Tender accept (P1-3-1)	Contractual Administration	* General information regarding project; Administration, Notification and Documentation * Contract conditions (type, payment, risks, liabilities etc.)

Figure 6.2: Contents of Current Operational Historic Building R&M Processes and Sub-processes for the Project Appraisal Phase

Nonetheless, compellingly, within this theme, there were two key issues identified; *silo working and no defined R&M process.* Unanimously, the respondents, remarked that in reality, *"it is typical to work in isolation, particularly at the pre-project stage as there is a reliance on professionals (such as Building surveyor and structural engineer), when in fact the appointed contractor has a huge amount of untapped practical experience and* *knowledge that could be utilised so much more effectively and contribute value, in terms of project requirements/scope of the work".*

Hence, given the level of experience needed for these processes to be effective, they require an extensive knowledge base and practical experience to be truly adept at it, for example, in the course of discussing and evaluating the conceptual Historic Building R&M process diagram, a number of respondents (n=10) were in agreement that *"if we want to improve quality, we need to address the inherent reliance on the expertise and skills of both the professional and contractor workforce".* However, when pressed further on solutions, despite their preference to their field of expertise, they conveyed a harmonious position for *"the need to embrace a multi-disciplinary approach*", to alleviate poor project delivery/performance, adding there is *"absolutely the need for effective communication and collaboration, it's about generating confidence within the whole supply chain".* Further commenting *"it not only requires a greater adoption of this type of approach but also for project practice to be structured and defined"* and enthusing, *"if there was a route map to facilitate the process, that would be great"*. Further agreeing, that it cannot be assumed that one discipline on its own will be able to specify an appropriate repair strategy and subsequent solutions (RA; RC; RF; RG).

Yet. despite within the literature, several practical management guidance documents existing (BS:7913; RICS, 2009), all respondents collectively challenged the lack of a cohesive, collective and structured approach to project delivery stating, *"the whole process seems very disjointed",* admitting having no defined process was *"normal industry procedure".* Respondent (RP) expanded on this practice by outlining a typical scenario for the scoping of works at the project planning stage and highlighting the industry's fragmentation, remarking; "*normally the Architect will come up with a generic scope of works; then it is passed, to a Building Surveyor to do a condition survey, resulting in a different set of scope of works (sometimes slightly different but invariably markedly different, particularly given if a historic building specialist is involved). Then it is given to the specialist contractor who will assess it again and offer a slightly different scope of works".* Although, they did paradoxically, recognise that the propensity of the sector to use specialist consultant and contractor, coupled with the intensity and diversity of historic building repair and maintenance information, makes it difficult to move away from silo-working, as there is difficulty for a clear lead to come from any one consistent source, reverberating the literature (see Pinsent Masons, 2017). This could partly explain why a large number of respondents (n=10) (RA, RB, RC, RL, RF, RG, RH, RI, RK RP) reporting, *"that disparate workflows between teams and all that this consists of, are creating extensive inefficiencies and adding to the already strained project budget through costly rework",* and that they felt *"project managers no longer have control over projects".*

The most striking result to emerge from the data was the sense amongst the respondents was that due to the lack of *defined process standard, allied to siloed approaches*, there were continual management issues at the planning and execution phases of the historic building R&M process. For example, SME contractor (RH; RI; RN) and SME professional (RH; RI; RN) respondents, revealed the timescale for providing a scope of works varied from project to project. They stated, *"Sometimes it's in far advance of any type of contract being issued almost pre-tender stage, sometimes the contract has already been awarded to the main contractor and other times it's a week or two before the project commences and the contract has already been let".* Yet, as outlined in the literature, the Project Management process of historic building repair and maintenance should be as simple as possible and sufficiently robust enough (BS 70913:2013). Moreover, anecdotally, compiling a scope of works is inherently difficult as the process has a propensity to rely on subjectivity based on the experience and knowledge of the professional or contractor engaged to carry out the scoping process e.g. there is a tendency to be unstructured in what and how project data is captured. The impact of these types of ad-hoc practices according to almost all the respondents has a propensity to "*add to the project costs and time resulting in inducing, incurred costs and monies which might be better directed towards actual repairs"* placing additional tension on the already strained project budget.

Interestingly, based on their experience, a number of respondents (n=7) (RD; RH; RI; RJ; RL; RM; RN) perspective suggested that to *"in some way to circumvent these re-occurring issues*" having an adequate level of project contingency was a necessity. Several SME contractors (RD; RJ; RL; RM) stressed, "*there should be a minimum 30% of the total project costs",* whilst SME professional (RH; RI; RK) suggested adoption of a rather more pragmatic processed based approach, due to the unpredictability in terms of the project scope of works (final content, extent and specification) (Smith, 2005). They offered, "*the contingency should be based on the areas of risk and the unknowns and estimated by a quantity surveyor with experience in this area".* Although, several respondents (n=4) (RB; RJ; RL; RM) added a typical inference from the building professional was that they sought *"a top dollar job but are only wanting to pay dimes"*, yet, the literature (Dyson, Matthews and Love, 2016; Bullen and Love, 2011 a&b; Shipley et al., 2006) has continually highlighted the intrinsic risk, in terms of time, cost and quality involved in delivering projects, driven by the complexities involved in historic building R&M.

Correspondingly, eight respondents (RA, RB, RC, RD, RJ, RK, RL and RM) observed adversarial procurement processes as the real issue that required attention. They pronounced *'traditional' procurement routes allied with clients' predilection to select the lowest price and not on who is most suitably experienced and qualified"* creates a restrictive and combative tendering nature, resonating *"a competitive type of arrangement, which when trying to win the project tends to lead to underestimating the work".* They attributed this to the fragmented nature of the industry, coupled with an inherently competitive tendering disposition of project contracts, as numerous respondents (n=8) offered that often, the current tendering process is based on *"economics and not on who is most suitable qualified or experienced to carry out the work".* However, historically, the perception that value and lowest cost/price do not necessarily go hand in hand is not a new one (Egan, 1998), as this ambiguity is fuelled by the wider industry's fragmented nature and its continual susceptibility to silo working (Dainty et al., 2005), unequivocally mirrored in the sector, given the complex nature of built heritage projects relies heavily on specialist professionals and contractors. Therefore, from a Project Management perspective, to maximise value for money, provide high quality and deliver within project timescales, when probed further, they harmoniously suggested, there needed to be a more active tactic; to adopt a multi-disciplinary methodology and *"approach a contractor in the project pre-planning/specification stage".* Perhaps adopting a holistic, integrated, structured and unified approach could provide a way to incorporate agreeable contract funding, along with acceptable tendering mechanisms and help neutralise, the widely acknowledged project risks and complexities, such as enabling the ticking time bomb of project scope of works unpredictability, to be defused, at a far earlier stage of the project delivery process than at present.

For example, one of the respondents (RA) provided a concrete example of the need for this integrated approach. Reporting; *"during the planning stage of a previous project we* *were involved in (R&M of McEwan's Hall, Edinburgh), before us being awarded the contract, as part of the scoping of works package a structural engineer along with a building surveyor carried out a structural investigation and a condition report on the building, which cost between £8000-10000 and specified repairs that were excessive in their requirements. If we were able to be brought on-board at an earlier stage this might have saved the client monies".* In turn, several respondents, (RB, RC, RL, and RM) further fuelled the need for adopting such innovative integrated practice, agreeing, *"because of traditional non-standard materials or details there is a heavy reliance on the specialist contractors' expertise and, skills and knowledge, particularly the need for a multi-disciplinary approach to specification"*, which could go some way to addressing the issue of improvement of the pre-planning stage of a project. Although they added, invariably it does not cease at this phase, as the tendency is to *"rely on us to appraise, construct and maintain the program"* throughout the project lifecycle.

This could partly explain, when further queried surrounding *limited progress management tracking*, they agreed that *"an over-reliance on subjective expertise had highlighted the inadequacy of current quality control and assurance processes".* Suggesting, that decision making, in terms of defective work, is typically dependent on whether it is completed competently from a workmanship perspective and not on the precise project standard and specification, in essence, it does not rely on objective key performance metrics or indicators. Therefore, what is crucially important is that if defects identification is predisposed to adding to project performance, then engaging in more objective, robust, rigorous, and comprehensive records is needed. Hence, this signifies, the primary focus ought to be not only an integrated approach and move towards a defined process standard but also an evolution towards a more structured and coherent system of data capture provision to meet the demands of repair and maintenance. In turn, given the literature review suggested a possible combination between process improvement and relevant digital technologies, could enhance Project Management of historic building practice enabling work prioritisation, scheduling/programming, and monitoring work progress and quality. Perhaps, using digital technologies such a mobile technology (cloud computing, mobile Apps, tablets/smartphones) and/or objective tools such as structured data capture forms (quality checklists, etc.) could be a way to circumvent the *limited progress management tracking* needs, in the short term. Whilst long term, perhaps adopting a truly multi-disciplinary defined process approach, whereby contractor and professional integration occurs from the project on-set, strengthened by incorporating structured objective data capture supported by digital technologies to achieve a more objective approach and enhance a tripartite project philosophy of quality, performance and effectiveness.

6.2.2 Theme 2: Human Resource Issues

Findings

Under this theme, three key issues were revealed, namely; *lack of expertise of the design team (Architect– Structural Engineer – Building surveyor); recruitment and retention of appropriately skilled craft workforce; and a lack of supervision from the management team* (see Table 6.2).

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of SMEs in agreement from	SME Interview total
Lack of expertise of design and construction team	8	6	14	14
Lack of supervision from the management team	6	4	10	14
Recruitment/retention	3	6	9	14

Table 6.2: Three Key Human Resource Issues

The main key issue raised by the respondents (n=14) was; *lack of expertise of the design and construction team;* where SME contractor background respondents (n=8) (RA; RB; RC; RD; RJ; RL; RM; RN) and professional SME respondents (n=6) (RF, RG, RH, RI, RN RP), agreed there was a lack of knowledge and skills across all levels, expressing that from their experience *"the most complex and difficult part of the project, is defining and assembling, the appropriate team with the suitable level of expertise and knowledge, from architect, to surveyor to structural engineer, to experienced specialist contractors is essential in project delivery success".* They further articulated, that this was without a doubt a key issue, commenting *"historic building projects are markedly different from typical building projects"*, expressing the sentiment that there was *"a lack of expert project managers, with historic building expertise".* Several respondents, who either had a role as a project manager or alternatively employed project managers in their SME (RA, RH, RL, and RM), offered the key senior management solution was to; adopt a multi-disciplinary approach, in part to create an improvement of the supervision of works of a project by *"mitigating the delays as they arise, not to try and mitigate accumulated delays at the end of the project"*.

Underlining, the validity of such reasoning, the majority of respondents (RB, RC, RD, RF, RG, RI, RJ, RK, RN, RP) (n=10) offered a *lack of supervision from the management team*, as the second ranked key issue, with several SME contracting respondents (RC, RD, RJ, RK) (n=4) attributed this to the lack of professionals with *"hands-on technical knowledge"*, a perspective substantiated by the literature (NHTG 2007, 2008: PYE Tait, 2013) e.g. the lack of practical learning elements. However, the consensus, intimated that given the unique and complex nature of projects, a high level of skill and in-depth knowledge of building conservation is becoming a requirement of not only craftsmen but also consultants. For example, a mixture of respondents from the aforementioned background (RA; RC; RF; RG) stated *"building professionals when specifying stone repairs, lack the knowledge of the complexities involved with R&M of a historic building"*.

Unsurprisingly, given the previous two key issues, the third ranked major human resource issue raised by the respondents (n=9) surrounded the *recruitment and retention of appropriately skilled workforce of skilled craftsmen* (particularly stonemasonry skills), collectively stressing that "*raising the quality of craftsman involved in repair and maintenance is essential because if the workforce is under-qualified the building suffers"*. When questioned further they offered different perspectives from both a Project Management perspective as well as a business viewpoint; a number of respondents (n=9) (RF, RG, RH, RI, RL, RM, RN, RP) acknowledged efforts are made to find the specialist contractors who suit the project based on, *"their references, past experience, trade qualification and samples of work"*. Yet dichotomously, they precluded *"at the end of the day it comes down to the budget, and what fits in the budget",* although they underscored*" historic buildings require distinct skills attributed to the unique character of the project"*. Hence, numerous respondents intimated that in previous projects *"the client and management team had carried out an interview process to determine suitably qualified contractors, based on previous historic building experience",* although they revealed,*" invariably it was an informal and subjective procedure*".

From a SME stance, three SME contractors (RA; RB; RC) ranked recruitment and retention, as the foremost issue facing historic building repair and maintenance practice, in particular stonemasonry, although it could be argued that this had a touch of bias given, they were prominent stonemasonry contractors. Nonetheless, a noteworthy perspective is that despite, current statistics concerning available positions, making it difficult to gauge the opportunities for apprentices and craftsmen, as they tend to not be advertised, symptomatic of UK construction as whole (Clarke and Herrmann, 2007). From the (n=6) professional SME respondents (RD, RJ, RK, RL, RN,RM), whilst they did agree it was a key issue, they pointed out, they have "*alternative recruitment and retention strategies*", such as promoting high standards of education/training coupled with providing in-house training for their already qualified staff believing there was an opportunity to not only train and employ the best/most suitable individuals but also revitalise their existing workforce.

6.2.3 Theme 3: Technical Issues

Findings

In this theme, respondents presented two main key technical issues; *lack of sufficient time for investigation work; and lack of understanding about the condition of the building,* facing historic building repair and maintenance Project Management practice and on-site processes, with two other key issues identified, namely; *inaccurate scope definition; and unstructured data capture,* (Table 6.3). In reality, the respondents stressed, all four key issues were intimately linked, causing a myriad of time, cost and quality issues, not only affecting the construction team but also affecting the design team. Respondent RC provided an example of this, where decisions surrounding stone replacement were not determined until the project works had started, reporting, *"Only when the scaffold went up on the project did the Architect decide on the various intricate stones to be replaced and give approval",* observing it is only possible for the design team to *"make the best guess estimate"* believing *"allowing sufficient time"* during the design stage *"goes hand in hand in having the ability to clearly define a scope of works".*

Adding to this, RC remarked, *"Some of the stones needed drawings as well as 6* or *7 templates to enable manufacture. you can spend 4/5/6 weeks: drawing it up, sending for approval, a couple of questions come back, another set of drawings is required, then once approved 8-12 weeks for stone delivery, it is just such an expensive way of approaching it".* Respondent RD; RM; RN with their supply chain background, emphasised *" It seems* *to take an enormous amount of time from the decision about what type of stone are we going to use and how much, and it seems almost as if with 20 minutes to go the scaffold goes up then everybody starts screaming about supply/delivery".* They further added, *"It affects the whole supply chain, suppliers included"* contending, *"the vast majority of clients do not quite comprehend the difficulty in sourcing the materials".* Respondent RD, elucidated, *"It seems to take an enormous amount of time from the decision about what type of stone are we going to use and how much, and it seems almost as if with 20 mins to go before the project starts, the scaffold goes up then everybody starts screaming about supply/delivery".*

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Lack of sufficient time for investigation work prior to project inception	6	6	12	14
Lack of understanding about the condition of the building	6	6	12	14
Inaccurate scope definition	4	6	10	14
Unstructured data capture	4	6	10	14

Table 6.3: Four Key Technical Issues

Moreover, numerous respondents (n=10) (RA, RB, RC, RF, RG, RH, RI, RK, RN RP) pronounced in some form or another, "*if the scope is not clearly defined and objectively recorded and documented, is it any surprise there is a lack of understanding of what needs to be done".* In terms, of defining the scope of the project, which has a legacy of being the most difficult component of a historic building R&M project. Critically, the same respondents (n=10), asserted, the problem lay with the so-called, *"big exercise"* of ensuring sufficiently accurate data capture, particularly at the project inception stage, which respondent RF intimated it is, *"invariably based on tacit knowledge and experience".* Accordingly, they believed, these deficiency paradigms cause *"the likelihood of project delays and cost increases, due to much work to be re-designed and re-documented after the construction phase starts".* Likewise, a number of respondents (RA; RC; RF; RG; RP) stressed this issue has an *"effect on the generation of project documentation, particularly the generation of specifications and work methods".* They suggested that because the lack of accuracy and detail in project documentation, requests for information *"has become an almost daily procedure"* and *"take a considerable time of the project, which in turn impacts the day to day supervision"* adding *" resulting in a slowdown of the repair works process".* All respondents acknowledged RFI's are a normal process within projects, although several contested that as a by-product, they had begun to *"to investigate alternative methods or tools"* to provide a deeper investigation not only at the project appraisal phase but also throughout the entire process. Corroborating this perception are the numerous studies that have highlighted a range of specified repair solutions, which have either been poorly specified or poorly practised. Hence, the responses given to this theme validate the literature and provide evidence; of the potential and belief that by adopting a stronger perspective on the appraisal and investigation processes. For example, determining the level of information and detail of the existing condition of the building, will in turn create a better appreciation of specified repair solutions as well as possible additional repairs required and direct the project towards improvements in terms of time, cost, and quality.

6.2.4 Discussion

The responses from the 14 key industry players are consistent with the various industry reports, and academic articles reviewed in the literature of the main issues regarding the efficacy of the management of current on-site processes and practice used in historic building R&M projects. Similar to Chapter 5, a number of project issues emerged from the data analysis, which were categorised under three broad themes; (*1) senior management; (2) human resource; and (3) technical.* The perspectives of the fourteen industry experts and the number of identified issues confirmed the complexity of the current historic building R&M Project Management and On-site Processes/practice, and demonstrated, they all have a coherent idea and evaluation of the importance of the three emergent broad themes. Furthermore, they were uniform in their view that the issues were inextricably linked, to the range of significant challenges facing the sector, at an industry wide and project level.

Unanimously they all believed given the unique and bespoke nature of built heritage projects, these issues present a number of questions, not only in terms of, how can quality, performance and effectiveness be achieved if project management is complications in this form to successful R&M, not only before work has commenced, but also throughout the process? When questioned further several respondents offered, alternative methods of working such as, implementing a more integrated approach, where a highly collaborative working environment in which shared values and goals are the vision, which for some may mean a radical re-think, in terms of their current perspective. Interestingly, several respondents (professional and contractor alike) suggested a pre-defined workflow as a way to enhance communication and collaboration through the sharing of tacit knowledge between project members. In terms of improved collaboration and communication,

Whilst all fourteen-industry practitioners indicated *having no defined R&M PM process and silo working* as key issues, on closer analysis, the importance of the remaining four key issues seems no to have been driven by the respondent's current role and background. Professional practitioners unanimously indicated the technical issues surrounding deficiencies in *"understanding building conditions "*and *"time allowed to investigate"* as the most important issues. Especially given, there are distinct skills attributed to the bespoke repair solutions of historic building R&M. (Cruickshank and Wyld, 1975, and CIRIA, 1998). Moreover, they rationalised, when *"uncovering something"* this drives you to *"design, price and agree on the methodology"* with "*the same process being repeated each time the project team uncovers something new"* (RH, RP) which results in "*the requests for more information (RFI) slowing the construction process down".* However, in reality, it is not just the case of RFIs slowing down both the design and construction process. Several SME contractor practitioners remarked from their perspective, felt these two issues, whilst important, there were a number of valid reasons as to why this occurs from *"insufficient funding to the lack of skills not just the discovery of hidden defects and latent conditions".* Interestingly, they intimated the senior management issue of *current tendering processes* and the human resource issue of *a lack of supervision from the management team,* as key issues from their perspective. In terms of *current tendering processes,* it was felt *"there was a need for "early works packages"* considered as a *"separate contract but housed within the main contract".*

In terms of *a lack of supervision,* whilst it was a contractor practitioners' key issue, in reality, professional practitioners deemed it a major concern also, although two of the six professionals interviewed, remarked from their perspective; that in their experience, they relied heavily on the inherent tacit knowledge and experience gained from the length of time involved in projects. A viewpoint validated by numerous industry reports (NHTG Report, 2008b; and Pye Tait, 2013) and academic research (Abdel-Wahab and Bennadji, 2013; Forster et al, 2013; Hyslop, 2004; Kayan et al., 2016), who found that various projects had encountered the Project Management challenges of increases in; project budget, planning; programming; poor scope of works and specifications, as well as difficulty in recruitment of appropriately qualified workforce at contractor and professional level. Relatedly, the majority of building professionals tend to have in an overinflated expectation of what the project budget can deliver, this could partly explain why in alleviating these problems, one respondent commented their preferred tactic was to adopt a multi-disciplinary methodology and *"approach a masonry contractor in the project pre-planning/specification stage"*. Hence, this supports, the conclusion drawn from *NHTG (2008) report: Built Heritage Sector Professionals; Current Skills, Future Training* that 65% of building professionals consulted felt that their formal education was not congruent with the practice setting and had not prepared them adequately for the intricacies and complexities of working on pre-1919 buildings.

However, as the responses came from a mix of both contractor and professional SMEs allied to the literature review. Pye Tait (2013) found 97% of contractors are general construction companies and 95% of the workforce do not hold formal qualifications relating to traditional buildings, whilst the National Heritage Training Group (2008) found out of a total of 507 UK conservation-accredited building professionals only 83 were registered in Scotland. Points towards a persuasive case for an increase in not only professionals but also contractors who are involved in administering projects. To undertake a high-level course in Project Management, to ensure that the historic building repair and maintenance projects engage in Project Management protocols, surrounding areas such as planning, cost, time, quality, health and safety, and contract administration, allied to the existing practical professional practices of CM (Ranns and Ranns,2016). As much like the construction sector as a whole it is essential to maximise the quality, efficiency and value for money from a project management perspective (Department for Business, Innovation and Skills, 2013b; Egan, 1998). However, as highlighted in the literature, current legislation (Historic Environment (Amendment) Scotland Act 2011) and guidelines (Historic Scotland, 2015; British Standard Institution, 2013; Urquhart, 2007; Knight, 1995) do not stipulate that specific qualification levels and skills are a pre-requisite to working on historic buildings. This apparent gap in the existing legislation and training practice, raises the question; how stakeholders can ensure not only suitably qualified professionals but also suitably qualified contractor are employed? Conceivably, a return to contractor selection based on the length and breadth of previously gained knowledge and experience of stone repairs may be a pre-requisite for historic building R&M buildings. Much like the current Dutch *"Monumentwacht"* initiative (Michiels, 2012), which employs appropriately certified and experienced personnel, when undertaking historic building R&M.

The perspectives of the fourteen industry experts demonstrate they have a coherent awareness of the importance of the significance of each issue and were uniform in their view all seven main key issues were of equal importance. However, in reality, the plethora of key issues offered by respondents indicate that the overarching recurring mantra; embracing a multi-disciplinary structured approach is fundamental in order to enhance project delivery and performance. This further emphasises that if industry stakeholders understood the value of a pre-defined workflow, both the productivity and financial benefits, more work delivered would increase the uptake, demand, and use for alternative project delivery strategies. Although implementing a more integrated approach, where a highly collaborative working environment in which shared values and goals are the vision. For some this may mean a radical departure from current practice. Hence, there is a need not only for a pre-defined workflow, but also the need for demonstration projects to provide exemplars of the benefits (financial, efficiency, performance, etc.) of adopting a collaborative, integrated, technology linked type of approach, which will be fundamental in promoting its uptake. The following section establishes, the 14 SME respondents understanding and awareness of CPMFs (in particular, the RIBA Plan of Work, 2013, CIOB Code of Practice, 2014, and BS 7913). As the main aim of the study seeks to develop a common structured collaborative integrated industry framework, which incorporates the use of emerging digital technologies suitable for historic building practice.

6.3 The Awareness and Understanding of Construction Process Management Frameworks (CPMF)

In line with the thematic analysis methodology described in section 5.3, the responses were classified under the same three distinct themes. Respondents were again initially posed an open-ended question; ***"From your perspective, what is your awareness and understanding about construction process management frameworks?"*** Further open-ended probing was carried out with a series of sub-questions, in order to gauge the level of awareness and comprehension of existing Construction Process Management Frameworks (CPMF), as illustrated in figure 6.3.

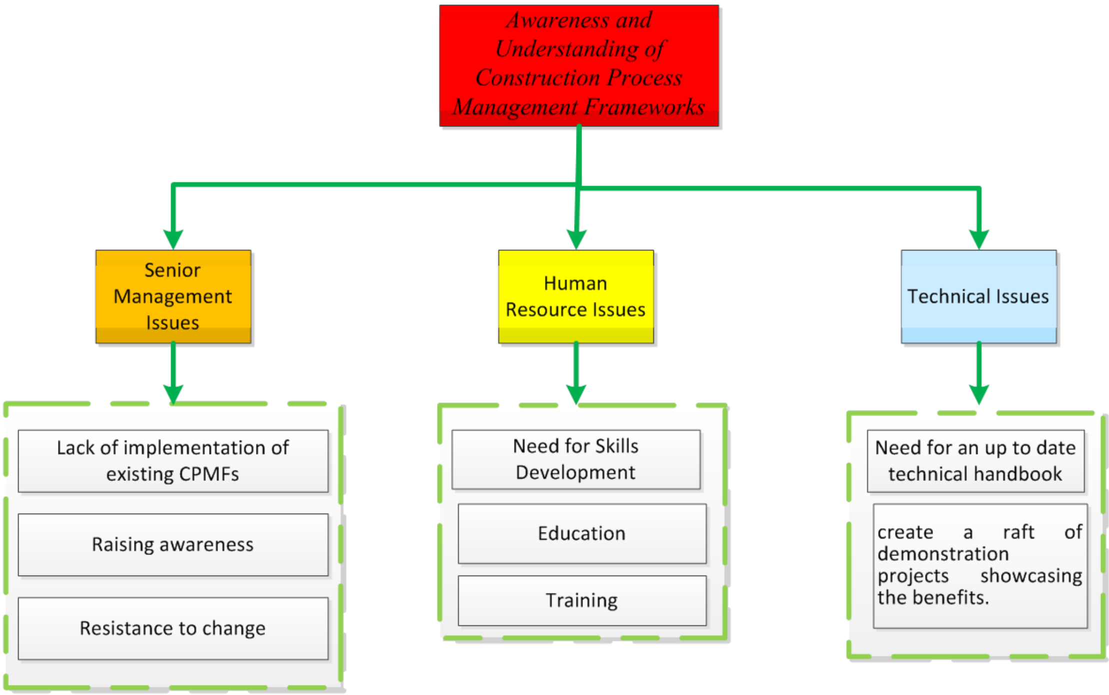


Figure 6.3: Themes of Key Issues affecting the awareness and understanding of CPMFs

6.3.1 Theme 1: Senior Management Awareness and Understanding

Findings

To provide some context to the discussions, a brief explanation of current CPMFs (RIBA Plan of Work, 2013; CIOB Code of Practice, 2014) was provided. Thus, once given insight and a brief description of these frameworks, the respondents were asked about their understanding and awareness of such frameworks. The overall response to this question was quite negative, particularly from MSME and SME contracting respondents, resulting in three main issues identified; *resistance to change, lack of awareness (inadequate level of knowledge and understanding), and uptake* (Table 6.4).

Emerging as a key evaluation was a distinct poor level of uptake, knowledge and understanding, unanimously from a contracting SME stance; all eight practitioners indicated that they had very limited or no comprehension of any Construction Process Management Frameworks (CPMFs), not just in terms of application, but also in terms of knowledge and familiarity, which logically prevented any effective employment when being involved in historic building repair and maintenance delivery. For example, several respondents (RA, RD) emphasised *"knowing about such frameworks, is something I don't even consider"* reasoning *"being a specialist contractor and dealing with bespoke components, raw material costs come first and process management arrives as last thought".* When asked to provide a main reason as to why they had never used such frameworks; five respondents (RA; RB; RC; RD; RK) mutually suggested the inherently *"traditional"* environment of historic building projects and its *"complex and interdisciplinary"* nature.

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Resistance to change	8	6	14	14
Lack of uptake	6	6	12	14
Lack of awareness; inadequate level of knowledge and understanding	6	0	6	14

Table 6.4: Three Senior Management Issues

Conversely, all six professional practitioner SMEs (RF, RG, RH, RI, RN, RP) indicated that they had used such frameworks in the past and, *"take part in things like CPD and ethics so that ensures they have knowledge and understanding of how to apply such frameworks".* Although, they further identified, the majority of times they had employed these frameworks was typically involving new build developments in historic building conservation areas, rather than on solely on repair and maintenance projects. They had found them to be of only a limited use within historic building repair and maintenance projects, indicating *"there is no relevant one at present; they're not particularly suited to the nuances of the industry".* Citing predominantly, the bespoke nature of projects allied to the terminology used in these frame works did not match the terminology used by the number of specialist construction SMEs that were involved in historic building delivery. In discussing this issue further, when asked if they believed, the work stages accurately reflect current industry practice, the SME contractor practitioners were harmonious in their views, observing, that they *"don't really use one when involved in historic building R&M",* confessing, "*these existing plans of work are aimed at professionals who are part of the institutions".* Although they remarked that these frameworks have *"a coherent workflow",* they deemed it was too general in outlook and that, "*you always hear about process management, and to some degree we do understand its use, but for us it would take time and considerable effort to actually use them".*

Therefore, when asked; what they use as an alternative management tool, the majority offered the general response that they *"tend to use experience and knowledge to guide me".* Some contracting SME respondents (RB, RC, and RK) felt *"in terms of our industry, it's not there as a single package and as an SME I don't have time to develop something like this. However, if one was available, I would definitely use it".* As such, all the respondents, when posed a question about the development of a*; defined and structured process framework,* for efficient project delivery and practice, they all agreed that it would be "*a welcome addition to our existing toolkit".* A number of respondents (n=11) (RA, RC, RF, RG, RH, RI, RK, RL, RM, RN, RP) reflected that "*anything that improves project management particularly the management of on-site practice is extremely useful because if everyone involved in the project buys in to it, we can undoubtedly gain improvements in work efficiency, as well as enhanced quality on site".* Two respondents (RD, RF) offered an area that could be further enhanced is the relationship between the supply chain, the design team and the contracting team stating "*improved collaboration and communication with clients and between contractors and professionals meaning better working relationships as well as using the skills set of everyone to its best potential".* Several respondents (RA, RC, RL, RP), enthused they were more than willing to be proactive partners to develop and be involved in the use of a common structured collaborative integrated industry framework.

Yet, despite the positive outlook, and support for such a framework, the mixture of contracting and professional SME respondents raised the divergent discourse of the *"demographic make-up and fragmented nature of the industry".* The overwhelming consensus (n=14) was they felt, such inherent nature, breeds the key issue of *resistance to change.* Candidly, four respondents (RB, RJ, RJ, RK) admitted, they are inclined not to adopt *"new ways of working"* or *"invest time and money into such areas"*, as they assume that engaging in new methods of project delivery also runs the risk of being viewed as hazardous. This is consistent with the findings of several studies (Hardie and Newell 2011; Sexton and Aouad, 2006) who investigated the barriers of the uptake of innovative processes and technologies by SMEs, such as the difficulties in evaluating cost-benefits of investments. Which could explain why in order for them to engage with such frameworks, they required the dual need *"to galvanise with proactive partners to develop and lead the use of such tools and to see the benefits; the real benefits which matter to them (time, cost and quality)".* Declaring *"we tend to only invest when we can* *see actual hard benefit; what I mean is the real benefits; cost, time and impact on the quality of our work".* Assuming

6.3.2 Theme 2: Human Resource Awareness and Understanding

Findings

This theme captures several correlated issues; *skills development, education, and training* (Table 6.4).

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Skills development	8	6	14	14
Education.	2	6	8	14
Training.	8	0	8	14

Table 6.5: Three Key Human Resource Issues

The replies from the 14 respondents suggest that, driven by their current role and background, they had a coherent idea of the need for skills development as the driver to facing the challenges of raising awareness, creating a better understanding and, in turn enhancing uptake of Construction Process Management Frameworks. They further stressed at the heart of skills development is the need for appropriate education (RF, RG, RH, RI, RN, and RP) and training (RA, RB, RC, RD RF, RG, RH, RI). Yet, given the highlighted lack of standardised terminology within the field, when discussing the importance of each issue, on analysis, it could be argued, that it was a case of semantics, given the two terms of *education and training* are homogeneous and often connected rhetorically. Nonetheless, they unanimously articulated that the skills development as a key issue, remarking it was both a need and an opportunity to increase the levels of knowledge and skills. Consistent in the view that it was the lack of awareness, understanding, and successful implementation of the frameworks stressing skills development was the major conundrum and enabler. Hence, this could explain why eight respondents of mixed roles and backgrounds echoed each other, remarking they were pro-active regarding skills development, from both a personal and employer perspective, and offered a number of individualised options, such as attending CPD. However, when asked to clarify, they indicated the importance of CPMF knowledge, whether that be existing or newly developed frameworks, suggesting that with the "*prevalence of specialist sub-contracting and MSMEs, it is unrealistic to expect SMEs to adopt such project delivery processes without technical support*".

6.3.3 Theme 3: Technical Awareness and Understanding

Findings

Under this theme, all the respondents (n=14) were unanimous of the viewpoint, that technical awareness and understanding were essential, in order to intiate a move towards engaging in modernising project delivery practice. Hence, collectively, they felt there were two key technical support areas, which would provide more relevance and currency, offering; *the need for an up to date technical Construction Process Management Framework handbook/guide tailored for SMEs, and create a raft of SME demonstration projects showcasing the benefits* (Table 6.6).

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Up to date technical CPMF handbook/guide tailored for SMEs	8	6	14	14
Create SME led demonstration projects showcasing the benefits	8	6	14	14

Table 6.6: Two Key Technical Issues

For example, respondent RA and RC stated, *"having a more specific framework tailored for SMEs and its subsequent guide would help direct my thinking"*. Whilst RH observed, *"guidance would improve and increase the possibilities of using a framework"* and highlighted "*as a by-product",* could, *"prompt other SMEs to adopt a more pertinent management function"*. Suggesting this would help guide, both practical and professional reasoning towards adopting and deploying a multi-disciplinary approach, particularly SMEs who had not engaged in existing framework use (RA; RB; RC; RD; RJ; RK). However, respondents who had previously engaged with such frameworks (RF, RG, RH, RI, RL, RM, RN, and RP), suspected the lack of identifiable benefits which could be realised from engaging in such construction process road maps, may not be conducive to adoption across the sector. Yet, despite the admittance, perplexingly, they did not indicate, they themselves would be averse to such a tool.

Hence, it was unsurprising, the secondary key area offered by the 14 respondents, surrounded the need to create a raft of demonstration projects highlighting the potential time, cost and quality benefits. A number of SME contractor respondents (n=8) (RA; RB; RC; RD; RJ; RK RL, RM), stressed they would be, *"a highly effective way to show pay back for all scales of projects from straight forward to complex projects,* reporting, *"to have greater access to hard evidence from real life projects would be extremely valuable".* It was striking to note that the professional SMEs interviewed underlined such an opportunity could provide a much needed *"silver bullet"*, to the overarching need for "*to have structured roadmap approach to the historic building R&M process"* enabling *"the whole team to work towards the same aspiration, allowing everyone to be on the same page resulting in swifter decision making, which would without a doubt be a major step forward in helping ensure the project's success".*

6.3.4 Discussion

Within the literature, the various industry reports, and academic articles highlighted that practitioners require to be bounded by Construction Process Management Frameworks and their related professionalism and ethics to ensure that best practice in the Project Management of historic buildings is undertaken for all projects (BS; 7913; SHEP, 2011). Yet, currently, there is a paucity of research exploring how *"process management and improvement"* for Historic Building repair and maintenance Project Management and on-site practice, through employment of a CPMF, can support improvement in historic building repair and maintenance performance. Hence, the findings from this section on the awareness and understanding of CPMFs, not only widens current knowledge into the sector's perception and use of CPMFs, but also lends support that there is a disconnection between current Project Management process frameworks for construction, as they are not integrated with on-site practice undertaken by SMEs (Poirier et al., 2015). Taken together, the results from the themes of; (1) senior management; (2) human resource; and (3) technical, confirm previous findings in the wider literature; that SMEs lack awareness of these type of PM frameworks and question their relevance for true collaboration, given the industry's risk averse culture (Pinsent Mason, 2017). Yet, despite a number of MSME and SME contractor respondents not; having awareness of what frameworks are currently available; and whether any developed framework for use in the field of historic building repair and maintenance practice, would be justifiable. The respondents collectively see the potential role of CPMFs to not only improve an MSME and SME ability to effectively manage the historic building repair and maintenance project and its processes, but to assist the practitioner in managing and carrying out on-site operations, within the inherent complexity and constraints of the proposed design and construction process.

In brief, Construction Process Management Frameworks may have an important part to play, but it is unrealistic to expect SMEs to adopt such project delivery processes without addressing the aforementioned key issues. Perhaps adopting a two-fold approach; firstly, developing a SME tailored process-standard, to enable a structured approach to the historic building repair and maintenance process, to support effective and efficient Project Management; and secondly, raise awareness across the sector; by creating a raft of demonstration projects, showcasing the benefits in terms of performance efficiency gains. However, when questioned on the possibility of specifically tailored framework for historic building repair and maintenance SMEs, the general consensus was that *"such a tool would be great, but it must be more simplistic and straightforward than existing frameworks"* and also *"not created for individual use, but for unified use"*. Overall, this is an important conclusion as Historic building repair and maintenance projects, inherently have a high level of risk (Dyson, Matthews and Love, 2016; Bullen and Love, 2011 a&b; Shipley et al., 2006). Yet, given the unique and bespoke nature of built heritage projects, pragmatically, all respondents agreed that such a bespoke framework, in order to negate encountering the same fate as current wider construction industry frameworks; whereby there is a resistance to change, the future ability and quality of implementation, needs to be underpinned by workforce skills development (education and training), which in turn needs a highly respected commitment from all sector stakeholders (Professionals, Contractors, Clients, Local authorities, NGOs, etc.).

However, the idea that there exists some wonderful solution or methodology, which solves one or more perceived Construction Process Management Framework uptake issues, must be tempered with caution. Consequences of a belief in *"silver bullets"* in the industry could result in continuing increases in schedule delays, time/cost overruns, poor quality of work conflicts, and other issues often associated with such projects and money wasted on tools that are never used. Nonetheless, overall these conclusions, validate the usefulness of such modernisation and innovation, given that these are issues that can be, for the most part, be fixed with a combination of better historic building repair and maintenance practices, better processes, or better technology. In essence, a common structured collaborative process-standard framework to enable an integrated approach to the historic building repair and maintenance process

6.4 The Awareness and Understanding of Digital Technologies and Innovative PM Processes (Integrated Project Delivery)

As the key aim of the study seeks to develop a structured, holistic and integrated workflow, which informs the use of suitable digital technologies to enhance process management and improvement in historic building Project Management and on-site practice. The interview process sought to establish the 14 key practitioners understanding and awareness of digital technologies and Integrated Project Delivery (IPD) suitable for historic building repair and maintenance practice. The following open-ended question was posed; ***"From your perspective, what is your understanding and awareness of digital technologies (laser scanning, cloud computing, etc.) and IPD being able to support process improvement in the historic building R&M process?";*** from which respondents, were probed further with a series of sub–questions (Appendix D), however, when analysing the responses, unlike the previous sections there was no demarcation of the issues raised into themed categories.

6.4.1 Findings

All respondents indicated they were conscious of digital technologies and their ability to support practice, offering they were aware of a number of options; from overwhelmingly digital images (n=14), and surprisingly, laser scanning (n=14), to Infra-red thermography (IRT) (n=8), to digital documentation (n=8) and cloud computing (6), to the more emerging technologies of Augmented and Virtual Reality (AR/VR) (3) and mobile apps (2). Yet, despite their awareness of such technologies, the level of understanding and knowledge, varied from low to high, with the general opinion (n=11) when discussing several of the digital technologies, encapsulated by respondent RD admitting, *"I know of the technologies, as they have been around for some time and that it can be adapted for historic buildings. Other than that, I'm kind of struggling".* In contrast, two respondents (RC and RN), provided a much deeper awareness and understanding, remarking they were, in their opinion, *"ahead of the game because of a strong interest in ICT,"* with respondent RN enthusing, "*I even have an attachment for my I-phone which turns it into an IRT camera".* Both respondents suggested their level of understanding and knowledge was resultant from personal curiosity, with respondent RC expressing that, *"in my former years, I was an avid gamer",* whilst, RN humorously stated, *"I am a bit of a nerd in that way, anything techy".*

Of the 14 respondents, again, despite the general awareness of digitisation, only respondent RP declared they had engaged in attempting to move to a digital workflow, commenting, *"we are proactive in the use of such tech, we already use I-phone and I-pads to help us gather site information. Whether that be during the planning phase of a project and all its intricacies or as a way to document what's going on on-site during the works phase".* For the remaining 13 respondents, they all candidly admitted they did not have the financial ability or the expertise to engage with such forms of digitisation. Conceivably, adopting current digital technologies such as laser scanning, IRT allied to standardised data capture forms, could be an additional way to alleviate the project issues of time, cost and quality, given they are becoming a critical function necessary to complete the integrated BIM cycle providing information to be co-ordinated between the specification model and the geometry model (Bosché et al., 2015). This could, in part explain why the eight respondents who had previously remarked they had used Construction Process Management Framework, declared that the focus on BIM integration at each stage of the project lifecycle had pushed them to move away from these frameworks. Moreover, all 13 admitted, they felt digital technology use, was inappropriate as the majority of their workload focused on small-scale projects, with the consensus, that as SMEs; digitisation "*is a not a high-level priority, it's a problem of cost and time to engage with it because at present we are snowed under with work".* Yet, as a collective, the general outlook was *"the value, in terms of being more efficient, that we have seen from using every tool, such as mobile apps, has us now seriously considering moving heavily towards the technology".*

Similarly, when questioned on Integrated Project Delivery (IPD), predictably, the same six respondents (RA; RB; RC; RD; RJ; RK), who professed having no knowledge of Construction Process Management Frameworks, conceded they were not familiar with such a concept. With some even confessing reservations about IPD, remarking, *"not another entirely new project management approach that they have to learn from basics"*, warning without training, would "*discourage them from implementation"*. However, once given insight and a brief explanation into IPD, the six respondents began to warm to the concept and believed such a Project Management approach could be adopted. Contrastingly, the eight respondents (RF, RG, RH, RI, RL, RM, RN, RP) who had previous experience with existing frameworks, revealed a positive pattern in their responses; ranging from "*I have heard of IPD but not truly aware"* to "*we are aware and already use some of IPD principles, but it is more internally within the business as opposed to externally when involved in projects"*. Perhaps adopting an IPD based approach is a way to circumvent the traditional ways of working and aid effective team working, especially given the main principle of IPD is to involve contractors early in the design process employing multi-party contracts (Garcia et al., 2015). For example, after the devastating earthquake to Christchurch, New Zealand, and its historic buildings, several historic repair projects adopted an IPD approach, highlighting the hard-wired higher-than-normal level of collaboration, across the design and construction team and supply chain partners, essential for the bespoke and complexities involved in projects, resulted in a number of savings in time and effort (NEC, 2018).

Hence, given these responses, two key issues that required addressing were raised; *overcoming resistance to change (n=14)* and *raising awareness (n=14)* (Table 6.7). Moreover, the consensus stressed the need for specialised training and education, specifically on the implementation of digital technology, remarking, current training does not sufficiently prepare industry specialists for current historic building R&M never mind, these developing areas of practice.

Response	SME; Contractors in agreement	SME; Professionals in agreement	Total no. of stakeholders in agreement from	SME Interview total
Raising awareness	8	6	14	14
Overcoming resistance to change	8	6	14	14

Table 6.7: Two Key Uptake and Implementation Issues

Hence, in order to promote the uptake and implementation of digital technology and IPD, they offered the following three key components; *attending workshops/seminars, case studies, and learning from peers.* For example, respondent RJ stressed, "*if there were seminars/workshops then I would attend and find out more to allow us to towards this* *type of modernised approach".* However, they cautiously declared *"our main focus is keeping a competitive business going and maintaining our existing position, however, if the chance soon to engage with such tools appears we will try and do so, although ideally, it needs to be low cost but above all easy, flexible and intuitive to use*".

6.4.2 Discussion

Given the responses from the key players involved in contractor SMEs are consistent with the views of the professional SMEs respondents, of the main issues namely, *raising awareness, and overcoming resistance to change/industry engagement*. The findings from this section of the 14 key industry players interview process indicate each respondent was consistent in their view that there is potential and a belief that by adopting a stronger perspective on the uptake of digitisation, and understanding of an integrated approach, will, in turn, create a better appreciation of the benefits possible. In order to address these issues and achieve raising the quality and response of the industry practitioners wishing to engage in such process management and improvement, they believed it was necessary to develop a quality skills development strategy. The suggestion of a skills development strategy strengthens the confidence that practitioners would be provide an opportunity to learn through reflection. To which they offered two ways of achieving this aim; either through a reflective mentoring and peer support system, by evaluating practice and assessing their mistakes and successes of implementation, or the availability of disseminated demonstration project data to evaluate the outcomes of completed projects, which have adopted digital technology and an integrated approach.

The responses provide evidence that, although each set shows preference to their field of expertise, they conveyed a harmonious position for developing a digital technology and a contemporary PM skills development strategy and, the results provide compelling evidence to suggest; perhaps, introducing new technology and processes at further education/higher education level by providing a series of formal trainee and upskilling continued professional development courses for the existing workforce (Abdel-Wahab and Bennadji, 2013; Pye Tait Consulting Limited, 2013). This could be a way for the workforce to gain the necessary skills and knowledge needed to achieve the uptake of innovative technology. Furthermore, this could provide an opportunity to tackle the other two key themes identified and raise the image of the construction industry by promoting that it is high-tech and not for underachievers (Abdel-Wahab, 2012).

Historic building repair and maintenance, by its nature, and the inherent need for a multi-disciplinary approach, lends itself naturally to such a cohesive innovative Project Management process as IPD and such digital technologies. Hence, there is an opportunity to have a technology linked workflow pipeline, which is readily accessed from survey, to procurement, to manufacture to installation with the ability to react in "real time". Yet, for such an evolution towards adopting such digitisation and innovative practice, they consistently stressed the need for valid data on the capabilities of relevant new tools and processes. These results extend the validity of the need to determine what benefits are associated with adopting such advanced tools and innovative processes. The single most marked observation to emerge from the data in this section is the need again for hard evidence. As to; what digital technologies are most appropriate, what is involved in IPD and what are the benefits and improvement impacts they both bring, in terms of time, cost and quality on the historic building R&M PM processes and on-site practice

The literature reflects this need, as there is a scarcity of specific industry and academic studies surrounding sector modernisation, innovation and process improvement, suggesting, sector difficulties in keeping informed of the latest processes and tools available to improve performance. Therefore, to arrive at a deeper understanding and awareness of the benefits facing modernising and enhancing repair and maintenance of historic buildings and help overcome SMEs uncertainties. There is a need to create a raft of demonstration projects showcasing the potential industry benefits; similar to the growing project-based data, provided by Historic Environment Scotland's refurbishment case study series (see HES, 2012 - 2018). However, there requires to be more focus of such case studies towards being evidenced by a demonstrable cost-benefit analysis (CBA), particularly given the literature offered workflow process digitisation was very susceptible to efficiency gains at scale (the more frequently used, the lower the cost of each project becomes) (Stroeker, & Vogels, 2012). Hence, demonstration projects would not only be a welcome addition to HES case study series, but also help to explain the rationale behind modernising historic building repair and maintenance Project Management and practice, and so remove misconceptions. Whilst also, support a change in the image of the sector by promoting it is high tech and progressive, enabling the ability to attract the best talent.

6.5 Summary

Chapter 6 has depicted the data analysis, its findings and given an insight into the numerous Project Management and On-site practice efficacy issues and concerns facing MSME and SME's, which were categorised into the similar same three categories as reported in Chapter 5: (1) Senior management; (2) Human resource; and (3) Technical, within which, a number of sub-issues were identified. In addition, the challenges faced in the move towards modernising and enhancing practice within the sector were explored by investigating the awareness and understanding of Construction Process Management Frameworks, digital technologies, and Integrated Project Delivery. However, when analysing the responses surrounding digital technologies and IPD, there was no demarcation of the issues raised into categories.

From the responses provided by the interviewees, they may have a coherent idea amongst their own organisation's evaluation of the importance of the project delivery process, but the responses are given highlight for high-quality historic building repair and maintenance practice, there must be a move towards a multi-disciplinary led system. According to the key efficacy issues identified, which led to a low SME motivation towards CPMF adoption, as a consensus was reached by respondents; not only about the absence of specific guidance and standards targeted for carrying-out and managing on-site operations but also the lack of communication and collaboration between project stakeholders resulting in silo working and ad-hoc approach to the collection of project data for R&M in historic buildings. The majority of interviewees did admit that there is a need to develop a defined and structured process framework for efficient project delivery and practice.

In terms of their perception of digital technologies and IPD, there was a definite misunderstanding and lack of appreciation of how these tools and practices could be used for process management and improvement. They suggested there was also a need to create a raft of demonstration projects showcasing the potential industry benefits in order to overcome the malaise of changing existing work practices within the sector. This confirmed the complexity and fragmented nature of current historic building repair and maintenance practice, and as such re-enforced the need for a common structured collaborative industry framework to support a collaborative, multidisciplinary approach facilitated through an IPD based approach, which informs digital technology application.

Hence, the next chapter presents the development of common structured collaborative digitised industry *(CrOsS)* framework that is aimed at supporting an effective multi-disciplinary and collaborative IPD based approach for historic building repair and maintenance projects, not only for Scotland and the UK, but also internationally. In effect, the development of a sector process-standard, designed to offer a process model, map and a management tool that supports collective integrated working, whilst informing digital technology use.

Chapter 7: Development of the "Common Structured Integrated Collaborative Digitised" Framework (*CrOsS*)

7.1 Introduction

Chapter 7 presents the development of the proposed framework for "*process management and improvement"*, begins; by giving an overview of the framework (background, assumptions), then discusses the framework development approach; process mapping and modelling (Business Process Modelling Notation (BPMN) and Generic Design and Construction Process Protocol (GDCPP) process model), followed by an overview of the integrated framework features, and concludes with a summary of the chapter. Furthermore, parts of Chapter 7 findings are published in the following Academic journal: Journal of Cultural Heritage Management and Sustainable Development (McGibbon, S., Abdel-Wahab, M., & Sun, M., 2018) (Appendix G).

7.2 Overview of the (*CrOsS*) Framework for Process Management and Improvement in the Repair and Maintenance of Historic Buildings

7.2.1 Framework Development Background

The "*process management and improvement"* framework, developed by combining the results from the pilot exploratory study (Chapter 5 & 6; Objective 1, 2 & 4), with the theoretical findings from the literature review (chapter 2 & 3; Objective 1, 2, 3 & 4). Whereby, the numerous strategic and project operational level challenges and issues, highlighted in the literature were mirrored in the face-to-face semi-structured interview process with 14 key MSME and SME practitioners (consultants and contractors). For example, the literature identified; a lack of a multi-disciplinary approach and specific guides, standards, and frameworks for Project Management and on-site practice; poor practice, quality, communication and collaboration, resulting in cost and time overruns; allied to the current skills shortages/gaps, as key triggers for lacklustre performance and productivity (Forster et al., 2011; Hyslop, 2004). Whilst, the key MSME and SME practitioners frequently described historic building projects, as, *"unique"* and *"bespoke"* who required, *"a far deeper level of collaboration, expertise and skills to ensure project success"*, but was *"disjointed"* and *"had no defined common project delivery process"*.

Hence, the synthesis of the findings, clearly shows that that the lack of a systematic, structured, and standardised management process, requires the historic building repair and maintenance sector adopting a more industry-relevant framework. A framework which promotes not only a multi-disciplinary collaborative approach., but also provides a defined delivery structure, which accurately reflects the intricacies and complexities of Project Management and on-site practice, to help support optimised project delivery. The aim of the developed *CrOsS* framework is to provide guidance to MSME and SMEs (professionals, contractors and sub-contractors) responsible for the delivery of both tendered and privately procured projects, as the means to; enhance project communication and collaboration, encourage process improvements, and lead to not only improved efficiencies, but also better management.

Thus, from a MSME and SME perspective, attaining efficiencies when undertaking and managing on-site operations, by providing a tri-fold approach of an integrated, systematic and defined approach to historic building repair and maintenance project delivery, is intended to support various project participants, with Project Management responsibilities and functions (e.g. project planning, design, construction, quality control, and assurance). Furthermore, in order to enhance the quality and level of project data capture, the developed framework, further intends to support and promote a structured and standardised approach to project data capture and utilisation. Hence, the focus was to embrace the concept of Integrated Project Delivery and inform the application of appropriate digital technology tools,

7.2.2 Framework Development Approach

A framework can be considered to be a methodical tool used to help practitioners organise and integrate various systematic mechanisms, such as; processes, practices, and responsibilities as part of high-level decision-making procedures (Bassioni et al, 2005). Furthermore, it provides a high-level level depiction of the system, its key processes, and the subsequent inter-relationships, which in turn, imposes a definite structure (Yang, 2012). In terms of "*process management and improvement"*; given inefficient construction management processes, have a significant effect on the management of project performance and in turn on workforce productivity (Heng et al., 2008). A Construction Process Management Framework (CPMF) is an instrument to support industry practitioners, in being able to deliver a viable project, in terms of practicality, cost, and quality. Whilst, in terms of guiding and defining the design and construction process, it provides; a structured vehicle, in the attempt to eliminate errors at the design/planning stage; offers a reasonable construction sequence prior to and during the construction works stage as well as guide and structure industry practice (Heng et al., 2008); supports enhanced data and information generation for performance measurement, in order to answer questions regarding what skills, knowledge, competencies, and experience issues affect the performance of projects (Yang, 2012).

In the context of the bespoke, complex, iterative and interdisciplinary nature of the historic building repair and maintenance process, a tailored CPMF framework could provide each activity or practice within the process, the ability to interact inside one overall framework, embracing the many individual yet interdependent work and operational tasks, activities and practices, involving many project participants. Therefore, to support the developed *CrOsS* framework as a; process model, a map, and management tool (see Figure 7.5 - 7.7), it becomes logical to combine, and adhere to following four principles;(i) reviewing current industry best practice, guidance reports, and standards on historic building R&M processes; (ii) synthesising existing literature of historic building repair and maintenance Project Management; (iii) generation of high-level generic Historic Building repair and maintenance process diagram, during the consultation with MSME and SMEs; (iv) blend the concepts of a framework and "*process management and improvement"*, and build on an existing framework, in this case, the GDCPP (Kagioglou et al., 2000); which could be simply comprehended simply and clearly communicated, employing process mapping and modelling, utilising the Business Process Model and Notation (BPMN) technique, to

7.3 *CrOsS* Construction Process Management Framework Process Mapping and Modelling

Initially, from the literature review, in order to provide validity of industry best practice. The concept was mapped and configured (see Table 7.1), against six relevant UK Construction Process Management Framework (CPMF), guides and standards, and their various key stages of a project lifecycle such as inception, design, construction and operation stages. Namely; CIOB (2014), RIBA (2013), COTAC's conceptual HBIM framework (2014), two applicable UK PM British Standards (BS 6079-1:2010 Project management. Principles and guidelines for the management of projects; and BS PD 6079-4:2006. Project management. Guide to project management in the construction industry), and the Construction (Design & Management) Regulations (CDM 2015).

Structured Digital Workflow	**Chartered institute of Building (CIOB); Code of Practice for Project Management 5th Edition**	**Royal Institute of British Architects (RIBA) Plan of Work 2013**	**Council on Training in Architectural Conservation (COTAC) HBIM Framework- 2016**	**PD 6079-4:2006; *Project management – Part 4: Guide to project management in the construction industry***	**BS 6079-1:2010; *Project management. Principles and guidelines for the management of projects***	**Construction (Design and Management) Regulations 2015 (CDM 2015)**
Phase 1 – Project Appraisal	1 Inception	0 Strategic definition	0 Identification of Asset Strategy	1 Inception	1 Conception	Develop Risk assessments
	2 Feasibility	1 Preparation and brief	1 Research Legislation Preliminary Survey	2 Feasibility	2 Feasibility	Health and Safety (H&S Strategy
	3 Strategy	2 Concept design	2 Determining Options	3 Outline design		
Phase 2 – Project Set-Up	4 Pre-construction	3 Developed design 4 Technical design	3 Define Detailed Survey 4 Determining Intervention	4 Scheme design 5 Detailed design 6 Mobilization	3 Realisation	Safe Construction Methods + Strategy
Phase 3 – On-site Practice	5 Construction 6 Testing and commissioning	5 Construction	5 Physical Intervention	7 Construction		H & S Strategies
Phase 4- Project Completion	7 Completion, handover and operation 8 Post-completion review and in use	6 Handover & close out 7 In use	6 Handover 7 Operation and Future	8 Testing and commissioning 9 Handover and Completion	4 Operation 5 Termination	H & S Strategies

Table 7.1: Comparison of six existing construction management frameworks, guides and standards with Conceptual model mapped onto existing PM frameworks

Within each selected framework there exists comparable, though not identical terminology, surrounding the description of a series of processes which, typically, infer a logical but linear sequence of activities and tasks, whereby there is movement from a generalisation to a multiplicity of detail. From the iterative mapping and comparison process, a 4-phase framework model was devised, shown as the first column in Table 7.1, and follows the pattern of the existing construction process management frameworks. With the study, seeking also to develop a common, structured, and holistic workflow, which supports integrated working, whilst informing the use of suitable digital technologies to enhance "*process management and improvement*" in historic building Project Management and on-site practice. The conceptual process framework was further represented and designed as a digitised process-wheel, which comprised of the following phases: *Phase 1, Project e-Appraisal; 2, Project e-Set-Up; 3, Project On-site e- Practice; 4, Project e-Completion* (Figure 7.1).

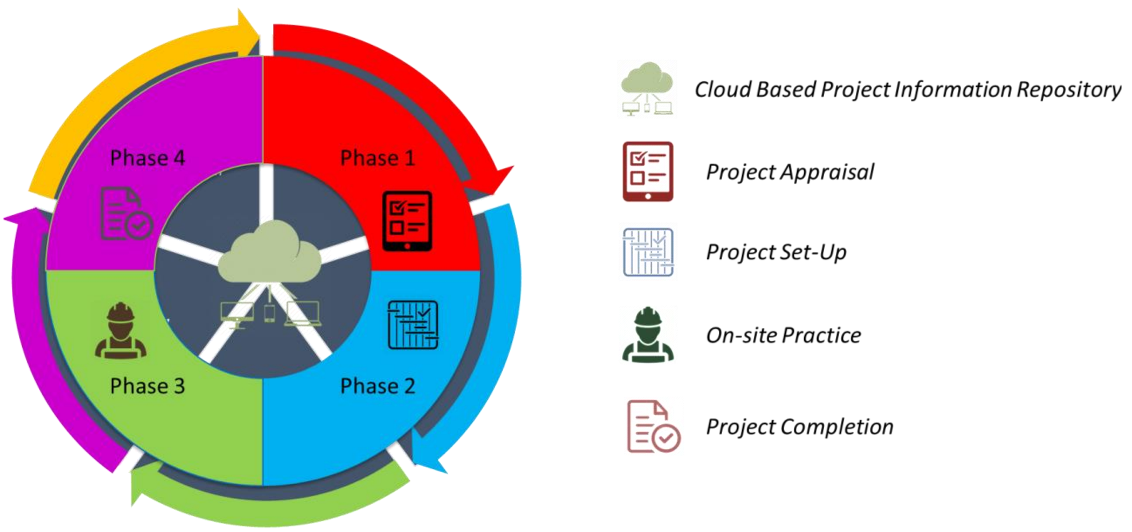


Figure 7.1: Structured Process Wheel

For the historic building repair and maintenance sector ecosystem and the complex, and multidisciplinary nature of projects, in order to support an analysis of existing processes; it was necessary to produce process maps, to communicate the complex processes involved in projects, in a more simplified and easily comprehensible form (Vom Brocke and Rosemann, 2015). Utilising the SME generated high level generic historic building R&M process diagram (see section 5.4.1; and Figure 5.2), and employing the Business Process Model and Notation (BPMN) technique, enabled, the further generation of a high-level process map for current Historic Building repair and maintenance, as illustrated in Figure 7.2.

The intention was then to; process map work activities and tasks, at a level of appropriate detail, in order to develop a detailed understanding of current implementation, using diagrammatic symbols to capture the sequence of work activities. With a dual goal to develop a framework for the UK historic building repair and maintenance sector, as well as being designed, so that it could be both scalable to project size and definition, allowing the possibility that the framework could be implemented internationally and perhaps across the wider European Union repair and maintenance industry, hence the reasoning behind the scope of the mapping process.

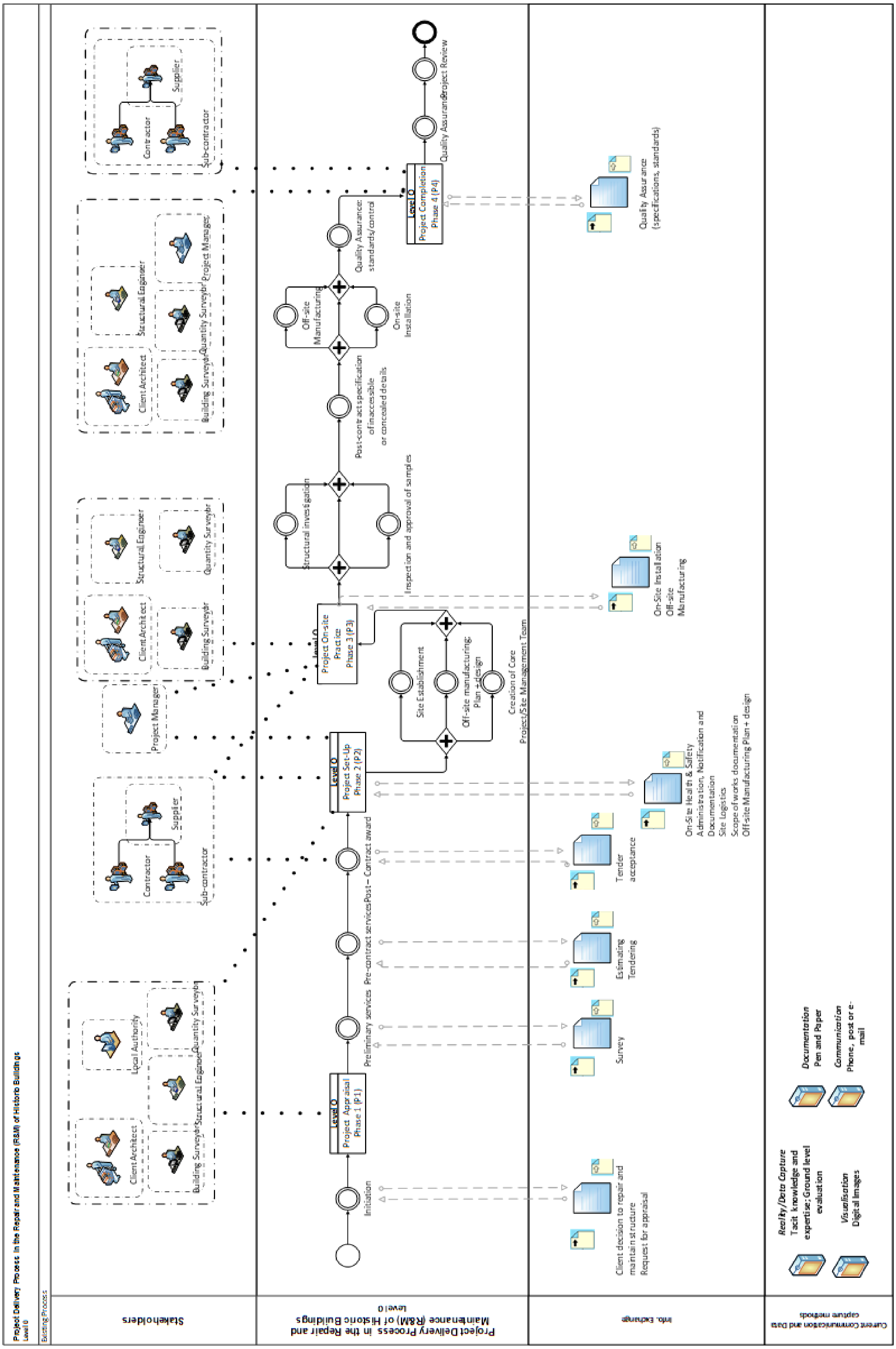


Figure 7.2: Conceptual Generic BPMN process map illustrating common Historic Building Repair & Maintenance 4 Phase Model and 8 Sub-phases

7.3.1 Business Process Model and Notation (BPMN)

Employing the Business Process Model and Notation (BPMN) technique allowed diagrammatical representation of the current interfaces, key information exchanges, and the communication and data capture methods, employed in projects between the internal and external stakeholders: (i) Project End users; Clients, Local Authorities; (ii) Design team (Architects, Building Surveyors, Quantity Surveyors, Structural Engineers, etc); and (iii) Construction team (Contractors, Project Managers, Specialist Sub-Contractors, and Suppliers). Within each phase, there are eight sub-phases, linked to different elements of historic building repair and maintenance management, which themselves have a number of sub-processes, which in turn require a range of operational activities to be completed during the four main phases (see Figure 7.2 & Table 5.6).

During the creation of process maps, the sequence of complex activities was simplified, thus depicting the roles, activities, and interactions between all project stakeholders (people, technology, information, etc.) in the project delivery process. Hence, the generated best practice process map contains four process levels (level 0, 1, 2, and 3); Level 0 is the highest level process that contains the four main phase and eight main sub-phases and down the left-hand side, of the BPMN map illustrates the following; (i) project stakeholders; (ii) project delivery process; (iii) information exchange; and (iv) digital technologies available (see Figure 7.3).

In terms of the remaining three levels; Level 1, contains the sub-processes of level 0; Level 2, contains the sub-processes of level 1; and Level 3, contains the activities within level 2, (see Appendix F for more details). Once the mapping process had been achieved, in terms of the processes within the *CrOsS* framework it was felt that for the actual framework development, to satisfy academic rigour, BPMN on its own, whilst highly illustrative, (see Figure 7.3), neglected the research study's need, to develop a SME focused process model template. Thus, based upon the findings of the study, it was decided to adopt an innovative methodology; combining BPMN with the Generic Design and Construction Process Protocol (GDCPP) (Cooper et al., 1998), to generate a process model, as a foundation for the development of the framework.

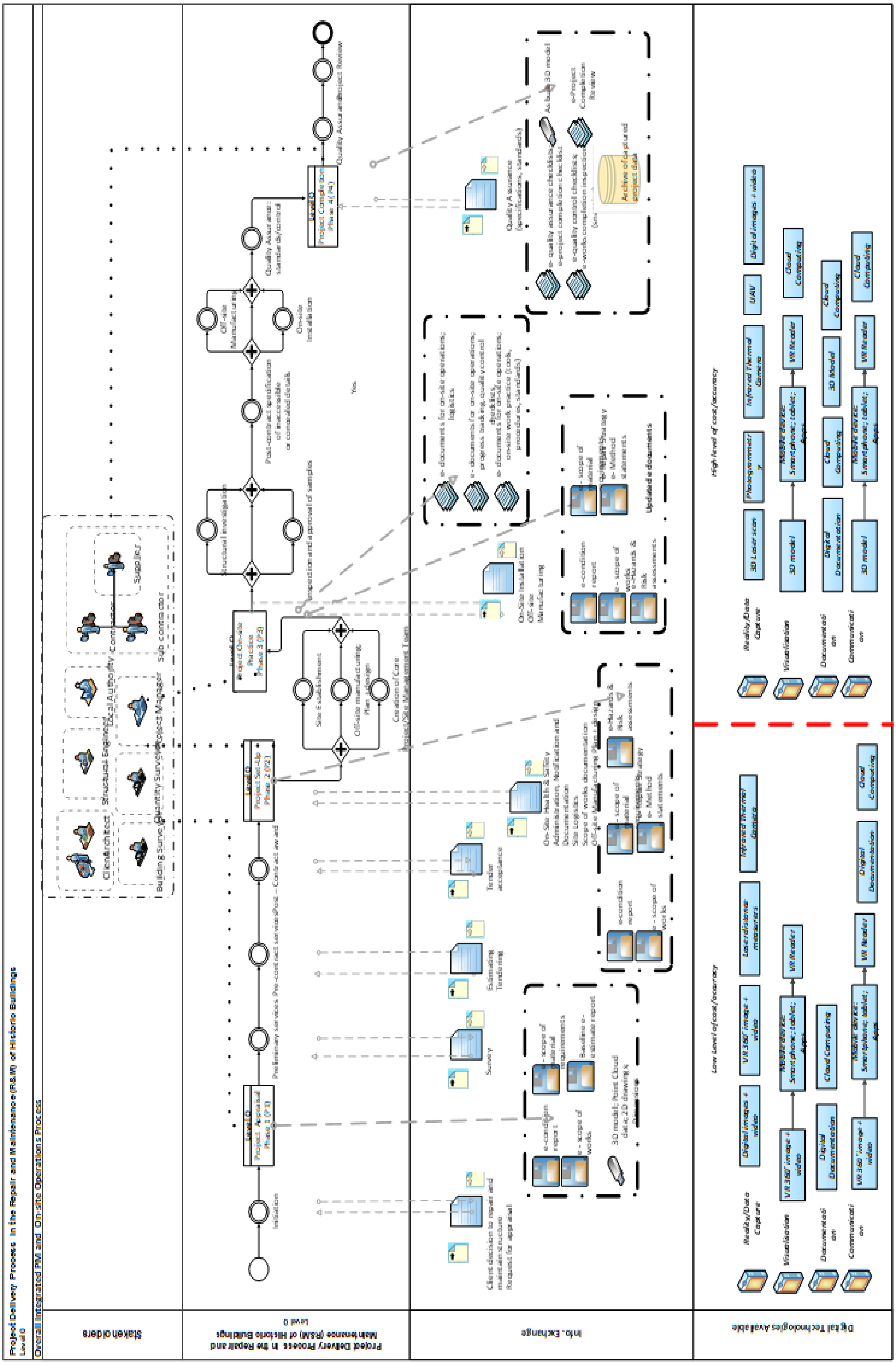


Figure 7.3: *CrOsS* Process Map

7.3.2 Generic Design and Construction Process Protocol (GDCPP)

The Generic Design and Construction Process Protocol (GDCPP), developed by the University of Salford in 1998, as a process protocol, to provide a harmonised framework, designed to help remove the issues and deficiencies of then current practices, was founded on the need for a support mechanism to drive project improvements (Kagioglou et al., 2000). Furthermore, the GDCPP framework was developed to encourage industry practitioners to appreciate processes more easily, and identify the appropriate stakeholders who were required to be involved, in order to enable more efficacy, in terms of project time, communication and resource management, through the control and management of work administration, by adopting a "*shared vision"* based on a set of common standard terminologies, documentation, and processes (Kagioglou et al., 2000). Thus, the typically broad covering terminology of four project phases (i.e. Pre-Project, Pre-Construction, Construction, and Post-Construction) were mapped across; the GDCPP's horizontal axis, which were sub-divided into ten individual phases, numbered 0-9 (covering areas such as project need, feasibility, design, construction, etc.); whilst down the vertical axis, known as Activity Zones; eight processes were mapped (e.g. project management, design management, health and safety, statutory and legal management, etc.) (see Figure 7.4) (Cooper et al., 2005). However, the majority of the phases mapped of the GDCPP were related to the design and planning phases of a project (i.e. eight out of the ten phases), consigning the phases of construction, operation, and maintenance to the final two phases (Chan, et., al, 2004). Nonetheless, it remains a valid process management tool for professionals and contractors alike (Chan et al., 2004).

Within the context of historic building repair and maintenance projects, the GDCPP provides a number of potential advantages, such as: allowing the realisation of the much heralded multi-disciplinary and collaborative environment, thereby, enabling the need and desire for professional and contractor integration. However, in order to utilise the GDCPP, as both a Project Management and a "*process management and improvement"* tool; demands innovative and creative composition in terms of project delivery management. Instead of adopting a traditional delivery system, as currently employed, embracing an IPD based system, would allow the required amenability and flexibility to allow certain processes and their associated activities and tasks to occur simultaneously given in historic building projects, the processes are not always linear (they tend to be highly iterative in nature).

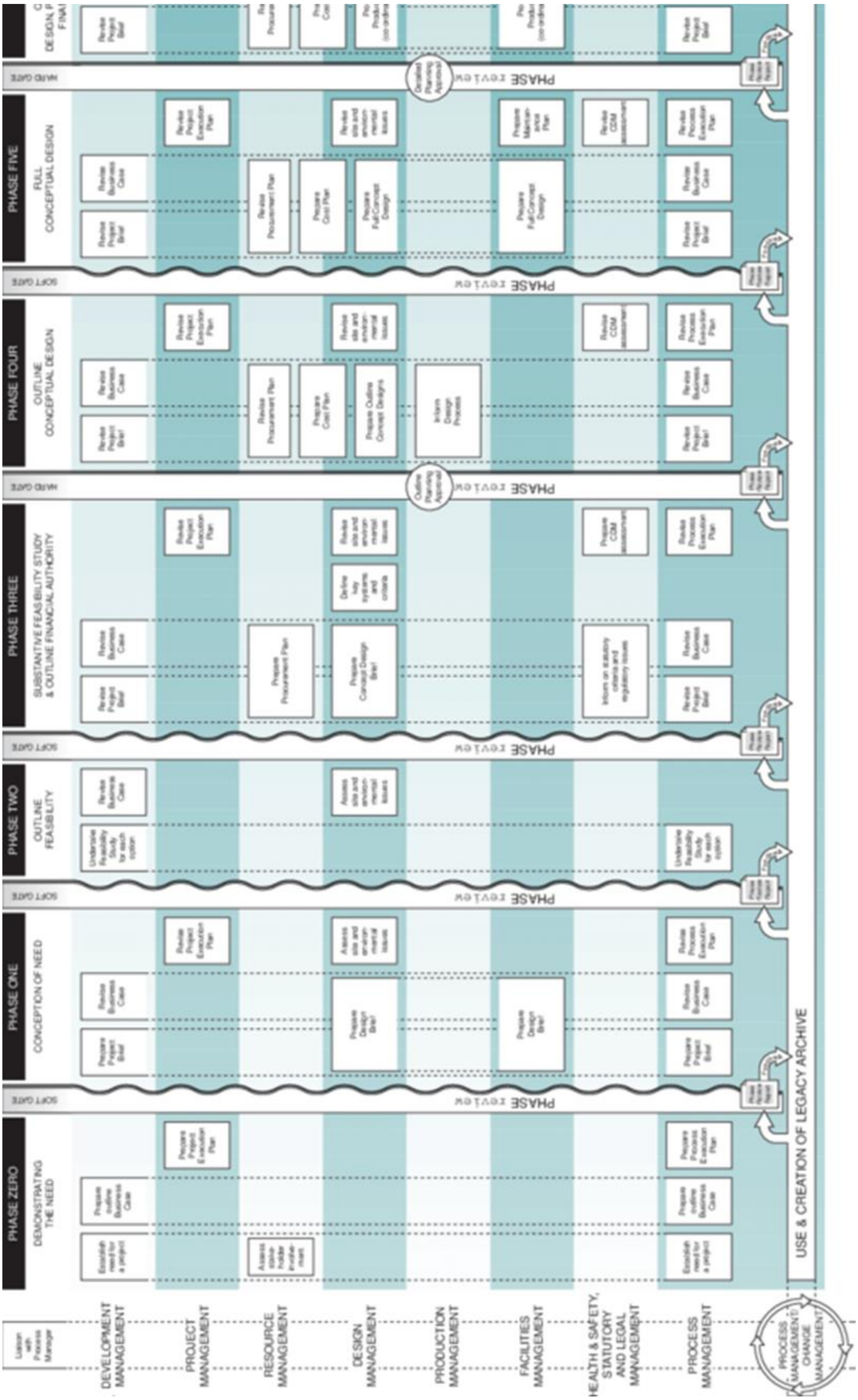


Figure 7.4: The Process Protocol Map illustrating Activity Zones along the vertical axis and Project Phases along the horizontal axis (Kagioglou et al., 2000)

7.4 Framework for Historic Building Repair and Maintenance Projects

Returning to the decision to adopt Business Process Model and Notation (BPMN) with the Generic Design and Construction Process Protocol (GDCPP), two key reasons, underpinned the decision and are as follows; (1) the BPMN method could accurately represent the cross-functional, multi-disciplinary nature of the historic building R&M process; particularly with its use of "*swim-lanes"* (see Table 5.8), to enable stakeholder communication, to be visualised and for being critical, to identify where digital data exchange requirements are needed (Tangkawarow and Waworuntu, 2016); (2) the X (horizontal) and Y (vertical) axes of the GDCPP allowed visualisation of the project processes and stakeholders, whereby, the X-axis indicates the phase, process, sub-process and process activities, whilst the Y-axis illustrates the stakeholder participation and integration in the overall process. Furthermore, in order to adopt an IPD approach, the GDCPP provides the mechanism of *"Stage Gates",* which invoke a phase review process, whereby, project teams and key stakeholders communicate; as to how the project is progressing, whilst collaborate to verify whether work can commence in the following phase. For the historic building R&M process, it will provide an integrated gateway to assist premature forward movement, given such a tendency results in poor decision making. Hence, the *"stage-gate"* approach dictates that collaborative decisions and the subsequent feedback can be corroborated and finalised, prior next phase mobilisation. The following sections will begin with providing a description of the; process model phases and features; followed by providing a description of the *CrOsS* framework.

7.4.1 BPMN & GDCPP Based CrOsS Process Model Phases and Features

Across the top of the process model; there are four main phases and eight key subsequent sub-phases generated from the qualitative participatory action research pilot study, and the resultant generated BPMN high-level generic process diagram (see Figure 7.5):

- *Phase 1; Integrated Project Appraisal (Preliminary services - Integrated Survey; Pre-contract services – Integrated Procurement; Post contract award*);
- Phase *2; Integrated Project Set-Up; (Site Establishment; Off-site manufacturing):*
- *Phase 3; Integrated Project On-site Practice; (On-site operations/Off-Site manufacturing)*
- *Phase 4; Integrated Project Completion; (Quality assurance; Project Completion*

Within each phase, the fundamental concept of a multi-disciplinary approach is facilitated by providing individualised integrated processes, which are supported by defining, establishing, implementing and maintaining a collaborative environment, whilst instituting digital technology awareness, knowledge, and preparation. Furthermore, within each key sub-phase, the key main processes, are associated with specific sub-processes, and their relevant activities and actions, linked to different elements of historic building Project Management.

Down the left side of the developed process model, five headings clarify the project team members involved in each phase (see Figure 7.5), which allows the identification and defining of the required level of collaboration to meet the project objectives, although this is project scale and complexity dependent. For example, a complex project will require a higher level of collaboration, in comparison to a simple project much earlier the project lifecycle:

(1) Client; (2) Design Team; (3) Main Contractor; (4) Sub-contractor; (5) Supplier

Within the *CrOsS* framework process model itself, the following seven major components are embedded (see Figure 7.6)*:*

(1) Project Phases and Sub-phases (see section 7.4).

(2) Process; a series of management and construction operation processes (such as surveying, logistics, and quality assurance etc.) and their relevant sub-processes, initiated within each process protocol phase.

(3) Project Stakeholders; adopting a multi-disciplinary approach, relies heavily upon the dissemination of the correct information, to the appropriate stakeholders, at the most suitable time. Hence, this feature of the *CrOsS* framework is to embed this concept visually, by identifying and prioritising the appropriate stakeholders involved at the various phases and sub-phases.

(4) Stage-Gate: enables a controlled evaluation check, at the end of each phase, as individually a series of key processes, sub-processes, and their associated tasks and activities must be dealt with and the subsequently required outputs achieved. Given the iterative and complex nature of the historic building R&M process, which lends to a considerable number of changes; two gate types have been incorporated*; "soft"* and *"hard"*; (1) *"Soft"* gates allow provisional process movement within a key phase, between the previous sub-phase and the following sub-phase. This allows on-going activities to not restrict the initiation of the following process and prevent process slowdown. For example, not completing the identifying and initiating of a collaborative environment process fully or in time will not affect the generation and preparation of tender documents, as full integration, will not occur until a specialist contractor has been appointed; (2) *"Hard"* gate signifies until all preceding processes and activities have been have been completed, no project mobilisation will occur into the next phase. Moreover, at a *"hard"* gate a phase review, digital technology checkpoint, and data bank consultation is undertaken.

(**5) Phase Review, Digital technology checkpoint and Data banks**: are focused and directed towards enhanced communication, collaboration and data capture, enabling the following; (i) Review prior tasks/activities; (ii) Explore and evaluate appropriate digital technology support options for the next phase based on various project dynamics (such as deliverables, outputs, costs, accuracy, speed, LoD etc.); (iii) recording and archiving captured project information.

6) Feedback: This feature allows analysis and evaluation of the completed project, whereby the lessons learned are fed back to all project stakeholders, as a systematic process improvement support mechanism to enable enhance and develop the efficacy of current processes within the project phases. The feedback feature encourages taking the lessons learned from the completed processes and allow them to be viewed as systems (people, process, products, etc.) which interact with each other and with their environment (Melão and Pidd, 2000). The creation and use of reviews, checkpoints, and data banks within each phase, will provide aid to continuous process improvement in historic building R&M practice. Moreover, such concepts aligning with historic building repair philosophy; the need to accurately document works prior to and after work completion, and to enable future management strategies to be implemented (see RICS, 2009; SHEP, 2011). In essence, adopting the Deming Cycle (Deming, 1950), an iterative four or five-step process improvement management method (i.e. plan, do, check, act (PDCA) or plan, do, check, adjust, strategy).

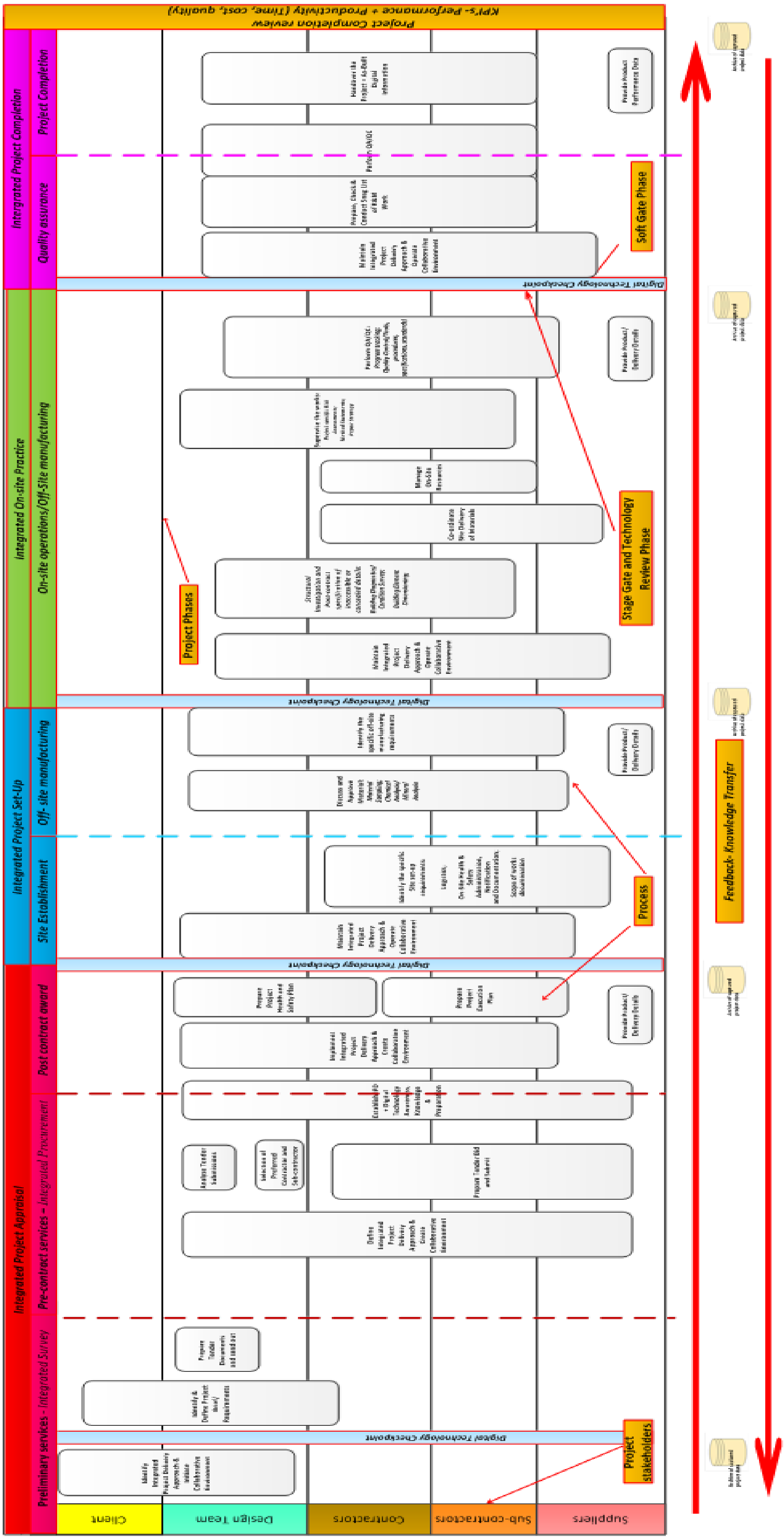


Figure 7.5: *CrOsS* Process Model

7.5 *CrOsS* Framework

Whilst, the framework was developed based on BPMN and the GDCPP, the following historic building R&M management guidance documents; RICS guide (2009); RIBA Conservation Guide (2013); and BS 7913 (2013), allied to the AiA Integrated Project Delivery (IPD) handbook (2014), have also directed the augmenting of content, questions, and outcomes. Within each of the four phases (*Phase 1, Integrated Project Appraisal*; *2, Integrated Project Set-Up; 3, Integrated Project On-site Practice; 4, Integrated Project Completion),* project delivery teams are encouraged to; adopt best practice; augment project vision by working multi-disciplinary and interdisciplinary; shared goal setting and achievement; objective data capture to drive decision making, and specify technology needs.

Replicating the BPMN/GDCPP based process model, across the top of the framework, four overarching phases, which encapsulate the project lifecycle and eight sub-phases, are described. Within each sub-phase, a number of sub-processes with their specific actions linked to different elements of historic building repair and maintenance management, require a range of operational activities to be completed during the four main phases. Therefore, it is paramount to recognise that, whilst, each of these sub-phases are individually relevant, and each should reach a positive conclusion, they are interdependent on each other. Nonetheless, each phase consists of the following seven principles (identified vertically on the left-hand side of the framework (see Figure 7.6):

(*1) Sub-phase description*

(2) Key data capture questions

(3) Action needed

(4) Sub-phase outcome

(5) Digital technology adoption question/s for on-site operations management

(6) Digital tools to assist with integrated-focused on-site operations management

(7) Structured & standardised data capture e-form (Figure 7.7).

The first four principals are adapted from the GDCPP (Cooper et al., 2008), whilst principal 5, 6, and 7 are based and authored in the findings from the literature review, on relevant digital technologies suitable for historic building repair practice (data capture, project visualisation, documentation, and communication). Furthermore, in terms of row 5 and 6, to facilitate Project Management, with reference to defining the required level of digital technology adoption, given there is no universal approach, the decision making process will be based on project budget, LoD, specifications, quality standards, and time schedule outputs, which will vary depending on project scale, complexity, and characteristics. Thus, a number of pertinent project contextual questions are required that are akin to a series of digital technology application checkpoint question/s (e.g., *what level of information is required? what level of data accuracy; usefulness; the level of detail; the level of information; and quality is required?)*

Whilst, for row (7) *Structured & Standardised data capture e-form*, standard data capture e-forms for each of the four main phases of the framework, have been developed to help support improved data capture, with a view of using on live sites. For example, for the Project Appraisal phase, the development of a holistic pro-forma e-Condition survey document, based on existing individual industry and academic guidance (HES, 2007; ICOMOS, 2008; RICS, 2009; SSLG, 2006; Smith et al., 2013; Warke et.,al, 2003; Young et al., 2003). It brings together this guidance into a singular entity and provides a structured and standardised approach for data capturing during the on-site operations process, by SME contractors and professionals (Appendix H).

The historic building repair and maintenance management framework guidelines discussed herein, the following sections, are based on the principles of the GDCPP and IPD, where data flow not only improves process efficacy but also encourages the flow of information (Cooper et al., 2008), offers information to MSME and SMEs (contractors consultants and professionals) with management responsibilities in the following ways: provide a structured, systematic, holistic and integrated approach to undertaking historic building repair and maintenance Project and on-site operations management tasks; and provides guidance on each of the *CrOsS* framework phases.

Main Phase	Phase 1 Integrated Project Appraisal			Phase 2 Integrated Project Set-Up		Phase 3 Integrated On-site Practice	Phase 4 Integrated Project Completion	
Description of the sub- phase	Preliminary services	Pre-contract services	Post contract award	Site Set-Up	Off-site manufacturing	On-site operations Off-site manufacturing	Quality Assurance	Project Review
Key Question/s								
Sub-phase Action needed								
Sub-phase Outcome								
Digital technology adoption question/s for on-site operations management?								
Digital Tools to assist with IPD-focused management	**Low Level of cost/accuracy**					**High level of cost and accuracy**		
Reality/Data Capture								
Visualisation								
Documentation								
Communication								
Structured & Standardised data capture e-form								

Figure 7.6 Project Phases and 8 Sub-Phases description

7.5.1 Phase 1 - Project Appraisal CrOsS Framework

Phase 1 of the *CrOsS* process framework, initiates a series of sequential interdependent processes, to successfully deliver a historic building repair and maintenance project; stating how to plan, manage and implement repair and maintenance practice tasks for projects. Detailed within this phase are three key sub-phases *(1) Preliminary services; (2) Pre-contract services; and (3) Post contract award*, which represent the key components of this first phase, which cover 12 main processes respectively, as presented in Figure 7.7. The nature of the integrated project appraisal phase is intrinsically multidisciplinary, as it consists of a series of intricate and interrelated sub-phases that detail the project, and its procurement needs, such as; *identify and define Project Brief/Requirements, identify integrated project delivery approach & initiate collaborative environment and analyse tender submissions*. In other words, detailing the scope of the project and contract, designing the technical requirements, and assessing the project costs, although a number of processes are specific to each sub-phase.

7.5.1.1 Preliminary services - Integrated Survey

The Preliminary Services-Integrated Survey phase, presents the first sub-phase of the framework, focusing on two key objectives; (i) to identify historic building R&M project requirements and site characteristics; and (ii) initiate an integrated and collaborative environment approach. Within these objectives, there are a number of activities and tasks that require performed (see Figure 7.7), whereby appropriate data capture and subsequent evaluation (surrounding the condition of the building, possible repair strategy and the site environment), requires co-ordination and engagement from the various project stakeholders(i.e. client, architect, structural engineer, and specialist contractor/sub-contractor).

As a first step, it is necessary to designate a core leadership team to support the concept of adopting an integrated project scope of works approach, as well as aid decision-making processes throughout the project and creating sustainable change management. Thus, embracing a new approach under non-traditional procurement arrangements (IPD based), the utilising of experienced specialist contractor/s, shifts the decision-making power from one single stakeholder (invariably the Architect) to full collaboration between all project stakeholders. This approach should play a significant role, in identifying a detailed scope of works and appropriate repair solutions with clear and complete specifications.

Main Phase	Phase 1 IPD Project Appraisal		
Description of the sub-stage	**Preliminary services; Integrated Survey**	**Pre-contract services; Estimating**	**Post contract award**
Key Question/s	***What are the project's strategic and R&M brief, definition & option needs ?*** ***What level of information is required?*** ***What level of data accuracy; usefulness; level of detail; level of information; and quality is required?*** ***Are there any additional survey requirements?***	***What are the allowances and assumptions SMEs have made, to provide a comprehensive, competitive and accurate tender quote?***	***What is the strategy for achieving the collaborative goals?*** ***What are the detailed project schedule requirements for achieving the project goals?***
Sub-phase Action needed	• **Identify R&M Project Brief/Requirements;** • **Identify & Implement Integrated Project Scope of works approach & Collaborative Environment** • **Identify Integrated Project Delivery Approach & Initiate Collaborative Environment**	• **Prepare Tender Documents and send out** • **Analyse Tender Submissions for Main Contractor's Selection** • **Define Integrated Project Delivery Approach & Create Collaborative Environment** • **Adopt a comprehensive tender strategy** • **Preparation of Tender Bid and Submit** • **Provide Product/Delivery Details**	• **Establish IPD + Digital Technology Awareness, Knowledge & Preparation** • **Implement Integrated Project Delivery Approach & Initiate Collaborative Environment** • **Compilation of project specific construction health and safety plan** • **Prepare Project Execution Plan** • **Provide Product/Delivery Details**
Sub-phase Outcome	• Define R&M Project Brief/Requirements; Provide a comprehensive statement of the objectives and parameters for the project based on close consultation between the client and selected organisation in line with the local authority requirements. • Generate Scope of works (Comprehensive on-site survey; site environment investigation; Building Diagnostics/Condition Survey; Structural Investigation; Building Dimensioning; Repair strategy; project specific pre-construction health and safety plan) • Provide an agreed document on project specifications, levels of details and processes for the development and utilisation of digital technologies. • Define Integrated Project Scope of works approach & Collaborative Environment Implementation Plan and Requirements • Define Integrated Project Delivery Approach & Initiate Collaborative Environment; Identify: how a collaborative relationship with other professionals and or specialist contractors could impact on the project; General Outline for Collaboration; communication and data exchange, sharing, management, and storage protocols; roles and responsibilities • Identify the most appropriate procurement strategy	• Define procurement strategy and provide a clear and well-defined type of contract documents (On-Site Health & Safety Administration, Notification and Documentation; Specification, Standards, Bills of quantities, Scope of works, Repair Strategy) in which roles and responsibilities are clearly defined and risks/awards/Quality Assurance are clearly explained • Review submitted tender documentation/cost submission; Analyse contractor track records; Carry out technical evaluation of contractors • Create + Define work plan to implement collaboration; Define communication and data exchange, sharing, management, storage protocols; Define roles and responsibilities; Identify & share project's objectives • Inspection of the structure to be repaired and maintained; site environment/logistics; contract documents; foreseeable project risks; generic H&S risks, work method statements and risk assessments, existing services and structural risks • Provide contractors with product specifications and costings; Off-site Manufacturing Plan + design	• Participation in a IPD + Digital Technology awareness workshop/programme • Identify & share project's objectives • Provide project specific construction health and safety plan • Create a work plan to implement collaboration; Align the work plan with QA procedures • Provide contractors with product specifications and delivery dates
Digital technology adoption question/s for on-site operations management?	What digital technologies are available to support the project's strategic and R&M brief, definition & option I needs? Are there any budgetary constraints to using digital technologies available to support the project's strategic and R&M brief, definition & option appraisal needs?	What digital technologies are available to support the project's strategic and R&M tender process? Are there any budgetary constraints to using digital technologies available to support the project's strategic and R&M tender process?	What digital technologies areas are required for upskilling to support the project's strategic and R&M objectives? Are there any budgetary constraints to establishing a digital technologies upskilling workshop to support the project's IPD approach?
Digital Tools to assist with IPD-focused management	**Low Level of cost/accuracy**		**High level of cost and accuracy**
Reality/Data Capture	Digital images + video; VR 360° image + video; Laser distance measurers; Basic Infrared Thermal Camera + Analyis (IRT) qualitative (description)		3d laser scanning; High – end Infrared Thermal Camera (IRT); UAV; Photogrammetry; digital images + video; VR360° image + video
Visualisation	Mobile device: Smartphone, tablet; Apps; VR Reader		As built 3D model (HBIM); As built IRT analysis check quantitative (measurement)
Documentation	Base line Digital Documentation; Digital images, structured e- documents; VR 360° images		In-depth Digital Documentation; structured e-documents; 3D model (HBIM); AR/VR/MR technologies; Fee based Cloud computing e.g. Trimbleconnect; BIM 360(Autodesk); 3D model (HBIM)
Communication	Mobile Devices + Apps + free cloud computing services (google drive, dropbox) ; VR technologies		AR/VR/MR technologies; Fee based cloud computing
Structured & Standardised Products to assist with IPD-focused sub-stage	Digital Documentation: e-building condition survey; e-repair strategy; e-project site environment checklist; IRT analysis check qualitative (description)		

Figure 7.7 Project Phase 1 and 3 Sub-Phases description

For example, during the survey process, the harnessing of professional and contractor experience, facilitated by the employment of a structured and standard form for data capturing and the application of appropriately suitable digital reality capture technologies, will not only enable higher levels of stake holder collaboration, resulting in better coordination and engagement but also provide objective, reliable, timely and cost-effective data.

Thus, by implementing an integrated project scope of works approach, the combination of historic building repair survey data and project site characteristics data, will assist with Phase 2 and 3; as capturing more objective data, with a measurable level of reliability, at this sub-phase, potentially prevents the need for additional data capture at Phase 2 and 3, and negates the need for additional site data capture visit. This suggests another value of the framework, whereby it not only supports process complexity reduction through providing a more structured methodology to the project delivery process, advocated by the literature but also provides data identification needs and insights at each sub-phase, potentially allowing early data capture for subsequent phases. See Appendix E for a sample of e-Condition survey template and site logistics plan template, developed to provide a structured and standard digitised approach for data capturing, during this process.

To define the required level of stakeholder collaboration, transparency and to meet the project objectives, it will be necessary to generate a collaborative environment implementation plan. In effect, this necessary activity is the beginning of an effectively produced change program, whereby the integration of Project management processes and on-site practice, focuses on outlining collaboration level requirements, which will be dependent on the project, in terms of scale, complexity and outputs, i.e. the more project complexity, the higher the need for better collaborative practice. Thus, it may be necessary, to produce guidelines across the project lifecycle from appraisal to completion, outlining and explaining requirements, as these will govern the collaboration mechanism and at which project phase it should take place. Hence, where a full collaboration level is required during the lifecycle of the project, such as; a highly complex project with an inherently high level of accurate data capture and dissemination requirements, could be based on providing a set of legal documents, outlining stakeholder roles and responsibilities required to achieve the required collaboration level, along with harnessing digital tools such as an industry-specific cloud-based Project Management platform solution, to host a number of digital outputs (3D models, 2D drawings, specifications, etc.). Whilst, for projects of lower levels of scale, complexity, and outputs, reciprocally, a lower level of collaborative environment implementation will be required, For example, employing only a consultant and specialist SME as part of the project delivery team, whereby non-formalised collaboration processes occur, such as freely exchanging knowledge, expertise and resources, in the form of; e-mails, documents, and images. Whilst, invariably for this type of collaboration, these digital tools can be employed, as a path to support the establishment of a low-level collaborative project team. However, it is fundamental that the collaboration remains structured, systematic, and held within a central repository, perhaps using off the shelf options such as DropBox, Sync, or One Drive, as opposed to dedicated Project Management platforms.

Therefore, in order to maintain and implement protocols relevant to; communication, collaboration and data exchange/sharing, the harnessing of a digitally enhanced collaborative environment, will help support the adopted integrated stakeholder approach, guided by the IPD principles of trust, information sharing, collaboration and transparency (AiA, 2007). Hence, project stakeholders, should look to establish, a digitised logistics Common Data Environment (CDE) (a central repository where onsite and off-site manufacturing project information, can be stored and accessed by all project stakeholders) (e.g. see British Standard PAS 1192-2:2013; PAS 1192-6:2018). As such, the project participants should establish the feasibility of adopting such an approach, through developing a high level of understanding of project communication and collaboration requirements, along with functionality needs, in order to determine a suitable cloud-based document management platform for collecting, managing and sharing information to meet this sub-phase requirement.

7.5.1.2 Pre-contract services – Integrated Procurement

This sub phase is the continuation and expansion of the move away from a traditional procurement system towards an IPD based approach, and the creation of a collaborative environment. Therefore, to holistically, establish an integrated project team, consideration of both the design and construction teams' processes and practices, and the need to select a suitable procurement strategy, which facilitates project team integration is fundamental to success. Thus, this sub-phase focus is on the concept of *"Integrated Procurement*", and the need to determine the most appropriate current contractual route available, to facilitate and foster the collaboration process and enhance the project culture (e.g. risk and incentive sharing).

Hence, additional processes within this sub-phase, focus heavily on tender document generation, production and subsequent awarding of the project delivery, to an appropriately experienced and knowledgeable SME specialist contractor based on competitive bidding. However, it is recommended that the invited tendering contractors and any subsequent specialist contractors selection, requires to be decided at the earliest opportunity and influenced, by the project procurement strategy and the associated contractual documents, by promoting a comprehensive tender strategy at this sub-phase, which exercises strong leadership and drives the collaboration process.

7.5.1.3 Post Contract Award

This sub-phase focuses on the *post–contract award* of the project, and its key aim is to determine how to administer, plan implement, and manage on-site operations processes and practice for projects. At this phase, the project team members should have a contractual agreement regarding the project delivery and their remit as part of the collaborative team. Thus, within this sub-phase there are two main objectives; (i) describe the project execution requirements of the on-site operations; and (ii) identify and define work activities and task risks (Pre-construction Health and safety plan; method statements, risk analysis, etc). As such, to enable the integrated project team and stakeholders, to establish, evaluate, check and review on-site operations management, all project team members and stakeholders, as part of a strong leadership approach, should co-operatively develop an on-site operations management template (see Appendix E for a sample of on-site operations progress template).

This will ensure that such an approach is exercised from *"ground zero"* of the planning and construction phases of a historic building R&M project, whilst effectively informing and enhancing potential current and future project success. However, it is worth noting that this initial project planning process document excludes any identified on-site operations and their resultant outputs. Rather it is a more focused Project Management methodology; the methods, practices, and tools, available to harness for On-site operations management such as; management objectives; roles and responsibility; budgeting; schedule of project; management meetings; reporting format; progress tracking. The On-site operations management planning should be generated and concluded during the appraisal phase, as it is vital to successfully conduct the other phases of the framework discussed herein.

7.5.2 Phase 2 Integrated Project Set-Up

Phase 2's purpose is to begin the process of the Project Set-Up, signifying not only the beginning of the site set-up sub-phase *(Site establishment)*, but also the planning and design requirements (*off-site manufacturing)* sub-phase. Furthermore, within this these two key sub-phases; five main processes are covered, respectively; (*1) Maintain Integrated Project Delivery Approach & Operate Collaborative Environment; (2) Identify the specific Site set-up requirements: (3) Discuss and Approve Material; (4) Identify the specific off-site manufacturing requirements; and (5)Provide Product/Delivery Details* (see Figure 7.8).

By providing an integrated Project Set-Up, enables a holistic approach to the involvement of all project stakeholders; from the design team (Architect, Quantity/Building surveyor, Structural Engineer) to the construction team (Main contractor, sub-contractors, suppliers, etc). It is holistic and integrated, in that it considers every project stakeholder's viewpoint, to help support the decision-making process, ensuring appropriate decisions are made collaboratively, transparently and guided by trust; with all the information shared in advance, whereby team success equates with project success.

At this phase fully employing an integrated and collaborative environment-based approach is fundamental, as this will enable the project delivery team to leverage design team data to provide accurate project environment information. Which, in turn can support an environment that is effective and efficient in terms of costs, quality, time and safety, required for logistical planning and optimise the on-site operations process such as reducing material wastage on-site i.e. assisting in validating the scope, risks, and delivery of the planning and design of bespoke traditional elements (see Appendix E for a sample of Site Setup/ Logistics Mobilisation Checklist template).

Main Phase	Phase 2 IPD Project Set-Up	
Description of the sub-stage	Site Set-Up	Off-site manufacturing
Key Question/s	***What are the project's site establishment, definition & option needs to address successful project delivery?***	***What are the planning and design requirements for bespoke traditional building material manufacture?***
	What level of information is required? What level of data accuracy; usefulness; level of detail; level of information; and quality is required? Are there any additional project set-up and/or off-site manufacturing requirements?	
Sub-phase Action needed	• **Identify the specific Site set-up requirements;**	• **Identify the specific off-site manufacturing requirements;**
	• **Maintain Integrated Project Delivery Approach & Operate Collaborative Environment** • **Discuss and Approve Material:**	
Sub-phase Outcome	• Define specific Site set-up requirements; Site logistics; specific H&S risks, work methods, risk assessments, existing services and structural integrity risks • Provide the specific On-Site Health & Safety Administration, Notification and Documentation requirements • Provide the specific site Scope of works documentation requirements	• Provide the specific/relevant Off-site manufacturing- Health & Safety Administration, Notification and Documentation requirements • Provide the specific off-site Scope of works documentation requirements • Provide the relevant dimensioned Construction drawings • Provide specific product H&S risks, work method statements and risk assessments
	• Continued Integrated Project Delivery Approach & Operated Collaborative Environment • Identify and Provide Material Sampling; Chemical Analysis/Mineral Analysis requirements	
Digital technology adoption question/s?	What digital technologies are available to support the project's strategic and R&M site establishment? Are there any budgetary constraints to using digital technologies available to support the project's strategic and R&M site establishment? What level of information is required? What level of data accuracy; usefulness; level of detail; level of information; and quality is required? Are there any additional survey requirements? What digital technologies are available to support data capture? Are there any budgetary constraints to using digital technologies available to support data capture?	What digital technologies are available to support the project's Off-site manufacturing requirements ? Are there any budgetary constraints to using digital technologies available to support the project's the project's Off-site manufacturing requirements ?
Digital Tools to assist with IPD-focused sub-stages	**Low Level of cost/accuracy**	**High level of cost and accuracy**
Reality/Data Capture	Digital images + video; VR 360˚ image + video;	3d laser scanning; UAV; Photogrammetry; digital images + video; VR360˚ image + video
Visualisation	Mobile device: Smartphone, tablet; Apps; VR Reader	3D model (HBIM); AR/VR/MR technologies
Documentation	Base line Digital Documentation; e-site logistics + VR 360˚ images; e-On-Site Health & Safety Documentation; e-Scope of works documentation;	In-depth Digital Documentation; AR/VR/MR technologies; Fee based Cloud computing e.g. Trimbleconnect; BIM 360(Autodesk); 3D model (HBIM)
Communication	Mobile Devices + Apps + free cloud computing services(google drive, dropbox) ; VR technologies	AR/VR/MR technologies; Fee based cloud computing
Structured & Standardised Products to assist with IPD-focused sub-stage	Site Logistics Set-up Checklist template; On-site operations site logistics plan template On – site operations management; e-RiskAssessment; e-Method statements	

Figure 7.8 Project Phase 2 and 2 Sub-Phases description

7.5.2.1 Site Set-Up

At this sub-phase of the framework, three main activities will help to identify and define specific *Site set-up* requirements, hence, all projects must consider the following:

(i) *Site logistics* (identify and arrange work activities such as accommodation and welfare facilities, site areas for material deliveries and storage areas; supply of temporary services, etc.).

(ii) *On-Site Health & Safety Administration* (prepare and obtain health & safety notification and documentation*).*

(iii) *On-site contract documents* (architects/structural engineer drawings, specification, scope of works, provide procedures to update documentation during the works, and establish work inspection regimes and quality assurance procedures).

As part of the framework's fundamental principles, surround information flows to enhance process efficiency, similar to the GDCPP (Cooper et al., 2008), it potentially captures key site mobilisation requirements, which are essential to the project performance and towards achieving the project objectives; by capturing and exchanging data at this sub-phase, as well as being aware of what data is needed at Phase 3 On-site Practice. As such, at this sub-phase, project set–up requirements require identified, thus an efficient and effective site establishment tool is needed, hence, a site set–up register can be generated to provide a foundation for three main site set-up requirements; configuring, structuring and organising the works on site (CIOB, 2014; Griffith and Watson, 2004; PMI, 2008). The site set–up checklist is a needed to not only support project teams, but also to report and record site-specific needs, albeit in the context of the project e.g. small scale historic building R&M works might require minimum temporary site establishment, whilst larger projects will require considerable site infrastructure, therefore the template can be adapted according to project complexity. It is also a useful tool, which aids the construction project team to monitor the status of the *Site set-up*, as it passes from project set-up to the construction phase.

7.5.2.2 Off-Site Manufacturing

This sub-phase indicates the activities that should be carried out as the *Site set-up* is being completed, but before the contractor commences work on site. The purpose of this preparatory sub-phase is to determine and provide the specific/relevant *Off-site* *manufacturing* requirements, as well as prompting SMEs to consider, how on–site element installation is achieved, in alignment with the detailed design identification requirement, along with the identified repair solution conditions. Given, a central feature of the GDCPP are design requirements (Cooper et al., 2008), in the context of historic building repair, this relates specifically to aligning with historic building conservation philosophical tenets, guides, and standards. This raises the inherent tensions of philosophy and cost, therefore, despite the bulk of management tasks and activities, in this sub-phase, carried out by the contractor, it is important that communication and collaboration between the design and construction team is transparent to avoid costly re-works.

7.5.3 Phase 3 Integrated On-site Practice

Phase 3 of the framework is directed towards the delivery of the project, in line with the project budget, specifications, quality standards, and time schedule. Within this one phase, there are seven main processes: *(1) Maintain Integrated Project Delivery Approach & Operate Collaborative Environment; (2) Structural Investigation and Post-contract specification of inaccessible or concealed details; (3) Co-ordinate Site Delivery of Materials; (4) Manage On-Site Resources; (5) Supervise the works; (6) Perform QA/QC; and (7) Provide Product/Delivery Details* (see Figure 7.9).

At this phase, *Integrated On-site practice* covers both the technical and management processes; hence, all project stakeholders are required to have in-depth awareness and comprehension of the intended delivery of the project to be delivered. Moreover, the design and construction teams should perform a significant role, as a part of the collaborative team, in making the historic building R&M scope of works, installation process, and quality of work constructible, with clear and defined specifications. Hence, specialised sub-contractors and suppliers are required to participate in this sub-phase, given they will have contributed to the fabrication and installation performance of the various traditional building elements. More importantly, the work to be undertaken should only be embarked on by competent and suitably experienced contractors and personnel (British Standard 70913, 2013; SHEP, 2011).

The *Integrated On-site practice* phase's predominant focus is on the delivery of the physical works involved in the historic building R&M process (Figure 7.9). Given the level of data generated and the subsequent information available, it is imperative the integrated and collaborative approach, is wholeheartedly and continuously executed, during this phase, to ensure that the difficult task of the management of on-site operations fully embraces a multi-disciplinary approach. For example, what was evident from the literature, was on-site fabrication allied to the methods used for the selection and application of traditional materials, has not always resulted in the most appropriate repair being used. Thus, the literature and the interview findings highlighted this tends to have a negative impact on the quality of work delivered and can result in damage to adjacent masonry (Hughes, 2012; Lott, 2013; Torney et al. 2014). Therefore, the client-facing SME organisation (i.e. the client's representatives) should continue to provide an effective PM, to ensure that strong leadership materialises the required level of control, in terms of; quality control implementation procedures such as; cost control, request for information (RFIs), variations, as-built/as constructed, etc. to ensure that the project team meet their own project targets (see Appendix E for a sample of Phase 3 On-site operations progress report template).

Main Phase	Phase 3 IPD On-site Practice	
Description of the sub-stage	On-site operations	Off-site manufacturing
Key Question/s	***What information and action is required to Co-ordinate, support and during the construction phase of the historic building R&M project?*** ***Has all the information been obtained for contractor/professional to co-ordinate, support and deliver the works during construction phase of the project?***	***What are the additional design requirements of bespoke traditional building material suppliers?***
	What level of information is required? What level of data accuracy; usefulness; level of detail; level of information; and quality is required? Are there any additional project set-up/off-site manufacturing requirements?	
Sub-phase Action needed	• **Inspection and approval of samples** • **Post-contract Structural investigation/ specification of inaccessible or concealed details** • **Manage On-Site Resources** • **Supervise the On-site Installation works** • **Identify Quality Assurance: standards and /or controls**	• **Identify the specific off-site manufacturing requirements for Post-contract Structural investigation/ specification of inaccessible or concealed details**
	• **Maintain Integrated Project Delivery Approach & Operate Collaborative Environment** • **Co-ordinate Site Delivery of Materials**	
Sub-phase Outcome	• *Plans, drawings, specifications, product information, and health and safety* information provided to operatives and/ or those involved in the construction phase of the project • Identification of the details of elemental or specialist investigation work required • Defined specific H&S risks, work method statements and risk assessments, and structural risks based on specialist investigation work required • Progress tracking; Quality Control;(Tools, procedures, specifications, standards) • On-site Installation of repair solutions in line with QA/QC	Provide specific off-site manufacturing requirements; material, dimensions, quantity etc..
	• Maintain communication protocols; data exchange and sharing; document management & transfer; record storage, etc.; roles and responsibilities; share project's objectives; work plan to implement collaboration • Define the specific Site logistics requirements • Provide specific material delivery schedule	
Digital technology adoption question/s?	What digital technologies are available to support and co-ordinate on-site practice during the construction phase of the historic building R&M project? What digital technologies are available to support the project's strategic and R&M Quality Assurance? Are there any budgetary constraints to using digital technologies available to support the project's strategic and R&M on-site operations?	What digital technologies are available to support the project's Off-site manufacturing requirements ? Are there any budgetary constraints to using digital technologies available to support the project's the project's Off-site manufacturing requirements ?
Digital Tools to assist with IPD-focused sub-stages	Low Level of cost/accuracy	High level of cost and accuracy
Reality/Data Capture	Digital images + video; VR 360˚ image + video; Laser distance measurers; Basic Infrared Thermal Camera	3d laser scanning; High – end Infrared Thermal Camera (IRT); UAV; Photogrammetry; digital images + video; VR360˚ image + video
Visualisation	Mobile device: Smartphone, tablet; Apps; VR Reader	3D model (HBIM)
Documentation	Base line Digital Documentation- documents for on-site operations, logistics, progress tracking, quality control, on-site work practice (tools, procedures, standards) e.g. e-Quality Assurance checklists, e-repair strategy, e-H+S Plan, e-Risk Assessment, e-Method statements; VR 360˚ images	High level Digital Documentation; AR/VR/MR technologies; Fee based Cloud computing e.g. Trimbleconnect; BIM 360(Autodesk); 3D model (HBIM)
Communication	Mobile Devices + Apps + free cloud computing services (google drive, drobox); VR technologies	AR/VR/MR technologies; Fee based cloud computing
Structured & Standardised Products to assist with IPD-focused sub-stage	On – site operations management; as-built repository which should also include all request for information (RFIs), change orders, and as built/as constructed changes	

Figure 7.9 Project Phase 3 and 2 Sub-Phases description

7.5.3.1 On-site Operations

Focusing on the *On-site Operations* sub-phase, crucial to ensure the key SME consultants and contractors, are equally assisted during the physical works phase of the historic building repair and maintenance process. Relevant project information is critical, prior to work commencing on the appropriate interventions, as aligned to the project scope of works (final content, extent, and specification) (Smith, 2005). By maintaining an integrated approach, by both SME consultants and contractors, within the project, will ensure that; all project safety issues have been addressed and all of the project management team are aware of specific hazards and risks; confirm and co-ordinate bespoke material site deliveries; installation work will commence on inspection and approval of samples; supervision and progress tracking of on-site installation works, and ensure objective Quality Assurance standards and /or controls are fully implemented. In addition, given the level of information required in projects during the construction phase, the literature surrounding appropriate digital technologies for historic building repair and maintenance, advocates digital information support options, should be continuously explored throughout, to help produce an ongoing as-built repository which should also include all request for information (RFIs), change orders, and as-built/as constructed changes that occur during the construction stage of the historic building repair and maintenance process.

Taking this into account, this sub-phase also ensures that SME practitioners provide any specialist investigations and post-contract specification of inaccessible or concealed details that are required once the on-site installation works have commenced. For example, given the bespoke and complex nature of historic building repair and maintenance projects, it cannot be assumed that one discipline on its own will be able to cover every eventuality (Hyslop, 2004; Maxwell, 2007; SSLG 2006; Snow and Torney, 2015; Torney et al., 2012; Torney and Hyslop, 2015). Therefore, in this sub-phase, the SME practitioners ensure effective communication and collaboration, can obviate the need for more disruptive and costly interventions, whilst in turn help prolong the life of historic fabric, by sustaining the heritage values of the building: a principal aim of historic building R&M (Forster et al., 2011). Therefore, full stakeholder consultation is vital, during this phase to approve the proposed digitally driven integrated solutions and to ensure all information required for managing the future upkeep of the building after the handover is readily accessible.

7.5.3.2 Off-Site Manufacturing

The purpose of this sub-phase of the framework is similar in context to the sub-phase of Phase 2 of the *CrOsS* framework, although, the main aim at this point in the project, is to comply with project-specific specifications, and to provide defined delivery dates in order to support the project scheduling process. This sub-phase is ultimately connected to the process of decision making, and its numerate available options, given, an important scheduling decision is establishing the logistics of materials and components (i.e. availability, lead-in timescales, delivery schedule, etc.). Within this framework sub-phase itself, many decisions are necessary, based on a variety of interconnected activities and thus requires concentrated collaborative reasoning from all project participants (i.e. consultants, main contractors, sub-contractors and the supply chain). Having accurate off-site manufacturing information will reduce the cost and time required for historic building repair and maintenance, whilst optimising the specialist workforce needed to complete the on-site operations. Accurate data can also provide the fabrication, and possible assembly of bespoke traditional elements at a location other than their final installed location, in turn, supporting the rapid and efficient delivery of appropriate interventions, within a safe, healthy, effective and efficient work environment. Indeed, given the literature review, highlighted the perennial issues of poor practice, time and cost overruns, allied to the challenges of skill shortages and deficiencies, this sub-phase process, requires to be engaged as early as possible within the project lifecycle. Moreover, it is strongly advocated, that this is supported, by a monitoring process (quality assurance: QA), based on "best practices" in the material specification data generation and exchange, to secure a formalised harnessing of practitioner experiential and expert knowledge; normally hidden beneath practitioners' tacit knowledge-based decision-making process, when engaged in the scheduling process. However, out with the scope of this research, is the way decisions are generated, whether intuitive or tacit knowledge-based, or based on heuristic evidence-based reasoning.

7.5.4 Phase 4 Project Completion

Aligning with the GDCPP (Cooper et al., 2008), whereby the completion phase substantiates building handover, based on confirmation; that all specified works have been completed as designated in contract documentation, and any defects have been remedied. Thus, Phase 4 of the *CrOsS* framework focuses on the completion stage of the project, concentrating on delivering the project successfully, as per the contractual obligations. However, within this phase, a number of structured processes require undertaken, centred on a series of inspections and certifications, whereby, objective as-built data/information is critical to determining if works have been completed in line with the project's specifications, quality standards, possible funding/grants and consent issues. Hence within this phase, there are two key sub-phases *(1) Quality Assurance; and (2) Project Completion review*. Similar to the previous phases, five main processes are incorporated, respectively: (*1) Maintain Integrated Project Delivery Approach & Operate Collaborative Environment; (2) Prepare, Check & Conduct Snag List of R&M Works; (3) Perform QA/QC; (4) Handover the Project and As-Built Digital information; and (5) Provide Product Performance Data* (Figure 7.10). However, the precise project specifics will differ according to the type of integrated procurement strategy and subsequent form of contract used; an area that is out with the scope of the research study.

Within this phase, two sub-phases envelop the evaluation process: QA and Project Completion review, where these, two verification sub-phases, perform a fundamental part of the *CrOsS* process framework, given the need to ensure the standard of workmanship meets the criteria expected by the plethora of industry guidance, governmental legislation, and standards, such as the Scottish Historic Environment Policy (SHEP) (Historic Scotland, 2011) and British Standard 70913:2013 (Guide to the conservation of historic buildings). Therefore, by adopting a pro-active quality assurance strategy (carry out site work inspections and reviews as the works proceed), can help identify and track defects, especially as defects are subject to a legal focus well after completion (see Appendix E for Phase 3 On-site operations Inspection checklist template).

Main Phase	**Phase 4 IPD Project Completion**	
Description of the sub-stage	Quality Assurance	Project Review
Key Question/s	***What are the project's QA needs?***	***Is the digitised IPD Approach operating in the way it is intended to? Does the digitised IPD Approach perform in the way that achieves the goals and requirements identified in sub-phase 3? What can we learn from the process?***
	What level of information is required? What level of data accuracy; usefulness; level of detail; level of information; and quality is required? Are there any additional QA/QC investigation requirements? Are there any additional QA/Completion review requirements? What digital technologies are available to support data capture? Are there any budgetary constraints to using digital technologies available to support data capture?	
Sub-phase Action needed	• **Prepare, Check & Conduct Snag List of R&M Work** • **Perform QA/QC**	• **Handover the Project + As-Built Digital information** • **Conduct Project Completion review** • **Provide Product Performance Data**
	• **Maintain Integrated Project Delivery Approach & Operate Collaborative Environment**	
Sub-phase Outcome	• Verification and assessment of completed work against project specifications and industry standards. • Mark - up changes to the 'final construction issue' drawings on-site supplemented • Provide as-built surveys (comparison of the exact dimensions, geometry, and location of all elements of the work), in order to allow the CA to produce as-built drawings and record drawings. • Completion of QA/QC Documents • Perform Quality Control;-Tools, procedures, specifications, standards • Implement QA/QC collaborative construction review	• Comply with project specifications • Completion of As Built Documents • Compile all related digital data prepared and used • Update Performance Data
	• Maintain communication protocols; data exchange and sharing; document management & transfer; record storage, etc.; roles and responsibilities; share project's objectives; work plan to implement collaboration	
Digital technology adoption question/s?	What digital technologies are available to support the project's strategic and R&M Quality Assurance and Project Completion review processes? Are there any budgetary constraints to using digital technologies available to support the project's strategic and R&M QA/QC and Project Completion review processes?	
Digital Tools to assist with IPD-focused sub-stages	**Low Level of cost/accuracy**	**High level of cost and accuracy**
Reality/Data Capture	Digital images + video; VR 360˚ image + video; Laser distance measurers; Basic Infrared Thermal Camera	3d laser scanning; High – end Infrared Thermal Camera (IRT); UAV; Photogrammetry; digital images + video; VR360˚ image + video
Visualisation	IRT analysis check qualitative (description); Mobile device: Smartphone, tablet; Apps; VR Reader	As built 3D model (HBIM); As built IRT analysis quantitative (measurement)
Documentation	Digital Documentation; VR 360˚ images	Digital Documentation; AR/VR/MR technologies; Fee based Cloud computing e.g. Trimbleconnect; BIM 360(Autodesk); 3D model (HBIM)
Communication	Mobile Devices + Apps + free cloud computing services(google drive, dropbox) ; VR technologies	AR/VR/MR technologies; Fee based cloud computing
Structured & Standardised Products to assist with IPD-focused sub-stage	Digital Documentation: e-Quality Assurance checklists; e-works completion inspection (snagging); e-project completion checklist; e-completion review report;	

Figure 7.10 Project Phase 4 and 2 Sub-Phases description

7.5.4.1 Quality Assurance

The sub-phase of Quality Assurance (QA), from SME consultants, contractors, and suppliers' perspective, should be a pre-requisite of their project delivery process and critical to determine if the works are completed in line with contractual obligations. This inspection sub-phase focuses on the verification and assessment of completed work against, objective as-built information (comparison of the specified material type, dimension, quality, location and classification of all the work elements), supported through; the already established integrated and collaborative environment allied to the quality control procedures implemented throughout the framework, based on the structured and standardised approach to project data capture and utilisation. Thus, SME organisations, suppliers and specialised sub-contractors (e.g.stonemasonry subcontractors) should be able to ensure that all project information generated is sufficiently precise and accurate for the production of appropriately specific as-built data, aligning with building conservation philosophy (Forster et al, 2010).

With the structured and systematic framework taking a digitised IPD based approach enhanced by employing digital technologies, the format and depth of such information can be influenced by the information exchange international standards known as Construction Operations Building Information Exchange (COBie) (Volk et al., 2014) (see BS 1192-4:2014); and newly released British standards BS EN ISO 19650-1 & 2; COBie supports the transfer of digital information within a new build BIM context. However, it is absolutely relevant for historic building repair and maintenance digitisation (EH, 2020), as the vast majority of pre-1919 historic buildings often have incomplete, obsolete or fragmented building data, which results in deficiencies in Project Management, ineffective process outputs, and time loss or cost increases in maintenance, retrofit or remediation processes manifested in the recurring levels of disrepairs (SHCS, 2016). Thus, implementing such standards would simplify future project activities, resulting in several benefits, one immediate, being an increase in monitoring and documenting of previous repairs, to circumvent potentially unnecessary historic building element repair or maintenance, and the considerable extensive associated costs. Once the project has completed the process of inspection, commonly referred to within the industry as "snagging" and completed to the satisfaction of the Project Management, as many acknowledge the beneficial dissemination of good practice, as a way of avoiding the repetition of mistakes (Carrillo, 2005). However, the scale of the project will direct the inspection or “snagging” process, as to whether it requires to be carried out progressively as the project proceeds or left until project completion.

7.5.4.2 Project Completion Review

As with all projects, typically, the natural course of action is to mobilise towards the next project, hence for the historic building repair and maintenance process, such pressures have led, to not dwell on the failure or success records of projects. Therefore, in terms of lessons learned and the future upkeep of these type of historic buildings, this appraisal sub-phase provides value to the framework, such as; ensures a Project Review is conducted with the aim to assess how well the project has been managed, in terms of Project Management and on-site practice processes, rather than the overall success of the project, in order to identify any lessons learned and take this forward to future projects (Eleyan and Loucopoulos, 2011); and provides recognised benefits of disseminating good practice, as undertaking such a sub-phase can support improvement in SME Project Management and on-site practice.

The details within this sub-phase are influenced by projects not only being complex, bespoke and one-off in nature but also they are transient phenomena, disaggregated with a reliance on specialist contractors and sub-contracting consultants and contractors, who tend to adopt a sort of ‘finish-and-go’ perspective. The reasoning behind this is few SMEs have organisational structures, money, systems or practices in place, to collect and improve upon transferable lessons of previous project processes (Williams, 2016); and such an ability to capture digital technologies implementation data, within the Project Management and on-site process in general, can support whether such modernisation and innovation, can indeed support both project and practitioner improvements (contractor and professional practice).

7.6 Chapter Summary

This chapter has presented the *“Common Structured Integrated Collaborative Digitised”* Framework (CrOsS) for Project Management and on-site practice in historic building repair and maintenance projects. The framework consists of four interdependent and continuous phases: *Phase 1, Integrated Project Appraisal; 2, Integrated Project Set-Up; 3, Integrated Project On-site Practice; 4, Integrated Project Completion),* represent a framework for on-site operations management within historic building R&M projects. The framework aimed at providing a simple, yet appropriate and systematic SME historic building repair and maintenance practice tailored process-standard framework methodology throughout the life cycle of a project. It was developed, using BPMN process modelling, allied to the adoption of the GDCPP, combined to SME consultation with SMEs, further supported by guidance (RICS, 2009; RIBA, 2013), surrounding managing and administering specialist conservation projects, with the intention to support an effective multi-disciplinary and collaborative approach and increase the propensity for achieving productivity and performance gains in historic building R&M projects.

This chapter has also presented and clarified the key processes, sub-processes, elements and features of the *CrOsS* framework, furthermore, whereby, using BPMN and GDCPP diagrams, has provided a visual illustration of all its processes and their main sub-processes, whilst several structured and standardised templates developed and designed to aid enhanced data capture were also provided. However, given the research study has adopted an action research strategy with the intention to solve an industry practice problem, the framework for cannot be regarded as complete, unless it has been validated/evaluated. Therefore, as part of the research methodology; the framework has been evaluated and validated through the means of dual approach; a demonstration project and focus groups. The findings from the demonstration project will be presented and subsequently discussed in the following chapter (8), whilst, the results of this secondary validation and evaluation process (focus groups) are presented in chapter 9.

Chapter 8: Demonstration Projects Evaluation and Validation of the "Common Structured Integrated Collaborative Digitised" Framework (CrOsS)

8.1 Introduction

Chapter 8 represents the qualitative findings, analysis, and discussions from stage 3 of the 4-stage research process (see figure 1.1); whereby a practical project-based demonstration project is presented (Project "A"), which provided, the prospect to observe the framework in a "real-world" context, and supplemented with the findings from four semi-structured interviews, performed with key project participants (SME consultants and contractor) from the case study, as part of the research study's pragmatic action research methodology. The concept behind this was to encourage the project stakeholders (SME practitioners) to invest in a theory based structured framework and contribute to assisting the modernising of existing practice. However, given the research study's limitation and constraints (time, budget, difficulty in sourcing projects etc.); only *Phase 1; Project Appraisal* of the CrOsS framework, with a particular focus on the key sub-phase of (*1) Preliminary services* and its associated processes, activities and tasks, was considered and demonstrated. For ease of presenting the findings, the following section headings are used: *(i) Demonstration Case Study Selection Process; (ii) Demonstration Project Background; (iii) Critique of the Conventional Project Appraisal Process; (iv) Critique of the framework process protocol.* Furthermore, Chapter 8 findings are published in the following Academic journal and conference proceedings: Journal of Cultural Heritage Management and Sustainable Development (McGibbon, Abdel-Wahab., & Sun, 2018); 2018 Proceedings of the 6th International Conference on Heritage and Sustainable Development (McGibbon, et al., 2018) (Appendix G).

8.2 Aim and Objectives of the Demonstration Project

The main purpose of this stage was twofold; firstly, the "live" project "A" would enable the demonstration of the applicability, and functionality, whilst support the determination of the feasibility of using the developed *CrOsS* framework in practice; and secondly, to provide an observable opportunity to document the framework implementation in detail as it progressed; rather than retrospectively to gain more in-depth data collection, in terms of it, meeting the needs of historic building repair and maintenance practitioners (SMEs; professionals; contractors etc.) (Figure 8.1). Supplementary to this dual purpose, the "live" project "A" enabled, the researcher to; organically discuss project issues and the potential benefits of modernising Project Management and on-site practice with the stakeholders, on an informal basis, in addition to formalised feedback; raise MSME and SME awareness, and highlight the benefits of augmenting practice, in terms of efficiency and effectiveness, particularly when employing suitable digital technologies; and, perform a rudimentary cost-benefit analysis (CBA), to illustrate where productivity and performance improvements can be made in the Project Management areas of scope, time, cost, quality, and Health and Safety.

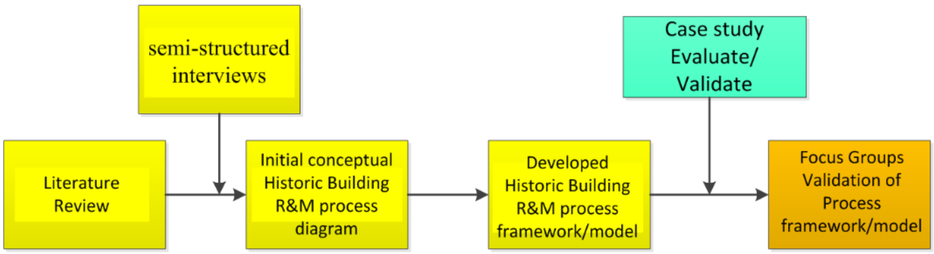


Figure 8.1: Case study contribution

8.2.1 Demonstration Project Limitations

Due to the research project's financial and time constraints, making it difficult to implement the complete *CrOsS* framework and resource all the intended technologies, the framework was not implemented in its entirety. In essence, no four-industry experts had the opportunity to observe or physically use the framework through all the phases or trialled the other developed structured data templates. Nonetheless, a decision was taken, to focus on *Phase 1; Project Appraisal*, in particular, *the preliminary services sub-phase*, with its associated processes, activities, and tasks, such as; the process of *identifying and defining Project Brief/Requirements*, and the complex activity of on-site surveying, which includes tasks such as; building inspection, condition survey, and structural investigation assessments. Furthermore, for Project "A", with a view of providing a comparative analysis for evaluation purposes, it was decided to demonstrate the developed process framework in *"parallel"*, but independently of conventional work processes, and on separate days, in order to avoid disruption to on-site operations.

8.2.2 Demonstration Project Assumptions

Based on the research study constraints (see section 8.2.1), and that, the project had already been awarded to SME "X", several assumptions have been made in terms, of Project Management and administration;

(1) The main processes within the preliminary services sub-phase had occurred, namely; *Identify an integrated project delivery approach; Initiate a collaborative environment, and Analyse tender submissions*.

(2) As part of the Integrated Project Delivery based approach, to facilitate full collaboration between the client, the design team and a specialist contractor/s (see Table 8.3), a professional SME (Architect) administered the project,

(3) For the cost-benefit analysis (CBA) of digital technology implementation, and the comparative analysis between conventional work processes and the process framework, the resultant cost figures assumed that both consultant and contractor rates, were similar in nature.

8.3 Demonstration Case Study Selection Process

8.3.1 Selection of SME Organisations

During stage 1 of the research study, and the pilot interview process, several MSME and SMEs, had voiced, that that they were more than willing to be proactive partners to support the development and be involved in demonstrating the use of a historic building R&M process framework (see section 5.6.2). However, to circumvent possible bias, the researcher used their sector contacts, and approached SME "X", a highly experienced, specialist stonemasonry contractor SME with a workforce of 20-25 operatives, based in central Glasgow, but delivered significantly diverse scale sized projects (small, medium or large scale) across different regions of Scotland, who offered the opportunity to use their projects. As collaborative partners for this research, perhaps more interestingly, they have tentatively started to move away from handwritten reports and begun to investigate the use of mobile digital technologies such as I-pads and digital cameras for reporting project information, as they recognise, the impact of having a more structured and integrated approach to historic building practice, has on their ability to deliver successful historic building projects.

8.3.2 Selection of the case study

Establishing a series of criterion allowed the research study to realise the most suitable case study offered by SME "X", focusing on five key areas with pre-defined key criterion: (*1) Area of Historic Building R&M practice; (2) Project Type/Characteristics; (3) Project "complexity" factor; (4) Project Size Definition; and (5) Project team* (see Table 8.2), however, due to a number of logistical obstacles (timing, appropriate projects, and client permissions), difficulty was found in sourcing a suitable case study, due in part to, possible contractual obstacles afforded to larger public-funded projects, such as difficulty in securing access to project information, resulting from various examples of bad publicity (e.g. Edinburgh city's troubled statutory repairs scheme). Nonetheless, given an essential component of SME "X" core business is involved in the managing and delivery of small-scale projects; it was rationalised that adopting the logic outlined, would overcome the possible barriers and obstacles, whilst also support a deeper understanding, showcasing and raising awareness of the accrued benefits; and the identification of the most appropriate digital technological mix to address specific project process issues, when modernising Project Management and on-site practice in detail.

Case Study Selection Criteria				
Demonstrate the CrOsS framework for Process Improvement in the R&M of Historic Buildings				
Area of Historic Building R&M	Project Type/Characteristics	Project Size Definition	Project "complexity" factor	Project team
Historic stonework repair interventions; (Re-pointing; Descaling; Stone Manufacturing; Stone Indenting; Stone replacement; Possible Structural Repairs)	* "Live" * Under different levels of historic building protection and requiring *Private sector funding *Residential and non-residential buildings	*Small scale *£15,000 - £100,000, and a timescale of 4-12 weeks	Cost/Budget Timescale/Schedule Scope of R&M Works Quality Assurance/ Quality Control Communication	Client; Architect or Building Surveyor or Structural Engineer; Project Manager; Contractor

Table 8.1: Case Study Selection Criteria

8.4 Case Study Interviewees

The four key project stakeholders interviewed had a varied level of occupational experience, surrounding the processes, activities and tasks involved this phase; from a technical practice level to senior management procedural level (Table 8.3).

Respondent	*Position and title of the Interviewee*	*Role*	*Experience Qualification*
CS1a	Owner SME Contractor	Managing Director	25 Years Not Conservation accredited
CS1b	Managing Director SME Design Professional/ Consultant	Structural Engineer	15 Years Not Conservation accredited
CS2a	Managing Director SME Design Professional/ Consultant	Lead Architect	15 Years Not Conservation accredited
CS2b	Project Manager SME Contractor	Project Manager (construction)	25 Years Not Conservation accredited

Table 8.2: Key Stakeholders Interviewed

Similar, to the exploratory study interviews, each interview lasted between fifty minutes to ninety minutes. In terms of due diligence, resulting from, the four-industry experts, not having the opportunity to observe or physically use the framework, through all the phases or trialled the other developed structured data templates, and to provide deeper value to their critique. During the interview process, a brief overview and training session was executed on the *CrOsS* framework process protocol, allowing for augmented and richer discussions surrounding the framework implementation and its promotion of adopting an IPD based approach and digital technology implementation. The training covered the following areas; reasoning behind the use of the GDCPP (Cooper et al., 1998) and BPMN, to inform the framework design; the concept of the *CrOsS* framework; describing and clarifying the developed phase content (the description of each phase; the fundamental questions which need addressed at each sub-phase; and the relevant sub-phase outcome).

Based on this process, the four key project practitioners' perceptions of the process were asked five open-ended questions, surrounding; *(1) clarity and comprehensiveness of the framework; (2) its main benefits; (3) possible barriers to its use; (4) framework limitations or weaknesses; and (5) for suggestions to further improve the framework* (Appendix D). To facilitate analysis of the qualitative data, interviews were; recorded, transcribed, then the collected data were coded, categorised, and grouped together. However, in this instance, due to the small number of case study interviewees, the need to group the responses into similar themes as stage 2 of the research study; (1) Senior Management; (2) Human resource; and (3) Technical, as well as, employing a data management tool like NVivo 11 software, to highlight emerging points drawn and grouped together, was unnecessary. Hence, a manual analysis approach was selected, which enabled the straightforward analysis and comparison of the collected data, through the consistent reviewing of transcripts, which resulted in a deeper familiarisation with the data, and producing a closer examination of the benefits and possible challenges prevalent within implementing the framework. The next section presents an itemised synopsis of the case study and summarises the demonstration project, highlighting the lessons learned.

8.5 Demonstration Project Background

For the demonstration/case study, a project site located within a conservation area, on the West coast of Scotland, (approximately 30 miles from Glasgow), was selected as an "observation" site. It is a typical pre-1919 block of tenement flats; constructed of solid wall composite construction, approximately 600mm in depth, consisting of a 10m high, 4-storey, red sandstone ashlar front façade with a brick internal leaf; and, whilst situated in an Inverclyde conservation area of Greenock, the building itself is not a listed building. The building, currently maintained by a co-operative of residential householders, whereby previous repairs had been executed on an ad-hoc basis and subjected to poor practice (bad workmanship and inappropriate use of materials). Such construction technology, when subjected to poor practice and neglect, in conjunction with exposure to the elements of weather, is susceptible to a spectrum of common repair defects, as the case with his project, as a number of areas of the façade were suffering from stone fabric decay, and deterioration along with areas of separation and structural cracking of external walls, leading to isolated areas of possible substantial loss of structural integrity throught the loss of historic fabric (Construction Industry Research and Information Association (CIRIA), 1994) (Figure 8.2).

Figure 8.2: Top left: Project "A": Front Façade; Top right: Pre-1919 Block of Tenement Flats; Bottom left and right; Examples of Loss of Structural Integrity

8.6 Demonstration Project for Framework Implementation: Phase 1 Project Appraisal Implementation

8.6.1 CrOsS Framework: Phase 1 Preliminary Services Sub-Phase Analysis

With the objective, to focus on the delivery of the *"Integrated Survey"* (Figure, 8.3), in order to provide timely, cost-effective data with a measurable level of reliability, and to generate objective and specific data regarding the project. Primarily, the framework requires a number of questions posed to the integrated project team, to support an accurate scoping of works and to allow the provision of an agreed repair strategy, project specifications, and ultimately provide a detailed set of costings.

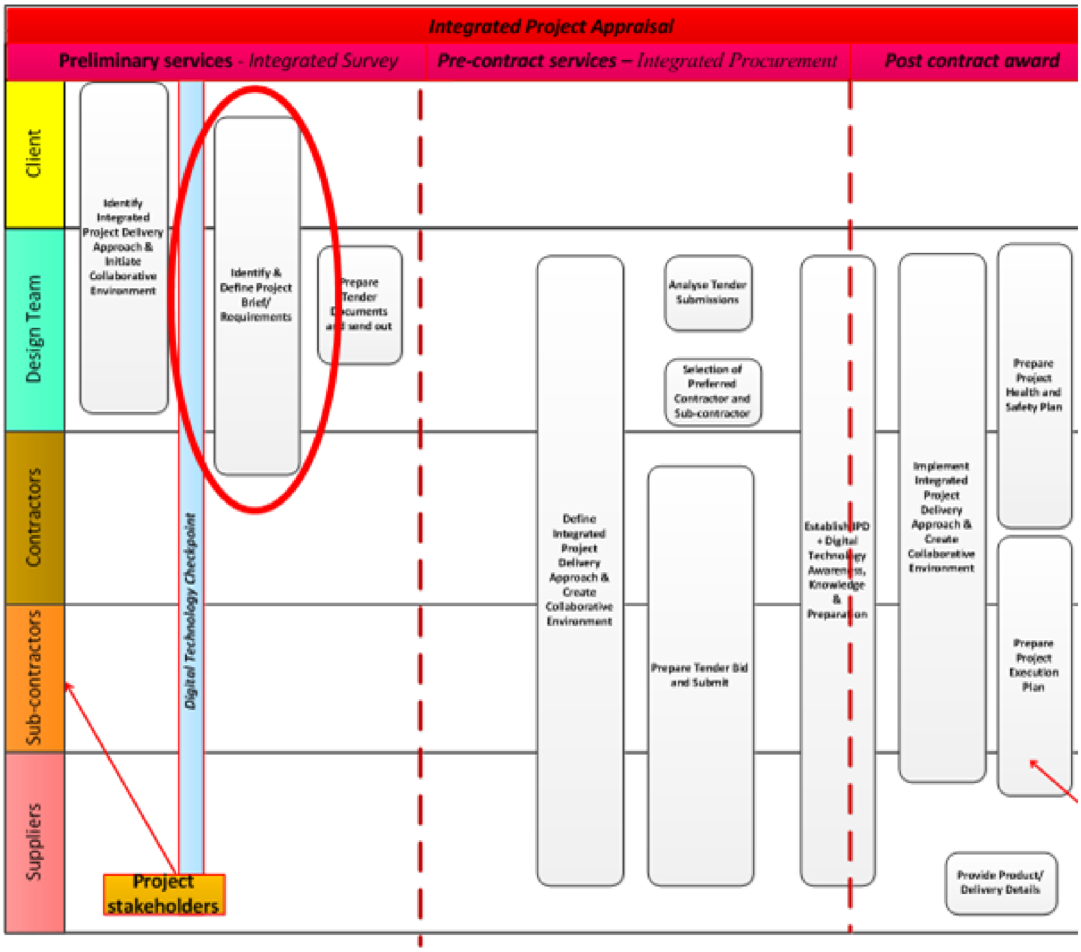


Figure 8.3: Process Model: Project Phase 1: Preliminary Services; See Appendix F for full illustration

Thus, integrated discussions took place between the Project Management team players (see Figure 8.4), such as; What level of information (LoI) is required?; What level of data accuracy/quality (LoDa) is required?; What level of detail (LoD) is required?; What is the value, and usefulness of the data is required? Are there any additional requirements? From this, communication, and central to *"Identifying and defining Project Brief/Requirements"* process, was the initial executed, collaborative ground level survey diagnosis. However, given the relative complexity in terms of data capturing, for example; the intricate nature of the repairs (planar, moulded and curved surfaces); variation in architectural elements being replaced (lintels, cills, rybats); and structural cracking to stone elements, required obtaining precise dimensions, profiles, stone type, etc., drove the need to gather more objective and accurate data. Central to this initial diagnosis was the collaborative ground level survey, whereby, the harnessing of the appointed stonemasonry contractor's experience and knowledge of traditional stonemasonry practice, evidenced, the importance of a multi-disciplinary approach and collaboration in reaching appropriate solutions.

Main Phase	**Phase 1 IPD Project Appraisal**		
Description of the sub-phase	**Preliminary services; Integrated Survey**	**Pre-contract services; Estimating**	**Post contract award**
Key Question/s	***What are the project's strategic and R&M brief, definition & option appraisal needs ?*** ***What level of information is required?*** ***What level of data accuracy; usefulness; level of detail; level of information; and quality is required?*** ***Are there any additional requirements?***	***What are the allowances and assumptions SMEs have made, to provide a comprehensive, competitive and accurate tender quote?***	***What is the strategy for achieving the collaborative goals?*** ***What are the detailed Pre-construction health and safety plan requirements for achieving the project goals?***
Client Client Local Authority	**Client decision to repair and maintain structure** • Request for appraisal by professional consultancy • Identify project description; functionality		
Design Team Architect Building Surveyor Structural Engineer Quantity Surveyor Local Authority	**Identify R&M Project Brief/Requirements ;** • Identify project description; functionality; • Identify if building requires either informal/formal protective measures/constraints (Desk study) • Identify + Define Project Scope of works; (Comprehensive on-site survey: site environment investigation; Building Diagnostics/Condition Survey; Structural Investigation; Building Dimensioning; Repair Strategy) • Identify the equipment and special services/requirements (i.e. Contractors) • Identify how a collaborative relationship with other professionals and or specialist contractors could impact on the project • Generate specific information regarding project **Identify Integrated Project Delivery Approach & Initiate Collaborative Environment** • Identify General Outline for Collaboration • Identify communication and data exchange, sharing, management, and storage protocols • Identify roles and responsibilities	**Prepare Tender Documents and send out** • Prepare tender submission documents • Identify the potential collaborative partners into Tender and the agreed collaboration level. **Analyse Tender Submissions for Main Contractor's Selection** • Review submitted tender documentation • Analyse project cost submission • Analyse contractor track records • Carry out technical evaluation of contractors **Define Integrated Project Delivery Approach & Create Collaborative Environment** • Create + Define work plan to implement collaboration • Define communication and data exchange, sharing, management, storage protocols and roles and responsibilities • Identify & share project's objectives	**Establish IPD + Digital Technology Awareness, Knowledge & Preparation** • Participate in a IPD + Digital Technology awareness workshop
Contractors Contractor	**Identify R&M Project Brief/Requirements ;** • Identify project description; functionality; • Identify if building requires either informal/formal protective measures/constraints (Desk study) • Identify + Define Project Scope of works; (Comprehensive on-site survey: site environment investigation; Building Diagnostics/Condition Survey; Structural Investigation; Building Dimensioning; Repair Strategy) • Identify the equipment and special services/requirements (i.e. Contractors) • Identify how a collaborative relationship with other professionals and or specialist contractors could impact on the project • Generate specific information regarding project	**Adopt a comprehensive tender strategy :** • Inspection of the structure to be repaired and maintained; • Inspection of site environment; • Inspection of Construction drawings • Identify foreseeable project risks; generic H&S risks, work method statements and risk assessments, existing services and structural risks **Preparation of Tender Bid and Submit;** • Prepare tender submission documents • Review and submit tender documentation • Identify the agreed collaboration level.	**Establish IPD + Digital Technology Awareness, Knowledge & Preparation** • Participate in the IPD + Digital Technology awareness workshop **Compilation of project specific Pre-construction health and safety plan** • Identify & Define comprehensive work activities and tasks risk and COSHH assessments, together with detailed safety statements and programmes in order to minimise the risk to those involved in the construction process **Prepare Project Execution Plan** • Identify & share project schedule of works • Create a work plan to implement collaboration • Align the work plan with QA procedures
Sub-contractors Sub-contractor		**Adopt a comprehensive tender strategy :** • Inspection of the structure to be repaired and maintained; • Inspection of site environment; • Inspection of Construction drawings • Identify foreseeable project risks; generic H&S risks, work method statements and risk assessments, existing services and structural risks **Preparation of Tender Bid and Submit;** • Prepare tender submission documents • Review and submit tender documentation • Identify the agreed collaboration level.	**Establish IPD + Digital Technology Awareness, Knowledge & Preparation** • Participate in the IPD + Digital Technology awareness program **Prepare Project Execution Plan** • Identify & share project's objectives • Create a work plan to implement collaboration • Align the work plan with QA procedures
Suppliers Supplier		**Provide Product Details** • Provide contractors with product specifications, pricing and Lifecycle costing	**Establish IPD + Digital Technology Awareness, Knowledge & Preparation** • Participate in the IPD + Digital Technology awareness program **Provide Product/Delivery Details** • Provide contractors with product specifications and delivery dates
Digital technology checkpoint question/s?	• What level of information is required? • What level of data accuracy; usefulness; level of detail; level of information; and quality is required? • Are there any additional survey requirements? • What digital technologies are available to support data capture? • Are there any budgetary constraints to using digital technologies available to support data capture?		

Digital Tools to assist with IPD-focused sub-stages	**Low Level of cost/accuracy**	**High level of cost and accuracy**
Reality/Data Capture	Digital images + video; VR 360˚ image + video; Laser distance measurers; Basic Infrared Thermal Camera + Analyis (IRT) qualitative (description)	3d laser scanning; High – end Infrared Thermal Camera (IRT); UAV; Photogrammetry; digital images + video; VR360˚ image + video
Visualisation	Mobile device: Smartphone, tablet; Apps; VR Reader	3D model (HBIM)
Documentation	Base line Digital Documentation; Digital images, structured e- documents; VR 360˚ images	In-depth Digital Documentation; structured e-documents; 3D model (HBIM); AR/VR/MR technologies; Fee based Cloud computing e.g. Trimbleconnect; BIM 360(Autodesk); 3D model (HBIM)
Communication	Mobile Devices + Apps + free cloud computing services(google drive, dropbox) ; VR technologies	AR/VR/MR technologies; Fee based cloud computing
Structured & Standardised Products to assist with IPD-focused sub-stage	Digital Documentation: e-Quality Assurance checklists; e-works completion inspection (snagging); e-project completion checklist; e-completion review report; IRT analysis check qualitative (description) As built 3D model (HBIM); As built IRT analysis quantitative (measurement)	

Figure 8.4: CrOsS Framework: Project Phase 1: Stakeholder: See Appendix F for full illustration

The framework instigated the need to ask a number of digital technology adoption question/s for on-site operations management, such as; (i) Are there any budgetary constraints to using digital technologies available to support data capture? ii) What digital technologies are available to support data capture? Allied to the need for effective communication and collaboration, between the four key stakeholders, involved in the project (see table 8.2), as part of the integrated approach and in order to better deal with dynamic environment of the project's communication and collaboration; an industry recognised cloud platform (Trimble connect), was used to allow all project stakeholders, to interact with the information that was captured (Figure 8.5).

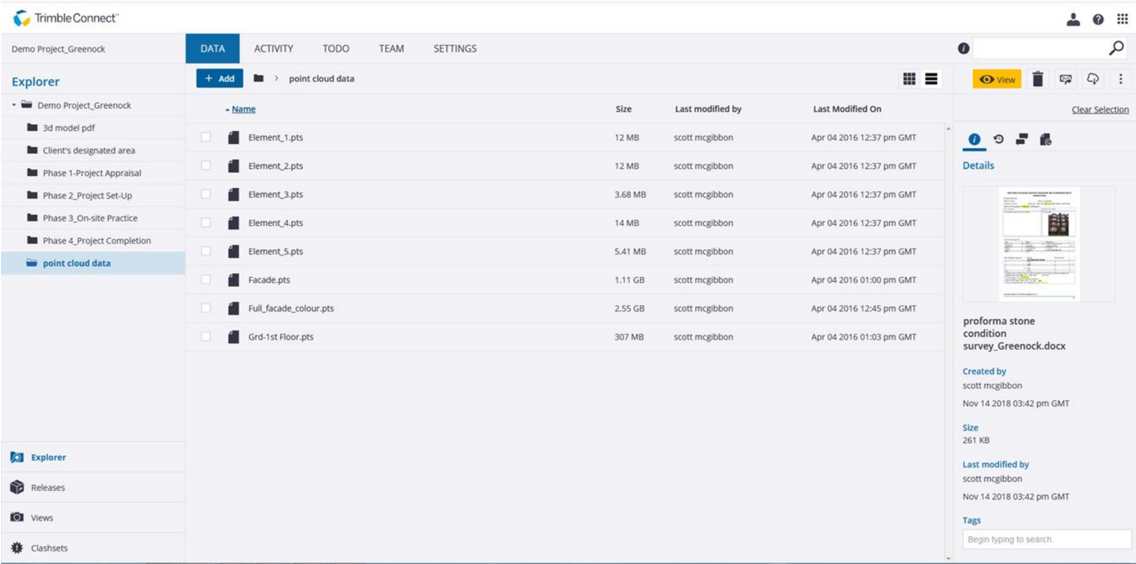


Figure 8.5: Industry Recognised Cloud Platform Repository (Trimble connect) holding 3D model, Point Cloud Data, 2D CAD drawings and e-documentation

Whilst, readily accessible and available; mobile, low cost, easy to use, off-the-shelf digital technology, that was still of high quality, was not disregarded. Based on the need for a high level of detail and accuracy, it was decided to incorporate 3D laser scanning of the building façade, to help capture and inform the proposed scope of works, as well as identifying the nature and scale of the stone repair required e.g. number of stones to be replaced and extracting accurate dimensions for creating templates. A 3D laser scan on-site was carried-out (using Leica 3D laser scanner: Laser class 1 in accordance with IEC60825:2014) with a remit of capturing point cloud data at various levels of scan resolution (Figure 8.6 and 8.7). This allowed the capturing of data from a global level to a regional level to a local level (Table 8.3).

Figure 8.6: 3D laser scanning of the building façade

Figure 8.7 High-resolution laser scan of the ground and first floor

Scan Resolution	Point Cloud density	Area
Low-Medium	6.3 mm of spacing @ 10 m	Whole Facade
Medium-High	3.1 mm of spacing @ 10 m	Ground/First floor elevation
High	1.6 mm of spacing @10 m	Elements

Table 8.3: Scan resolution of Point Cloud data

From the point cloud data, it was decided to; only create a 3D model and 2D CAD drawings of each element (8 in total) being replaced, with the point cloud data 3D reconstruction, conducted using Leica Cyclone stand-alone software, Leica CloudWorx, and TruView plug-in tools for CAD systems. In addition, Autodesk Architectural Revit and AutoCAD 2017 was used to generate highly accurate 2D section drawings of individual stones with each element drawing showing basic dimension extraction (length; breadth; height) (Figure 8.8), although the breadth was assumed @ 250mm, based on the 3D laser scan, which captured window returns of 150mm and typical construction technology of tenement buildings (CIRIA, 1994)

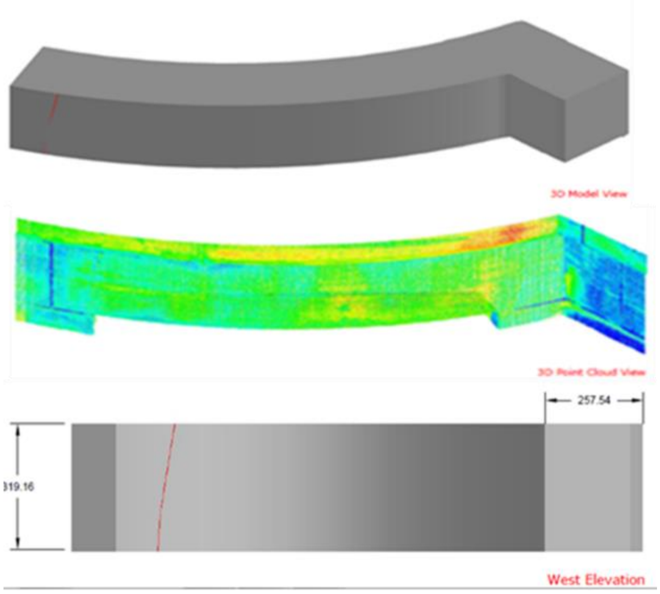


Figure 8.8: Top/Middle: 3D Revit model and 3D Point Cloud Data; Bottom; 2D CAD drawings showing position of crack

In addition to the laser scan data, an e-condition report form also held on an industry recognised cloud platform (Trimble Connect) was populated using an I-Pad (Figure: 8.9). Moreover, the developed e-condition form incorporated a Traffic Light (red, amber, green) colour coding system. In order, to determine individual elements of the building and highlight any areas of concern (based on RICS (2012) condition survey guidelines). In addition, it provided a link to ICOMOS International Scientific Committee for Stone (ISCS) illustrated glossary on stone deterioration patterns (2008) to help support the workforce carrying out the survey to formulate an appropriate diagnosis and offer applicable prognosis at the point of survey.

This provided a structured approach for capturing additional relevant information in relation to stone characteristics (type, detailing, decay symptoms, etc.); the nature of the stone repair required (stone/mortar replacement, plastic repair, strengthening and consolidation, structural repair, etc.); and resulting in the captured data being transferred to the Trimble Connect platform, to allow all project stakeholders to interact with the information.

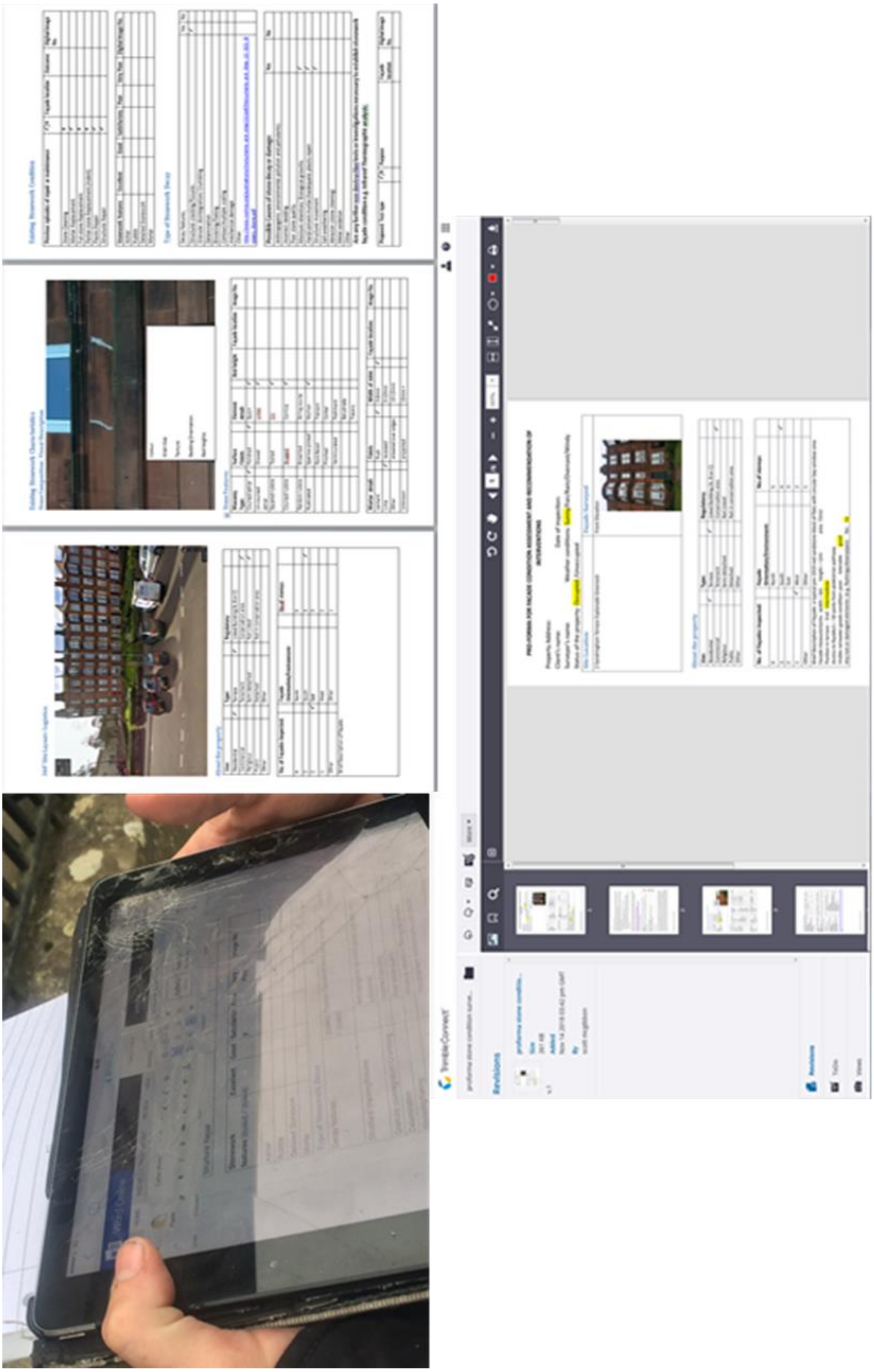


Figure 8.9 Developed structured e-condition survey report form populated using an I-Pad held on Cloud Platform. See Appendix E for full e-condition survey report form.

8.6.2 Preliminary Sub-Phase Key Findings

Although the project itself, was relatively small-scale, regardless, it is crucial, to achieve increased efficiencies such as improved productivity, raising performance and, to help meet project delivery goals of time, budget and scope/quality workmanship. This demonstration case study clearly shows the benefits of implementing the *CrOsS* process protocol and framework; as it can encourage the adoption of an integrated multi-disciplinary, structured and highly collaborative and communicative approach, by enhancing stakeholders' ability to communicate and collaborate timeously and provide enriched project data capture. The following sections provide a brief overview into the primary efficacy impacts on the Project Management and on-site practice processes, at the project appraisal phase and summarises the benefits offered:

(1) Common Integrated SME defined Project Management process; given the catalytic role MSME and SMEs provide, to historic building repair projects, in delivering success, the subsequent impact of adopting the *CrOsS* framework, initiated, a much more dedicated, adoption of a multi-disciplinary and collaborative approach, resulting in the following impacts; increase in shared information, knowledge sharing, and professional respect. Whereby, the harnessing of each project stakeholder's expertise, to develop a shared team ethos and goal setting, facilitated the ability of the project to be scheduled and subsequently programmed. For example, traditionally the lack of an integrated approach and communication can subject the project to a number of risks, such as, wasteful of resources, prohibiting the emergence of a common building condition record and more importantly from a client perspective, a poor experience of the sector, which in turn, underscored the sector's tendency to adopt siloed working practices. Yet, all the industry experts are keen to have a more integrated, structured, defined, and holistic approach to historic building practice, to be able to, provide a more accurate diagnosis and prognosis, and a better indication of the actual scope of works, costs, and timescale. Thus, as a benefit of adopting the framework, a much more defined scope of works, more accurate building solutions, and project costings, resulted in an integrated specification, rate, and agreement on the repair methodology (architect– engineer – contractor) being generated.

Unsurprisingly, all the project respondents believed, providing a common structured integrated collaborative digitised framework for project delivery, in a user-friendly interface is the first step for providing a data-driven approach for informing timely repairs of historic buildings, providing an enhanced ability to deliver successful historic building projects, particularly within the private sector. This was substantiated by, both CS1b and CS2a, who acknowledged this was invaluable as their own limitations, in terms of experience and knowledge, admitting, *"They were not formally trained in the complexities of historic building practice";* re-in forcing, the findings from the earlier semi-structured interviews, and to some extent the literature review (see NHTG, 2008; PYE Tait, 2013). They further remarked, that adopting an integrated survey, as part of the framework, identified a number of positive aspects, in particular, the breakdown of this phase into *"moderately simplistic" sub-phases, employing terminology that "doesn't try to be fancy, rather it has a relative ability to be used simply and clearly in practice"*, yet was still *"technically comprehensive"*.

(2) Adoption of multi-disciplinary and collaborative approach: Hence, when informally questioned, in terms of business impacts, they all conceded and recognised that adopting a multi-disciplinary, structured and highly collaborative approach, allied to timeously communication, would undoubtedly not only help in their day-to-day operations, as part of an effective and efficient Project Management strategy, but also resulting in an increase in business efficiency, growth, reputation, and quality assurance. Although they admitted, adopting a multi-disciplinary and integrated approach is difficult, given the number of specialists involved, with all varying subjective perspectives, they acknowledged, such an approach, supported by the framework, offers the ability to harness a deeper level of expertise, across all project lifecycle phases. From, informal discussions, it was raised that from a MSME and SME consultant, contractor, and supply chain perspective, the framework provides a pathway to having *"the golden thread"* for linking design-construction-operations-manufacturing; inherent issues themselves given the transient and nomadic nature of the sector. For example, it was raised the time taken to produce a finalised, accurate and dimensioned scope of works and subsequent specification took almost 6 months, as much of the project communication and data collection, occurred in silos, rather than adopting an integrated approach and discussing how to improve on the progress made. Moreover, anecdotally, in terms of masonry fabric repair with its extended lead-in time (between 8-16 weeks), such fragmented practice has a direct effect on the stone supply chain (manufacturing, fabricating, and delivery of bespoke natural stone components). Unsurprisingly, given the level of data required, such as; dimensions, stone type/characteristics, element profiles, intricacy and complexity of the stone being manufactured. Hence, employing the framework with its inherent collective and collaborative approach, supported by its digital focus, project stakeholders can access project data from anywhere, at any time; for on-site staff, it provided the ability to undertake structured condition inspections, and the details would be immediately available to all project stakeholders (client, consultants, SMEs (contractors and professionals), supply chain, etc.).

(3) Enhanced ability to capture an accurate, objective, and structured data; when employing the *CrOsS* framework, as much of the project data capture and collection, was achieved through objective approaches, negated the possibility of an increase in project logistics (timescale, scheduling, planning, and programming). For example, when engaged at the project appraisal stage, whether as part of the survey process or part of the tender stage, both contractors and professionals are typically requested to provide a condition report of the building along with a scope of works or specification or both, in order to help formulate project costings. The trend is to carry out a ground level, a survey using high-powered binoculars to determine the condition of the building. The primary impacts of this issue are borne out in the following ways. Much of the data acquisition is subjective in nature and relies heavily on the inherent tacit expertise and knowledge of either the contractor and/or the consultant (Armesto-González et al., 2010) presenting a number of quality issues. Resulting in objective information deficits, in terms of fabric deterioration issues, decay causes, dimensional, and repair specification accuracy, typically recorded solely as a narrative written report. Although CS1b indicated, that typically *"to augment these inspections, normally digital images are taken by the surveyor tasked with the responsibility for compiling the project data"* and that the data captured is invariably sporadic in depth and detail, reflecting, *"There is typically variation in the type and amount of data collated by the personnel who carry out the surveys".* Moreover, to gain an in-depth of the façade of the masonry repair problems as well as the ability to gather accurate data (dimensions, profiles, stone type etc.). As part of the conventional process, this could only be achieved when erected scaffolding to the front façade of the building allowed a close hand visual and dimensional investigation and inspection (Figure 8.10).

Figure 8.10: Scaffold for Conventional in-depth survey access

Thus, capturing structured data by introducing document templates (supported by coming CEN 442 standards) held on an industry recognised cloud platform and populated using an I-Pad. Allowed the production of accurate and detailed records of the building in its present state, as well as capturing additional relevant information in relation to stone type, and the nature of the stone repair required. In addition, by employing a 3D laser scanner, allowed the production of highly accurate and detailed measurements of not only the complex architectural elements but also the full façade. This also allowed the creation of highly accurate stone carving profile templates of the decayed stonework without the need to cut into the façade, as well as providing a reference point for future quality assurance for ensuring quality workmanship. With e-forms easily created and exchanged, allowing all the information to be stored in electronic format, permitting the forms to be uploaded directly to the project information repository at the point of data collection. This provided effective real-time information to project stakeholders along with producing a more efficient on-site operation process., as the sharing of project information, ensured that there was one common reference point for project stakeholders.

From a costing perspective, for both the Project design and construction team, capturing structured data can also aid in informing costs estimates and supporting the development of e-Risk assessment and method statements. These in turn can facilitate the provision of an e-Quality Assurance checklist to ensure that the repairs were carried-out to the required standards and provide a level of confidence and protection for both the client and contractor in terms of quality and defects liability period of contract work. For example, some of the key project participants did lack the technical expertise and skills necessary to not only provide appropriate diagnosis and prognosis, but more importantly identify appropriate repair interventions and specifications in line with historic building legislation and guidance (BS 70913: British Standards Institution, 2013; Historic Scotland, 2011a; Scottish Government, 2014a).

In summary, the demonstration project highlighted, employing the *CrOsS* framework throughout a project lifecycle (from planning to completion) could be fundamental for successful delivery, has different skills, knowledge, expertise, and understanding are required for each occupation (craft and professional) and often over-lap during projects on historic buildings. Additional data collection, from the key project practitioners interviewed, allowed the research study an attempt to measure the benefits and impact of adopting integrated surveying in terms of KPI impact on time, cost, and quality of data captured and health and safety. These results imply, that if the proposed framework was used across the whole project lifecycle to assist SMEs, process inefficiencies could be minimised, with a combination of better historic building R&M practices, better processes, or better technology. The following section will provide an overview and discussion on the comparative analysis of digital technology implementation and the resultant cost figures.

8.6.3 Estimated Impact: Productivity and Performance Improvements (Cost, Time, Quality, Health and Safety

The concept behind measuring the impact of the *CrOsS* framework is to illustrate where productivity and performance improvements can be made, when the integrated framework (in part) with the incorporation of digital technologies, in comparison to traditional surveying methods, which highlighted a number of benefits (see Table 8.4). For example, currently when capturing on–site data (stone characteristics, the scope of work, site logistics, etc.), the tendency is to capture handwritten data, then transfer it to a digital format off –site, which can take at least a full day or more, dependent on the scale of the project, as well the potential to have transcribing errors. The structured e-form eliminated the need for duplication, as well as a reduction in transcribing errors between site and office, borne out in comparison with the conventional survey; 25-30% estimated time and cost-saving were experienced; as CS1b enthused *"A move away from handwritten reports to the use of mobile digital technologies such as I-pads and digital* *cameras for reporting project information. Will enable us to provide a better level of detail and submit not only more accurately specified report but also provide a more quality driven, transparent and competitive process to clients; a win-win for everyone".* However, caution must be taken when interpreting these figures as they were based, on the assumption, both consultant and contractor rates were similar in nature (see Table 8.4). Nonetheless, these results are very much in line with the literature (COTAC, 2014 Stroeker, & Vogels, 2012), which suggested that digitisation could; enhance work prioritisation, project scheduling/programming/monitoring work progress, and that it was very susceptible to efficiency gains at scale, in essence, the larger the project, the lower the cost of digitisation. Whilst from a SME contractor perspective, CS1a imagined it could facilitate the production of in-depth condition reports without the need for high levels of knowledge and experience, observing, *"Digital technologies and a structured e-Condition report will help in taking-out the guess work from condition surveys to get a real sense of the state of the building. I would just get my site manager to fill in the structured and standardised e-condition report on his tablet, capture digital images of the decay issues, then share with everyone in the project team".*

Survey Process	**Conventional Approach**	**CrOsS Framework Approach**	**Benefits**
Time in total	40 hours Inclusive of survey re-visit (on-site & off-site)	28 hours – no need for additional site visits	12 hours (25-30%)
Cost+ vat	£4100.00	£2870.00	£1230.00 (25-30%)
Quality	Tacit knowledge/experience reliance Ground level survey Paper based data capture	Exact dimension extraction & element recording Digital accuracy to +/- 1mm 3d models and 2D CAD drawings of the identified repair areas	Benchmark comparison of the on-site work completed with the intended designed R&M Effective collaboration and communication Cloud based documents accessible to all project stakeholders through mobile devices. Reduction in transcribing errors between site and office
H&S	Access issue; for extracting dimensions accurately H&S documents tend to remain static	No access issues E-H&S documents tailored to project specifics and site conditions.	Elimination of working at height when taking measurements E-H&S documents tailored to project specifics and site conditions.

Table 8.4: Conventional Survey Process and Integrated Survey Comparison

Furthermore, integrated surveying, incorporating digital technologies, not only meant the survey data could be communicated more effectively, but also increased the speed of decision and project understanding, by satisfying the technical needs of the project while increasing client confidence through a highly transparent, and collaborative process. Furthermore, it not only provides a snapshot of the buildings current conditions and the repairs required, but also would provide a reference point for quality assurance, as well as a baseline for assessing future changes in the building condition.

The combinations of the proposed integrated framework and digital technologies, establishes that highly collaborative processes, are fundamental and becoming increasingly important, for all scales of historic building repair and maintenance projects, given their bespoke and complex nature. Adopting such an integrated approach is quickly becoming indispensable for such projects not only for the UK but also internationally, given the level of R&M required. As it cannot be assumed, that one discipline on its own will be able to specify an appropriate repair. Whilst, alternatively, one technology alone will not be the panacea in addressing the challenging agenda and the resultant higher-level skill development needs. Collating data on the condition of historic buildings will indeed help in informing prioritisation of building repairs, the workforce skills needs and in addition funding allocations. Hence, this study is one of the first cases to demonstrate these types of savings, by using a common structured integrated collaborative digitised approach. Thus, similar demonstration project data, becomes paramount for showcasing, how the proposed framework and its integrated approach, allied to the application of technologies can be used pragmatically, in a live project along with the accrued benefits. The following section will provide a discussion centred on the responses provided by the experts regarding the five open-ended evaluation questions.

8.7 Case Study Practitioners Framework Evaluation: Findings and Discussion

8.7.1 Clarity and Comprehensiveness of the Overall Framework

When asked their opinion on the framework's overall clarity and comprehensiveness, the consensus was there were a number of positive aspects, in particular, that the framework provided, *"a simplicity and practicality to an otherwise bespoke and complex project environment and landscape".* CS1b and CS2b resonated, "*the framework is thorough and unambiguous, particularly the way in which the processes within the various phases were illustrated",* whilst, both CS1a and CS2a similarly articulated, "*the framework is* *well structured, succinct and concise, but at the same time covers the key historic building R&M PM processes with clarity and detail, supported by its guidelines".* However, they all highlighted, that, "*no matter the breadth and simplicity or even the practicality of the framework",* the framework faced a number of inherent sector issues, such as, *"the under regulated nature of the sector, the plethora of specialists, constraints of current procurement options and so on".* Nonetheless, based on the opinions of the demonstration project practitioners, the proposed *CrOsS* framework can be substantiated, in terms of both its technical clarity and comprehensiveness.

8.7.2 Key Benefits of the Framework

All interviewees agreed that the key benefits and advantages of the framework surrounded the practical applicability and suitability of the framework, in terms of the demographic make-up of the sector. Suggesting that it would offer specialist SMEs and MSMEs (professional and contractors alike), *"a logical progressive means for carrying out and managing on-site operations*", to which, CS2b, alluded in his experience, that, *"historic building projects tend not undertake rigorous project process management and tend to mitigate when and where it is needed".* Intimating that process management is done on an *"ad hoc"* basis, and that this "*percolates throughout"*, remarking very much, like how the process of data capture is approached; which is borne out in reality, evidenced by the lack of appropriately specified repairs resulting in continuing levels of pre-1919 buildings disrepair (PYE Tait, 2013, SHCS, 2016). Hence, the ability and the provision for *"documenting lessons learned, at each phase of a project, for not only supporting following phases, but more pertinently for future projects"*, was another key benefit of the framework.

Another key benefit highlighted, was the allocation of responsibility; as to who does what at each phase, particularly through visualisation of the framework using BPMN. CS1b enthused, "*to be able to see at a glance not only where I fit in or what my role is as a project stakeholder, but also being able to see where that relates to the other stakeholders and also give me an indication as to where and when they come into play".* Overwhelmingly, the overarching key benefit was expressed towards the integrated approach, and early composition of the project design and contractor team, reverberating, *"the concept of bringing in more stakeholders early, really resonates and is vitally crucial"* CS2b added, *"The tendency in current practice is to work in silos rather than* *together, despite various specialists coming on board at differing stages of a project"*, whilst, both CS1a and CS1b reasoning that, *"moving some of the design work, as in the framework, to a later stage is crucial, due to the unknowns involved in specifying a historic building repair project".* CS1a and CS2b added further weight to these perspectives, re-iterating a multi-disciplinary involvement, and allowing an integrated approach, early in a project, will not only help minimise delays and changes but also help reduce final project costs, by improving the management and employment of on-site operations through early design process involvement.

8.7.3 Barriers to the use of the framework

Despite the positive views held by the four key project practitioners', when posed the question: "what was their thoughts on barriers to the implementation of the CrOsS framework?" They gave significant credence to the relative concerns of; responsibility, time, cost and quality of framework implementation, however, they intimated that these factors were not as result of the framework itself. It was more so of the challenges of using the proposed framework in practice, fuelled by sector apathy and resistance to change; they all felt, that it was not just about barriers to modernising and innovating processes, but also about people-centric barriers. Interestingly, CS1a, likened it to being caught in a historic building R&M practice "*pseudo time warp"* remarking, *"the last time there was any sort of innovation was the introduction of power tools in the 70's-80's, which is still regarded as modernisation"*. Whilst, there is some element of truth in this comment, echoing the literature, respondent CS2a reasoned that *"naturally people don't like change, that probably the biggest barrier and I am sure most people recognize things aren't necessarily working at 100% there is a tendency to accept this. It's a "If it's not broke don't fix it mentality".*

Hence, when probed further on barriers, they suggested framework users, might presume that it would lead to the need for an additional cost, an increase in documentation and would be time-consuming. As one key project practitioner stressed *"it comes back to the question of not adoption, but cost, where is the value, to employing such a framework?"*, with project stakeholders felt given *"nobody wants to shoulder extra costs"* that it could lead to and in some cases cause adversarial relationships. Yet, this is the complete opposite of what the framework hopes to achieve, however, whilst agreeing that this was a possibility, the consensus of opinion, remarked; the potential benefits would exceed the time and money spent, pronouncing *"given the expense of managing projects, it would* *help support; the efficient delivery of the project; the reduction of variations and subsequent delays, along with going some way to reduce legal disputes and claim".* Interestingly, when posed; *"How could such barriers, be overcome?",* they suggested perhaps, it would make sense not to attempt the entire framework, as in this project, but rather try different project phases with correlated phases of the framework. Thereby, creating less impact on the project and all involved, but concurrently presenting an opportunity to undertake, and scrutinise this integrated approach with its augmented processes. CS1a expanded on this viewpoint, stating "as *a company involved in many smaller projects, going forward using such a tool, we need to determine at what point does the model overall, in its true holistic sense become economically valuable".*

8.7.4 Limitations/weaknesses of the framework

When posed the question: *"In terms of limitations or weaknesses of the framework, what did they consider the key weaknesses?"* The four key project participants' answers were almost identical, agreeing that whilst the *CrOsS* framework was beneficial to their practice. The following are two key potential weaknesses were identified; firstly, it surrounded the robustness of the framework, that, "*perhaps a limitation of this framework with respect to any framework, is that it could limit creativity in design or specification*", with both, CS1b and CS2a, driven by their professional background, adding, "*a lot of professionals will see themselves as providing that ingenuity or creativity".* Suggesting again that process and people were inherently connected, highlighted by CS1b, who remarked, "*there was a need to answer the question; How do we get people to work in this prescriptive or in some case restrictive ways without stifling that creativity?"* When pointed out that in fact, the framework does accommodate the need for such robustness, One of the industry practitioners CS1b, a structural engineer was more specific, offering, an explanation for the first key fragility that it might be a case of cultural behaviour, as professionals and contractors tend to work with a silo mentality. Nonetheless, it does raise the challenge of integrating all the specialty work that surrounds historic building repair, into the framework. Which itself raises the further question; does there need to be specialist frameworks embedded within the generic framework?

For the secondary key weakness, it surrounded potential engagement limitations, as CS2b underscored *"the integrated framework, for a first-time user, whilst appearing at first glance to be simplistic is in fact, slightly more difficult to navigate, than first thought, it* *needs be more end user friendly".* When discussed further it appears this is driven by expertise and familiarity, in terms of embedding change into their practice, as respondent CS2a, offered "*sticking with what you know is a norm for the industry and certainly with new processes and technologies there is a general fear of it, although I believe it is a generational thing"*. Although, it was perceived by all the respondents that *"using the framework may be useful, but without workers commitment and engagement, the effect of the framework could be diluted in its attempt to achieve successful application".* Therefore, they suggested unanimously, that in-house training or a formalised guide is needed to promote and embed the changes into their practice, although, they did stress, that training alone would not be the *"universal remedy",* adding that *"such a step change"* would need to be embedded over time, in order to facilitate the changes into their practice. Rationalising that during busy periods, they have a tendency to revert to their conventional ways of working, when attempting to change the way they do things *"as they don't have time to think about the new ways of working".*

On analysis, the responses confirmed that when considering the adoption of the proposed framework, a fundamental question for the future use of the framework is; could the high levels of demand of the framework, in terms of its need to make sure that accurate data capture occurs, make the proposed framework become redundant, in terms of uptake? However, CS1b, re-iterated the early comment of " *the need for cultural change"* observing, it may be a case of *"does industry want that data to be truly recognised because there is a lot of poor practice out there in the industry that is effectively allowed to be signed off because no-one really wants to acknowledge it".* This does suggest that strategies to overcome these possible mitigating circumstances of usability, quality, and responsibility need to be developed. Especially given that the current UK governmental spotlight, homed in on the issues of construction quality, particularly site supervision and project management within the specialist sectors of the industry (see Hackett, 2018; Cole, 2017). However, this type of debate is out with the scope of the research study. *"From a structural engineer perspective; a limitation is perhaps there needs to be an area highlights the importance of having an in-depth structural survey".*

8.7.5 General Overview and Recommended Improvements for the Framework

For the final question in the interview process, the four key project participants' consensuses, was that the overall framework is pragmatic, valid, and credible from an industry practice perspective. From a construction team perpsepctive, CS2b (Project Manager), stated, *"for a Project Manager, the framework provides a methodical, structured and systematic process, for the project life cycle, in particular, the planning, monitoring and reviewing processes";* whilst, from a design team perspective, CS2a, (Project Architect), re-asserted this opinion, remarking, *"the framework' strength lies in its use of data dump points. Think of these as productive documents which could be used for a schedule of works, common pricing documents, allowing apples to be priced against apples so to speak, as the more accurate contract documents are the more realistic and truer price you receive".* Whilst, CS1a, and CS1b provided a more holistic opinion, observing, *"Just having common ground or in this case a common roadmap for all project stakeholders, is a powerful tool.* They further added, *"Given the increasing pressure that's put-on cost, time and quality, the framework makes everyone work together better and could allow us to gain more acknowledgement of progress, quality checks and more importantly what did not work".*

Whilst the industry practitioners provided a positive general overview, they offered and recommended improvements for the framework, suggesting following five possible improvements for the future application and development of the framework: (1) Increase awareness across the workforce, of not only consultants and contractor management teams but also the on-site workforce in general*;* (2) Summarise the most appropriate and suitable UK recognised forms of contracts for adopting an integrated approach; (3) Provide case study examples, a mix of hypothetical projects and actual projects, which have used the framework, although the second option may be difficult to establish, given the undoubted industry resistance to change and industry fragmentation; (4) Outline medium to long-term options for storing the captured project information. Particularly, given the framework advocates the utilisation of digital technologies for the data capture processes; and (5) Distribution of the framework through a "R&M hub" to all concerned parties in the project, in a similar vein to the manner wider construction industry hubs function.

From the responses of the four key project participants, in terms of the recommendations made, there were a number of valid points raised, particularly, that further demonstration projects would provide practitioners with valuable data on the framework and its associated benefits. Creating a database of demonstration projects, is an interesting one, as it could also be used as a vehicle to increase workforce awareness and possible uptake, delivered through a dedicated programme of training. The recently opened National Conservation Centre (NCC) in Stirling, which had a total investment package of £8.4 million underscores the importance of supporting skills development for the application of modern technology and processes (where appropriate) to support learning and practice. This presents an opportunity for industry to collaborate further with the highly regarded NCC to specifically build-up the construction industry capability in R&M for heritage buildings, considering the development of emerging technologies and required quality and performance standards.

8.8 Chapter Summary

This chapter has presented the results of the demonstration project and the semi-structured interviews, in order to; (i) to provide a preliminary validation /evaluation of the framework, in terms of it meeting the needs of historic building repair practitioners (SMEs; professionals; contractors, etc.); and (ii) to demonstrate the applicability, functionality and determine the feasibility of using the developed framework in practice. The results from the demonstration project has shown that as a means for attaining a multi-disciplinary and collaborative approach (an approach the wider industry has been yearning for in numerous government reports (Farmer, 2016; Government Construction Strategy: 2016; Wolstenholme, 2009). The move towards a common structured integrated collaborative digitised *(CrOsS*) framework, provides a good basis for process and workflow improvement for historic building repair and maintenance practice, through a number of performance benefits, such as; enhanced the objectivity and quality of data captured; improved project communication and collaboration, and it also highlighted possible reductions in project time and costs.

Based on the responses from the four key industry practitioners, the subsequent results and discussions suggest that the framework, is a pragmatic, valid and credible from an industry practice perspective, and it is evident, with the increasing demand for delivering high quality building repairs and delivering value for money, the need for modernising and optimising the on-site practical work and effective project management becomes fundamental. There is an undoubted need to bring consultants, contractors, and the supply chain together, as current project synergies between all stakeholders, naturally creates a stimulus for risk/award sharing and in turn the dynamic and multi-disciplinary oriented nature of historic building repair and maintenance will create a more collaborative work environment focused towards better performance and continuous improvement.

However, despite it observable that the existence of a SME focused Project Management framework, based on evidence from the demonstration project and subsequent interviews. The research is not suggesting that the framework presented is the only ‘right’ methodological approach to take, although, to arrive at a deeper understanding of the challenges and benefits facing implementing, the *CrOsS* framework, there is a continuing need for similar demonstration project-based data, to contribute to the development of a framework and enhance a wider knowledge of the major challenges to delivering successful historic building repair and maintenance in the UK..

The following chapter presents the primary the framework evaluation and validation, through employing qualitative approaches such as; the use of focus groups, allied to the use of questionnaires with SME professional historic building repair and maintenance practitioners, to substantiate if the developed framework would add value across the historic building repair and maintenance sector by supporting *“process management and improvement”* processes and enhancing the Project Management and on-site practice.

Chapter 9: Evaluation and Validation of the Common Structured Integrated Collaborative Digitised" Framework (CrOsS)

9.1 Introduction

This chapter presents the primary validation/evaluation of the developed *CrOsS* Framework (presented in chapter 7 and demonstrated in Chapter 8), in order to extract valid and reliable feedback on the developed framework, as a means to satisfy Objective 5. Therefore, to evaluate the credibility, suitability, applicability, and clarity of the framework and to determine if the framework meets the needs of historic building repair and maintenance practitioners (SMEs; professionals; contractors, supply chain, etc.), an interpretive qualitative validity assessment methodology was undertaken. This methodology employed the following techniques; two focus group sessions, supported with a questionnaire, with six practitioners, in each focus group, from representatives of SME professional organisations, involved in the Scottish historic building repair and maintenance sector. Hence, chapter presents and discusses the validation process undertaken (Figure 9.1).

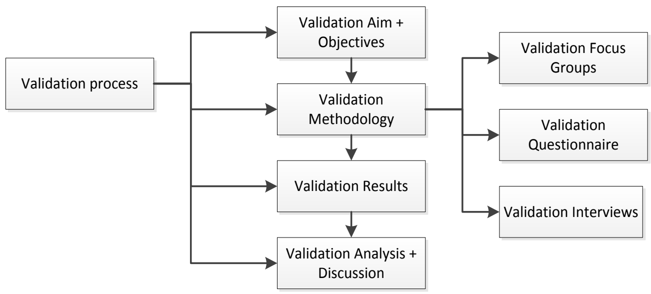


Figure 9.1: Overview of the Validation Process

9.2 Methodology Adopted for Framework Validation/Evaluation

Fundamental to Construction Management research, is the need to improve the efficacy and proficiency of existing practice (the current processes and procedures), thus, framework evaluation and validation is critical in establishing whether, the research meets the required quality standards and fulfils its objectives (Lukas and Roja, 2009). Whilst, a considerable amount of literature on the subject exists, resulting in a large number of developed approaches and models, presently, in selecting an appropriate methodology for framework validation, there exists a lack of formal guidance; as each evaluation tool has its own peculiar challenges, whilst both terms (evaluation and validation), are used reciprocally by academia and framework/model developers (Calidoni-Lundberg, 2006). However, it is beyond the scope of this study to examine the field in-depth and provide a scholarly discussion. Nonetheless, a two-part structured selection process was undertaken, to determine an appropriate validation and evaluation approach; firstly, three main evaluation theory models were reviewed, each developed to address specific outcomes, to allow developed frameworks to be used with conviction. Thus, the following models were considered; *the effectiveness model*, designed to measure either the effectiveness of a framework (i.e. the actual effects or if it meets a previously specified goal); whilst, *the economic model* tests, whether the framework's operating costs provide adequate outputs, value, and practicality; and finally, *the professional model*, which emphasises the criticality of end-user evaluation of participants, especially proposed end-users of the framework (Calidoni-Lundberg, 2006). After careful consideration, the professional model was selected, and adopted for the framework; in that researchers collaborate with industry practitioners to establish credibility, and to corroborate the proposed *CrOsS* Framework validity and reliability. As a second part of the selection making process, the research study reviewed four uncomplicated validation methodologies (Sargent, 2005) (Table 9.1). After prudent deliberation, a combination of approaches were selected to validate and offer credibility to the framework, namely; approaches two and four.

Validity Determination Approach	Relevance
Approach 1; Make a subjective decision based on results collected throughout framework development	Difficult to evaluate and consider this approach as valid and credible as merely involves the researcher(s) in the validation process
Approach 2; Framework end users combined with the researcher(s):	Considers potential framework users validation data to determine; credibility legitimacy, and belief
Approach 3; Employ an external third party; in essence, independent validation carried out throughout the framework development or at the end	Highly dependent on an external level of knowledge and integrity.
Approach 4; Employ a scoring model: employ scores (or weights) to measure framework and its suitability in context of its purpose	Only considered valid and credible if it scores across all posed questions above the minimum acceptable scores (i.e. 3.5 for a five-point Likert scale).

Table 9.1: Overview of the four basic approaches to framework validation; adapted from Sargent (2005).

9.2.1 Focus Group Selection Process

To provide a balanced and rigorous approach to the research study, given the developed framework, using the results obtained from predominantly MSME and SME contractor focused semi-structured interviews, albeit some of the interviewees were SME professionals. The research study decided to gain the perspectives of professional SME practitioners involved in Project Management, with attendees/interviewees from the vocations, such as; architecture, surveying, structural engineering, as presented in Table 9.2 and 9.3. A total of 12 focus group participants (FGP) attended (i.e. six validators per each individual focus group); to ensure relevant sector currency, 15 years minimum experience was set as the main parameter for participant inclusion, in order to provide industry reliability and acceptability in terms of results.

Focus group participant - total no:6	Position	Professional Membership	Organisation type	No. of projects involved in in the past 3yrs	Experience
FA	Building Surveyor	RICS, CIOB	Design Professional	12- 15	25 Years
FB	Lead Architect	RIBA	Design Professional	7-10	15 Years
FC	Structural Engineer	IStructE	Design Professional	4-6	15 Years
FD	Project Management	RICS	Consultant	7-10	20 Years
FF	Project Management	CIOB	Consultant	4 - 6	15 Years
FG	Building Surveyor	RICS	Consultant	7-10	20 Years

Table 9.2: Background information of the Glasgow FGP

Focus group participant - total no:6	Position	Professional Membership	Organisation type	No. of projects involved in in the past 3yrs	Experience
FH	Project Consultant	Stone Federation	Consultants	7-10	25 Years
FI	Structural Engineer	IStructE	Design Professional	4-6	15 Years
FJ	Structural Engineer	IStructE	Design Professional	4-6	15 Years
FK	Lead Architect	RIBA	Design Professional	6-8	20 Years
FL	Building Surveyor	RICS	Design Professional	8 - 10	15 Years
FM	Project Manager	CIOB	Consultant	4- 6	25 Years

Table 9.3: Background information of the Edinburgh FGP

9.2.2 Focus Group Format

Each focus group session (FGS), involved six participants, and were conducted in venues provided by the researcher’s contacts within academia, due to the limited budget available to the researcher to conduct the validation process. Each venue supplied a fully integrated meeting room, complete with a number of resources, such as: Focus Group guides, participant sign in sheet, name tags, Focus Group agenda, notepads and pens. The first FGS was held at the City of Glasgow’s Riverside campus; a contemporary Further Education (FE) learning centre, situated in the city centre of Glasgow, whilst, the second FGS was held at the researcher’s own university (Heriot Watt University); at its Edinburgh campus, situated on the outskirts of Edinburgh (Figure 9.2 and 9.3). Considering good practice, each FGS lasted approximately 120 minutes, as extending beyond this timescale, focus group participants (FGPs) are subjected to possible lethargy (Krueger and Casey, 2014).

Figure 9.2-9.3: Fully integrated meeting room @ City of Glasgow College and @ Heriot Watt University

During both FGS and the subsequent discussions, the researcher assumed the important role of facilitator and mediator, to ensure process efficacy, whereby; an explanation of the FGS process was outlined; confidentiality concerns were addressed; dialogues were managed to ensure all FGPs were kept on track and had the ability to engage in all discussions. During the sessions, the FGS comprised of four main parts, as illustrated in Figure 9.4, whilst due to the difficulty in the retention of information during a workshop, the provision of four sets of documents helped stimulate and support discussions, (Table

9.4). Following each session, as a matter of due diligence, the researcher provided a PDF copy of the presentations and a summary of the session.

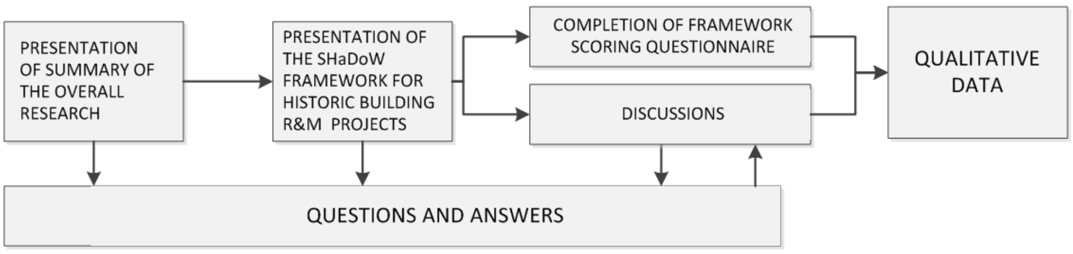


Figure 9.4 Focus Group Framework Validation Process

FGS Components	Action
Part 1; Synopsis of the overall research process and the BPMN and the GDCPP process mapping undertaken which led to the framework development	15 minutes power point presentation (PPT) (plus paper copies).
Part 2; Overview of four phase *CrOsS* framework	30-minute PPT explaining the developed four phase CrOsS framework Issued set of framework diagrams to help FGP follow and navigate the framework, supported with various structured data capture templates for each phase of the framework
Part 3; FGP Discussion digitally recorded in order to avoid possible deficiencies in data capture	45 minutes discussions, where the FGPs were posed the same five open ended questions presented to the demonstration project stakeholders, in order to provide a correlated validation process (see section 8.8 and Appendix 2).
Part 4; Provision of an evaluation (scoring) questionnaire, in order to provide a deeper analysis and perception of FGPs validation data	A five-point Likert scale evaluation (scoring) questionnaire distributed and completed. Typically completed, by the validators in five minutes.

Table 9.4: Overview of the four basic approaches to framework validation; adapted from Sargent (2005).

Furthermore, after each FGS, the digitally recorded discussions were transcribed verbatim, whilst any observations noted by FGPs along with the completed issued questionnaire were collected for analysis. As a multi-method data capture methodology was adopted, two sets of data were collected; thus, the processes of thematic analysis (see section 4.8.5) and statistical analysis (questionnaire) were employed during the framework validation exercise. Relating to the statistical analysis, due to the qualitative focus of the research, allied to the small sample size, the researcher decided to adopt a subjective route to the latter analysis; employing the descriptive statistics methodology of univariate analysis was deemed appropriate (see section 4.8.5 and 9.5). The following sub-sections presents the FGS data examination and resultant findings, based on the mixed method data capture approach: thematic and statistical analysis.

9.3 Results of Framework Validation/Evaluation

9.3.1 Questionnaire Results

The questionnaire (see Table 9.5) comprised of two sections covering general background information and eleven close-ended questions aimed at assessing the overall effectiveness of the framework.

Code	Questions: 12 responses
V1	How beneficial is the overall framework for the PM of Historic Building R&M Projects?
V2	How simple is it to comprehend the BPM/GDCPP based process framework (framework)?
V3	To what degree can adhering to the framework support implementation of PM in Historic Building R&M Projects?
V4	How effectively can the framework facilitate the efficient operational delivery of historic building R&M projects?
V5	How effectively does the framework focus on PM processes relevant to historic building R&M projects?
V6	How well does the framework establish a multi-disciplinary approach between the phases of historic building R&M projects?
V7	To what extent, is the applicability of the framework in historic building R&M projects?
V8	To what extent, is the logical structure of the framework?
V9	To what extent, is the comprehensiveness of the framework?
V10	How valuable would you rate the framework in decision making?
V11	How valuable would you rate the framework in improving performance and productivity?

Table 9.5: Framework Validation Questionnaire: 11 Close Ended Question

Table 9.6 and Figure 9.7 presents the results from the closed questions, surrounding the key elements of the framework. In order to provide result clarity, based on the questionnaire scoring scale the percentage scores for each question were calculated; Table 9.6 displays a statistical percentage level summary of the FGP, whilst, Table 9.7 illustrates a clustered column denoting the same percentage scores. From the analysis, the FGP rated the questions either 3 (Satisfactory), 4 (Good), or 5 (excellent), with none indicating the questions warranted a rating of one (Poor) or 2 (Fair). Whilst, the individual participant scores reveal that only four FGP validator scored the questions V2, V6, V8 and V11 relatively low (8.33%), in comparison to eleven FGP validators scoring these high; ranging between 33.33% - 75% for a score of 5 (excellent), and between 16.66% - 58.33% for a score of 4 (Good). Hence, indicating the vast majority of the FGP validators finding the framework easy to follow, integrated, effective, applicable, and impactful, in terms of performance/productivity. These results favourably indicate the *CrOsS* framework is simplistic and straightforward enough to comprehend, whilst still being robust and rigorous enough to satisfy the needs of highly experienced industry professionals and practitioners. This conclusion is further strengthened by 75% of the FGP validators indicating that the framework was 5 ("Excellent") in its comprehensiveness. Furthermore, this conclusion is authenticated by 100% of the FGP validators (V1, V3, V5, V9, and V10), indicating either that as a tool to help support PM and on-site process management or to facilitate decision making, the framework was either 4 ("Good") or 5 ("Excellent") (Figure 9.5).

Code Validation	**1 Poor**	**2 Fair**	**3 Satisfactory**	**4 Good**	**5 Excellent**
V1				50%	50%
V2			8.33%	58.33%	33.33%
V3				50%	50%
V4			25%	33.33%	41.67%
V5				25%	75%
V6			8.33%	58.33%	33.33%
V7			25%	58.33%	16.66%
V8			8.33%	33.33%	58.33%
V9				25%	75%
V10				50%	50%
V11			8.33%	16.66%	75%

Table 9.6: Percentage scores of the key aspects of the framework based on the scale points

In terms of the Mean, Median and the Mode, the sample produced the following data set, for all the 11 questions: the Mean ranged from 4.18 to 4.67, indicating the scores were above the permissible measure of 3.5 for a five-point Likert scale (Sargent, 2005); although the lowest mean recorded by the question V4 was a score of 4.18 out of 5, surrounding the strength of the framework in effectively facilitating successful projects, comparatively the lowest framework validation score recorded. Conversely, the highest mean score of 4.67 out of 5, was recorded by the question V9 and 11, surrounded the framework's overall comprehensiveness and its ability to improve project performance and productivity. With regards the Median and the Mode: the sample Mode data ranged from four to five for all 11 questions: for the Median, the data reciprocated this range and was actually 4.5 due to an equal split of responses (six indicated 4 (Good) and six indicated 5 (Excellent).

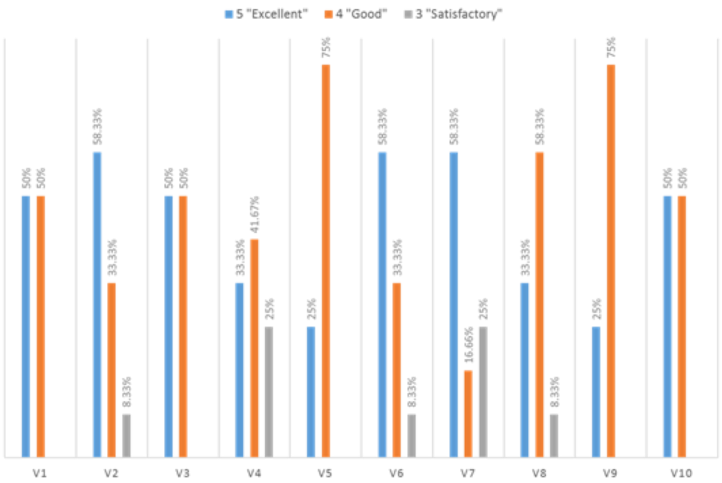


Figure 9.5: Clustered Column Denoting Percentage scores of framework questioning based on the scale points

Code	Minimum	Maximum	Mean	Median	Mode	STD
V1	4	**5**	**4.5**	**4.5**	**4 or 5**	**0.52**
V2	3	**5**	**4.25**	**4**	**4**	**0.59**
V3	4	**5**	**4.5**	**4.5**	**4 or 5**	**0.52**
V4	3	**5**	**4.18**	**4**	**4**	**0.87**
V5	4	**5**	**4.33**	**4**	**4**	**0.49**
V6	3	**5**	**4.5**	**5**	**5**	**0.67**
V7	3	**5**	**4.33**	**4**	**4**	**0.79**
V8	3	**5**	**4.5**	**5**	**5**	**0.67**
V9	4	**5**	**4.67**	**5**	**5**	**0.49**
V10	4	**5**	**4.5**	**4.5**	**4 or 5**	**0.52**
V11	3	**5**	**4.67**	**5**	**5**	**0.65**

Table 9.7: statistical summary of the 12 validators' scores on the key aspects of the intended purpose of the framework

Regarding the standard deviation (STD) (a measured summary of every value within a dataset, where an amount varies from the mean), ranging from 0.49 to 0.87 across the eleven questions, suggesting a normal distribution, gave valuable information of percentage of data positioning, in terms of the dataset dispersion and a valuable indication of the potential wider sector perspective on the credibility, and validity of the framework.

Assuming that for one standard deviation (1SD) relates to 68% of values are less than 1SD away from the mean value, whilst two standard deviations (2SD) relates to 95% of values being less than away from the mean and that three standard deviations (3SD) relate to 99% of values are less than away from the mean (Wan, et. al, 2014). This indicates that if presented to industry practitioners; 68% (1SD), would rate the framework as excellent; whilst almost all industry practitioners, about 95% (2SD) would rate the framework as good, which presents a favourable outcome, that if presented to most MSME/SMEs, they would rate the framework as valid and credible to their practice.

The following section presents the qualitative results of the FGP responses and discusses the responses of the FGPs regarding, the following five main themes surrounding the framework: (1) clarity and comprehensiveness; (2) main benefits; (3) barriers to the use; (4) limitations or weaknesses; and (5) recommended improvements.

9.3.2 Focus Group Discussion Results

For the focus groups data analysis, thematic analysis, was employed, utilising the adoption of a combination of Braun and Clarke's (2006) and Maguire and Delahunt (2015) procedural guidelines and processes (see Table 4.15), whereby a six-step process was engaged; Step 1: Become familiar with the data; Step 2: Generate initial codes; Step 3: Search for themes; Step 4: Review themes; Step 5: Define themes; Step 6: Write-up. However, it was not always a linear process, as it was actually more an iterative and reflective process, whereby moving forward and back between each step allowed different themes and sub-themes to emerge from data. Each of the focus group discussions were analysed, whereby respondents' professional understanding of the framework, in terms of the previously generated themes; technical, human resource and senior management themes, allied to the researcher's extensive experience and existing knowledge in the field, resulted in a level of preconceived themes expectancy. Yet, it must be highlighted, unlike, the pilot study's thematic analysis, there is no demarcation of these previously generated themes. Nonetheless, based on the discussion, two fundamental themes and several main criteria emerged from the thematic content analysis of the open-ended questions, which were categorised, based on the benefits of, and barriers to, the *CrOsS* framework implementation, as illustrated in Figure 9.6. The findings and a subsequent discussion of each key theme and the main criteria now follows.

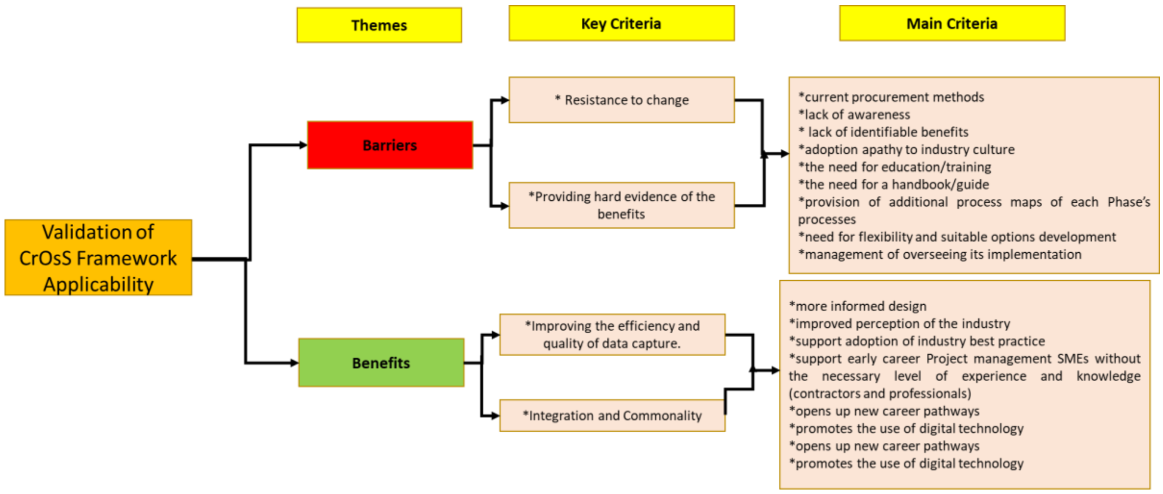


Figure 9.5: Key Themes and Main Criteria Emerging from Focus Group Discussion Analysis

9.3.2.1 Clarity and Comprehensiveness of the framework

From the thematic analysis, there was a consensus among the FGPs across both FGs, that the framework clarity and comprehensiveness was effective and pertinent for use in practice, offering comments on its; *technical clarity, robustness, structure, and simplicity.* FGP FI stated it provided a much-needed structure to the existing historic building R&M process, observing, *"The technical clarity of the framework is the most important, particularly given clarity is a thing we lack when doing historic building R&M work".* Moreover, FD expanded on this thought, and reflected, *"With a current lack of understanding of the process and having a clear, simple framework with a suitable level of depth and breadth allied to the ability to visualise the framework, as well as the added bonus of having a process map provides a robust tool".*

Interestingly, FG and FL (both building surveyors) contended, that there is a structure in current project delivery, although they conceded, it was only to a certain degree and that, "*the robust manner in which the processes were outlined here", suggest the framework, "was full-bodied enough that it could enhance the procuring, production and delivery of historic building R&M across the whole supply chain".* Furthermore, FGP FC, FK, FL, and FM concurred with this perspective, appreciating the concept, that it, *"uses existing guidance out there"*, and that in their opinion, *"there was no omission of key processes or important details within the framework".* They further intimated they perceived it as an augmentation to their existing toolkit, rather than a new addition., with FL articulating, *"no-one, I think, will look at the framework and say it is revolutionary, nonetheless, it provides a relatively simple well-needed structure to the existing historic building R&M process, without a doubt it's a type of tool we need and have been asking for"*. Moreover, given that the FGPs had very little experience of the selected process methodologies used to visualise the framework (BPMN and GDCPPP, respectively), encouragingly, FB highlighted, the beneficial use of these tools, in providing clarity to the framework, enthusing, *"having the ability to visualise the framework with a process map, sounds really simple, yet in reality, it's not something we do as a sector"*. To which FF resounded, *"We definitely have a need for this kind of tool; in fact, I would argue there is a demand to have more process analysis like this in the industry"*, which led to a majority perspective, who implied, *"that existing measures have a lack of process understanding, which is leading to a reduction in productivity and leading to a number of issues surrounding poor workmanship"*.

9.3.2.2 Main benefits of the framework

The FGP identified several benefits of the framework, such as *more informed design; improved perception of the industry; support adoption of industry best practice*; *support early-career SMEs without the necessary level of experience and knowledge (contractors and professionals) stepping into PM; opens up new career pathways; promotes the use of digital technology*. Thus, such offerings gave persuasive credibility from the industry experts towards the framework, however, there were two key benefits of the framework, which they all agreed were the most practical, in terms of existing practice, namely: (i) *Integration and Commonality* and (ii) *Improving the efficiency and quality of data capture.*

To support, the first key benefit of *integration and commonality*, they all agreed, the framework provided a logical systematic process, which effectively integrates the historic building R&M PM process. In supporting the validity of this viewpoint, FGP FM remarked, *"that having a more integrated, standardised and structured approach, undoubtedly, can mean better working relationships, as well as using the skills set of everyone to its best potential"*, whilst, FB expanded on this comment, "that when it's applied on site its true benefit will be in *its strength"*. When asked to elaborate, *"Having a cohesive approach, all sharing the same work process/framework standardises projects* *in a way the industry has not attempted to do before".* This invoked FGP FH to add, *"It's about providing a level playing field by having the benefit of transparency, from client all the way through to the supply chain".* Whilst FI complemented this by declaring, "*It will promote confidence in not only what I do but also what everyone else does because we will be far more unlikely to be constantly fighting about extra monies or time".* FL pragmatically observed, *"this framework/model would undoubtedly help support the knowledge and experience we all have, to deliver a much more integrated and value-based product but not at the detriment to time, cost and quality".*

With a view to the second key benefit; *improving the efficiency and quality of data capture*; according to FK, adopting the use of structured unified format forms, sheets and templates is vital to continuous improvement, perceiving such practices, as, *"taking a systematic, structured and standardised approach to the quality of the project from day one can help improve efficiency and quality of on-site operations, by moving away from subjectivity to objectivity".* FGP FD and FJ reinforced this perspective intimating *"bringing equality of information we collect as an industry, would shows we are in fact forward-thinking, looking to improve"*, and led to both similarly intimate, *"we can now have records of buildings having been repaired going forward, evidence of what was done, how it was done, what the costs were, basically lessons learned, which gives an incredible insight into future resource spend".* FA offered an interesting viewpoint, in terms of both the framework and its harnessing of digital technologies, *"that with this tool, companies now had the ability to "sell" captured data capture, as having data sets that you can review in 5-10 years' time is fantastic for everyone; from a business perspective to a client perspective, allowing more transparency to flourish".*

Substantiating, this residual comment is the fact that, indeed the haphazard nature of communication and collaboration led some MSME/SME contractors to feel that generation of accurate project information, *"was left to them to prevent problems or errors".* However, when this was raised to the FGPs, they pointed out much of this was down to sector culture and the tendency to adopt a siloed approach to projects, which they acknowledged, the role over-reliance on specialist contractors, coupled with poor communication and lack of negotiation, meant that Project Management and on-site practice, was not optimal, and is generally regarded as undertaken on an, *"ad hoc"* basis, with many similarly responding, *"I think we are viewed as being ad-hoc, haphazard in our approach, when in fact we are highly professional".* Yet, ad-hoc practices occur frequently, although paradoxically they are not regarded as ad-hoc by industry, therefore FG provided a possible solution, stating, *"To get the industry to adopt the framework, a series of factual, objective evidence based projects of it working in practice would be incredibly useful".*

Whilst undoubtedly, there is a need for a cultural change, based on the perspectives offered by the FGP, it can be determined, that the benefits of the *CrOsS* framework, provides strong endorsement that the framework is a positive step forward, towards efficient production and performance gains., and offers value to the softer areas, such as skills development and the need of a wider acceptance of the importance of adopting a multi-disciplinary approach, to looking after our historic buildings and the value it ultimately brings to the economy.

9.3.2.3 Barriers to the use of the framework

A number of implementation barriers were identified by the FGP identified a number of operational barriers of the *CrOsS* framework in historic building R&M practice ranging from *current procurement methods, lack of awareness to adoption apathy to industry culture to the need for training to providing hard evidence of the benefits*. However, in reality, the FGP repeatedly identified one key barrier, namely: *resistance to changing current practice*, to which FD encapsulated this viewpoint remarking, "*Most people recognise things aren't necessarily working at 100%, yet there is an inherent tendency to accept this. Sticking with what you know is a norm for the industry".*

Given the consensus of both focus groups, several validators were more specific, alluding to the fact from their viewpoint that resistance centred more on the logistics of implementing the framework. For example, FGP FB offered the viewpoint, *"when it comes down to adoption; the barriers will surround fundamental principles of PM: when they adopt it, who adopts it and how they oversee that adoption".* To which FB added, *"consider existing Plans of work they are aimed at professionals who are part of institutions that provide things like CPD and ethics, which ensures frameworks are readily understood and applied, whereas something independent, it's how you suggest the use of the framework, who suggests that and who picks it up".* FF offered a valuable PM insight into this obstacle, remarking that, *"maybe it is less of a fear from a* *professional perspective. However, with contractors, the fear will be; if it gets too complicated it will be time to go to back to their norm. Although it has to be said it really depends on the company outlook; are they proactive, and to a certain degree the organisational make-up and size of the business".*

Hence, several FGP FA, FC, FK FL, and FM felt there was a likelihood that framework uptake may be hindered, suggesting, *"project stakeholders might be worried that it would be time-consuming, require additional resources lead and create additional administration work*". Which in itself, mirrors to some extent the findings from the demonstration project interviews, whereby it was indicated users felt implementing the framework would lead to additional cost and no-one indicated who was responsible for such cost, as FD, FF, and FM suggested, *"there needs to be a massive shift in the competitive tendering process because that is where most of the contractual problems begin"*. In the frameworks defence FJ remarked, "*the framework gives the ability to close the circle on a project, therefore in reality it would not truly invoke any extra project costs".* When asked what they meant by that, they explained that the potential for cost incursions was there, however they highlighted, "*quality potential gains far exceed the potential cost threats"*. Hence, unanimously, all FGPs agreed there was need for case studies, to which FA offered the view that *"being able to show and tell with exemplar projects would help overcome inherent industry barriers. It's about a change in mind-set; it's about just driving home the message; that for a bit of work and a bit of investment it would be a big benefit to them".* In summary, they all agreed that it would take time to overcome the key barrier of resistance, with one FGP presenting the analogy that, "*we are talking about an oil tanker here and trying to turn an oil tanker in mid-stream and to change course, is no easy feat".* However, for some of the FGPs, it is not a case of focusing on one individual barrier, but rather view barriers as interconnected, especially as they focused on; responsibility, cost and time related concerns, highlighting that there needed to be a shift in cultural and behavioural thinking.

9.3.2.4 Limitations/weaknesses of the framework

In terms of framework limitations and weaknesses, both FGPs, concurred and believed *"until it is really tested in its entirety it's difficult to determine its limitations or weaknesses".* Voicing concerns surrounding the economic worth and feasibility of the framework, and at what point does the overall framework, in its true holistic sense become economically viable and valuable. To which some FGPs suggested, the framework needs to define itself, by outlining what makes it different from other frameworks, in order to provide industry practitioners valid reasoning behind attempts to integrate the framework into current and future practice. Especially, with projects having a bespoke and complex nature, necessitating the need for early project stakeholder engagement allowing the opportunity to access collective expertise and knowledge to facilitate a better understanding of the complexity of the R&M process. Several FGPs, whilst not necessarily a hard and fast limitation/weakness, concurred mobilisation of well organised project team would be needed to consider the bespoke and unique environment of historic building R&M and involvement of all the specialists (professionals and contractors).

Yet, when pointed out, that this is one of the contractual principles for IPD in general (AIA, 2017), the evaluation feedback revealed, there should be administrative procurement rules to guide the framework; in order to maximise the value/benefit from its use rather leaving individuals to deal with their identified processes. Otherwise according to FF *"there will be an evasion of instructions,* as they highlighted, it is not unfathomable to think that there will be a tendency for some to adhere to it more than others. It was noticeable that most of the weak points or limitations feedback gained from the FGPs were related to improvements and will be useful for enhancing user experience, as well as providing areas for future development.

9.3.2.5 Recommended Improvements for the Framework

As a final question, in the series of five semi-structured questions, both FGs were posed the question; *"Are there any improvements that you would recommend for the framework?* In general, the FGPs found, that it was a robust, fit for purpose, framework which has significant potential for improving historic building project performance. In fact, FGP FH enthused *"in fact I can't wait for it to happen, it's such a no brainer for us to buy into this"*, whilst concurring with this positive perspective FA remarked, *"this common roadmap could be a powerful tool"*, reasoning *"more and more pressure is put on cost, time, quality and even more acknowledgement is required of how the project is progressing"*. It is, therefore, not surprising, given conventional sector practice, when performing historic building repair, to try as feasibly possible to lessen timescales and costs, with the consensus, that any improvement, needed to be driven by hard evidence, "*really it needs to be tried and tested, to be torn apart, to be criticised to allow improvements to be made":*

The FGPs suggested several options towards improving the framework, however, four main offerings were continuously raised. Firstly, flexibility and suitable options require to be developed, in order to permit accommodating varying project scales and circumstances. Secondly, embedding education into the framework, whether that be training in the use of the framework or be that of the fidelity of using digital technologies or provision of perhaps a guidance reference on how you gather the appropriate data. For example, how a client who has never commissioned work before, how does he go about engaging in SMEs /professionals. With regards the third recommendation, there needs to be provision of additional process maps of each Phase's processes, to a similar detailed level as produced for the integrated surveying process within Phase 1: Project appraisal initial sub-phase. As a final offering, they also suggested such maps could provide clarification within the framework, of the appointed responsible person, earmarked with the distribution and management of the structured data inputs and outputs. Allowing all stakeholders to determine questions surrounding Intellectual Property (IP) and extra funding costs, as a result of storing the captured data.

9.3.2.6 Discussion

Considering during the FG validation process, two sets of qualitative data collection occurred, a dual qualitative analysis methodology was adopted. Thus, thematic analysis and statistical analysis (questionnaire) provided a comprehensive investigation into the FGPs perspective of the applicability of the developed framework. Whereby, through the convergence of data surrounding the mean, median, mode, range, and standard deviation of the sample size, coupled with the key emergent themes from the FG discussions. Allowed examination of the distribution, the central tendency and the dispersion of the data along with the interpreting of patterns of meaning. From the findings and subsequent results, there was an overall positive impression, as to the potential success of the framework in practice. Thus, the framework was not only rated valid and credible to practice, but also from the FGP perspectives, the framework was given persuasive credibility, in terms of its appropriateness, applicability, practicality and clarity. Hence, a number of positive comments extolled the practicality and entirety of the framework.

Returning to statistical analysis (questionnaire), each of the 11 closed questions minimum and maximum scores, illustrated in columns 2 and 3 of Table 9.7, allowed the research study to reach some specific conclusions about scores in the data distribution. For example, the lowest mean suggested that determining whether the framework can effectively facilitate project success, is difficult without hard, verifiable evidence. Interestingly, this correlates with the focus group discussion findings on barriers to uptake, as the majority of the participants cited the need for demonstration projects or exemplar projects, to provide valid reliable data surrounding the benefits of the framework. Given the research study, was limited in terms of resources for collecting information. With regards to the STD, providing a means to postulate the statistical findings in the context of the wider population of the sector. The results (either 1SD or 2SD) indicates that if the framework was presented to most industry practitioners, they would either rate the framework as excellent or good. Whilst encouraging, exercising caution is vital, when interpreting such conclusions. Especially, given the literature review highlighted the anomalies of sector fragmentation and the contradictions provided by the deficiencies within national statistical evidence (lack of occupational specificity, granularity, and accuracy of data) regarding current and future skills supply.

From the thematic analysis of the discussion transcripts and notes taken during the FGs, in terms of; clarity, comprehensiveness, benefits, barriers, limitations or weaknesses, and the recommended improvements, the results concluded that industry practitioners were optimistic about the framework. For example, during both focus groups, there was an unwavering harmony towards the concept of the structured framework and that it was *"absolutely spot on"*. They all believed there was a fundamental need for the use of structured unified format forms, sheets, and templates in historic building R&M on-site operations management documentation. The FGPs continually brought the response of the need for demonstration projects to the fore, suggesting creating a bank or database of demonstration projects, would provide a platform to highlight the positive benefits of the framework in terms of project time, cost and more importantly quality, that far outweigh the reluctance of the industry to adapt and change. Moreover, such responses not only concurred, but also endorsed the need for such hard data, whilst correlating with the literature and the need for a multi-disciplinary approach. Although, it would be naïve to expect demonstration projects being an answer to all adoption obstacles as some FGPs noted that there is always resistance to change. They suggested as part of a combined approach, to circumvent this mind-set, the need for training or a guidance manual would likely be required to support a deeper understanding of the process framework and the concepts (IPD and digital technologies) contained within it. Although it was raised that some may view training as peripheral, as well as not having the capacity to engage with the framework, reasoning time is of the essence in project contracting. Noteworthy, as resistance to change in current practice is without a doubt embedded in industry culture, suggesting that framework adoption and implementation may be considered, an unnecessary practice by industry and a possibility the framework may be viewed as just another unnecessary process to add to the already bespoke and complex landscape. Thus, the initial and continuous integration of all relevant stakeholders will help provide a willingness of industry practitioners to integrate the framework into the current practice, as well as raise awareness of digital technologies.

Nonetheless, the FGPs felt that whilst the *CrOsS* framework was beneficial to their practice. The offered several suggestions towards improving the framework, centred on the framework's flexibility, its training requirements, and the management of overseeing its implementation. The need for flexibility, whilst a valid position has particularly given the inherently bespoke nature of historic building projects, in reality is a difficult to thing to achieve given the undoubted constraints of current procurement routes, allied to contract conditions, and as such, the provision of flexibility, will require further research to determine whether, projects of varying complexity, scale and size can be supported by the framework. The second recommendation, that the framework should have education/training embedded within its structure, in order to support industry practitioners is another area for further research; given one of the key characteristics of the framework is to collaborate and communicate project data, and information. Yet devoid of auditing their current practice, to identity the gaps it will be difficult to determine as to the more effective areas for training, e.g. a considerable workload with QA and process improvements are at risk of being lost. Therefore, as mentioned previously, whilst the majority of the FGPs feedback agreed that the current iteration of the framework is relatively straightforward. Ultimately, they felt for supporting and strengthening the framework, it required two key support vehicles; firstly, provision of additional process maps of each Phase's processes, correlates with the researcher's perspective that this would be an area of further research and this may help support further simplification of the framework and; secondly, the provision of examples of the framework in use from real projects and its associated benefits.

9.5 Chapter Summary

Chapter nine presented the results of the evaluation and validation process of the *CrOsS* framework, from the focus group session with 12 industry experts, from across the central belt of Scotland, held in Glasgow and Edinburgh respectively, indicating, that the framework, based on the results, is valid and credible. Grounded in the dual qualitative data analysis: thematic and statistical analysis; the study further adopted triangulation to test validity, through the convergence of different sources of information from different sources, for extending the scope of theory in this field of Construction Management research. Whereby it combined the use of focus groups and Likert-scale questionnaires, underpinned by the results from the case study semi-structured interviews. Furthermore, the validation of the *CrOsS* framework is further substantiated, as the FGP had no prior involvement in the research, resulting in unbiased perspectives on the way in which the framework was developed, hence, it is reasonably safe to assume that the developed framework has the ability to serve, its intended purpose of guiding and supporting PM and onsite practice *"process management and improvement"* for SMEs historic building repair. Moreover, the results provide a basis for a reasoned argument, that the framework could be considered as an emerging step change in providing industry practitioners a systematic, standardised and structured approach in real-world practice as a means of improving performance (time, cost and quality) and communication and collaboration, although several recommendations were offered for framework improvement. Nonetheless, what is certain is that historic building R&M experts at a strategic level will be fundamental in promoting the future use of the developed framework, should industry consensus mirror the results from the focus groups that were held. The following chapter concludes the study and makes recommendations for further research.

Chapter 10: Summary and Conclusions

10.1 Introduction

Chapter 10 encapsulates the overall research findings and presents conclusions, in regard to the specific objectives set at the beginning of this PhD study. In addition, this chapter discusses and clarifies the study's contribution to academic theory and industry practice knowledge. Followed by sections discussing the limitations of the research, and recommendations for further research.

10.2 Summary of the Overall Research

The key aim and focus of this research study, was to develop a common structured collaborative process standard *(CrOsS)* framework, which accurately reflects current MSME and SME repair and maintenance practice, aimed at supporting an effective multi-disciplinary, approach. The framework is designed to facilitate an integrated approach, whilst inform digital technology application, when carrying-out and managing on-site operations and processes in UK historic building repair and maintenance projects. In effect, a "*process management and improvement"* standard, designed to offer a process model, map, and a management tool, in order to aid increased Project Management and on-site practice efficiencies, for optimised project delivery.

It was anticipated that the implementation of such a framework would provide a stimulus and improvement in terms of; (i) reflect better Project Management; (ii) identify an increase in efficient construction practice; (iii) support improved communication and collaboration; (iv) aid informing planned and future R&M works; and (v) provide objectivity in project data capture. To fulfil the research study's aim, the research set five specific objectives (see section 1.5), whereby Objectives 1, 2, 3, and 4 were achieved through a combined strategy of stage 1, 2 and 3, whilst objective 5 was achieved as part of stage 4 of this PhD study, as illustrated in Figure 10.1. Thus, the following sections will review the individual research objectives illustrated, provide a synopsis of the research findings, and based on these, offer conclusions.

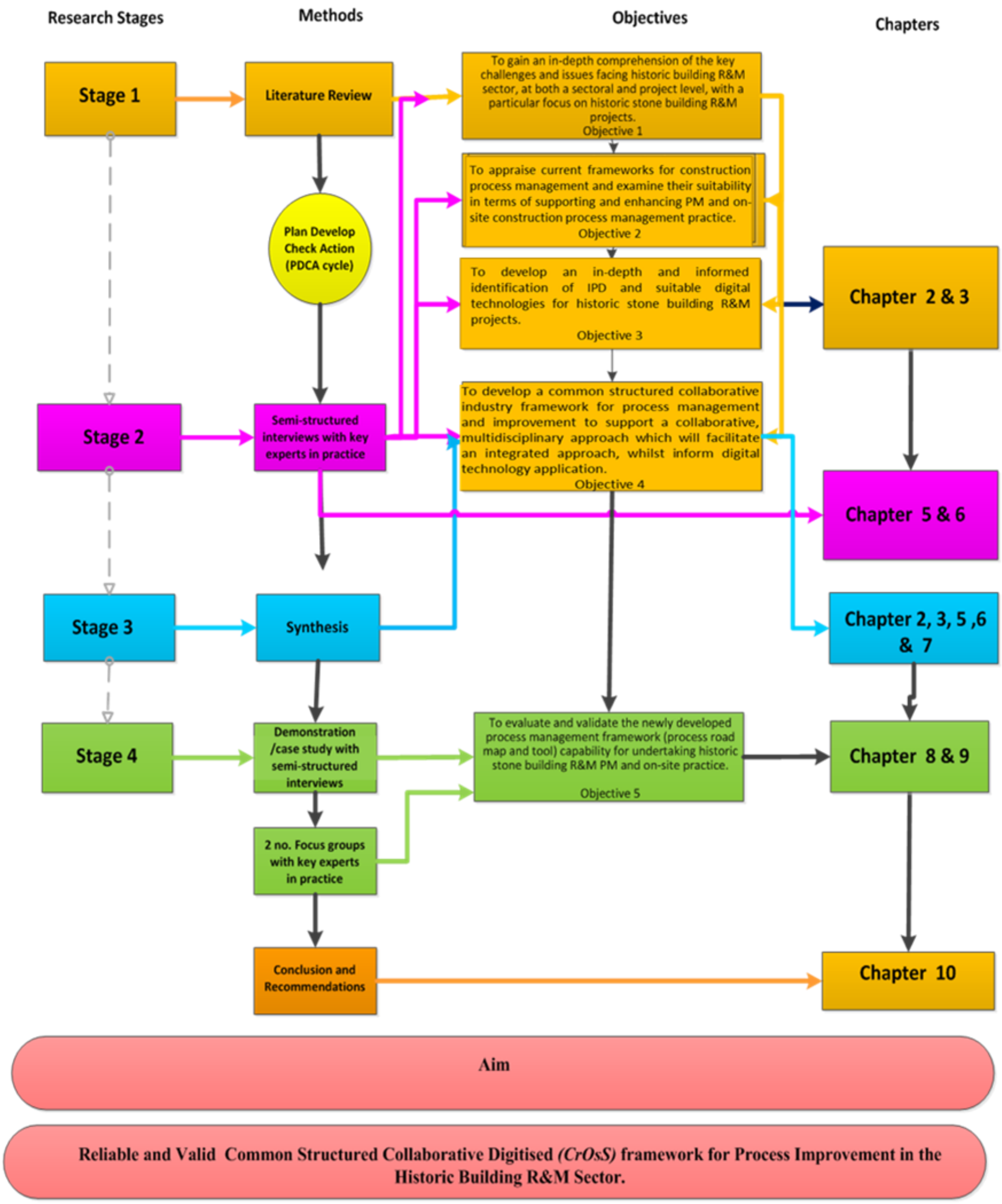


Figure 10.1: Research Objectives Process across the Four Stages of the Study

10.2.1 Research Objective 1: *To gain an in-depth comprehension of the key challenges and issues facing historic stone building repair and maintenance sector, at both a sectoral and project level, with a particular focus on historic stone building repair and maintenance projects.*

Accomplishing Objective 1, as part of stage 1 and 2 of the research study, was achieved, through an extensive review of available industry intelligence reports and academic literature, allied to the 14 semi-structured interview exploratory pilot study, focusing primarily on Scotland, pertaining to the sector-wide and project-specific level challenges and issues. The literature review highlighted, that there was a limited number of academic studies undertaken on this subject, however, a small number of technical process studies exist, pursued by a small number of industry "*advocates"* and not mainstream academia, to explore the specific issues that contribute to poor performance (time, cost, quality) of historic building repair and maintenance (Bullen and Love, 2011a&b; Dyson, Matthews and Love, 2016; Forster and Kayan, 2009; Forster et al., 2011; Hyslop, 2004; Kayan, 2013; Shipley et al., 2006; Shenhar and Dvir 2007; Smith, 2005). Nonetheless, at the research's disposal, there were a number of periodical industrial intelligence reports and documentation available, at both a sectoral and project level (Angus College, 2009; Historic Scotland, 2011, 2012a, 2012b, 2012c; NHTG Research Report, 2005, 2007a & b, 2008 a & b, 2009; Pye Tait, 2013; SCHS, 2016; SHEA, 2016; Scottish Stone Liaison Group (SSLG), 2006), which resulted in making the comprehensive literature review, a very pragmatic and practical task. Moreover, these studies provided a valuable *"snapshot"* of the existing project landscape, highlighting, various project-specific level challenges exist, such as; (*i) up-skilling the workforce; (ii) conforming to current quality and performance standards; (iii) cost overruns; (iv) poor quality of work; (v) in-adequate project specification; and (vi) employing new technologies and processes*. In addition to such challenges, current project processes such as; *surveying, on-site practice and QA*, are faced with a number of discrepancies, for instance; (*i) inaccurate data capture; (ii) lack of understanding of building physics; (iii) lack of effective and efficient construction practice* (see Abdel-Wahab and Bennadji, 2013; Forster and Carter 2011; 2013; Forster et al., 2011, 2013, 2018; Historic Scotland 2012c; Hughes, 2012; Lott, 2013; Odgers and Henry, 2012; Torney, 2015; 2016; Torney et al., 2012; 2014; Torney and Hyslop, 2015). Such issues, in turn, result in reduced project delivery efficiency and a lack of true communication and collaboration between project stakeholders (silo-working) (Baiden, Price, and Dainty 2006; Baiden and Price, 2011). Clearly, there appears to be a gap between industry practice, guidance, and legislation, which is manifested in the recurring levels of disrepairs (SHCS, 2016).

From a Project Management and on-site practice perspective, given the undoubted importance of the historic building R&M and the economic wellbeing impact it has on the UK (ECORYS, 2013; 2012), the extensive literature review, revealed a range of similar correlated, sector wide and project specific level challenges and issues, facing the historic building repair and maintenance sector, such as*; fragmentation; the prevalence of specialist SME sub-contracting, the perennial problem of skills shortages and skills, education and training, recruitment, supply and demand, disrepair levels, economics, technology, sustainability, modernisation, process improvement and performance measurement.* For example, in terms of the sector demographic landscape, a number of gaps were identified;

(1) *Lack of reliable and consistent official statistical data and project-based data on the supply, demand, and provision of traditional skills;*

(2) *Lack of an in-depth deeper assessment of the size and scale of the historic building R&M at the micro-scale (project and individual occupational level);*

Whilst, in terms of project performance, a number of gaps were identified, within the academic and industry intelligence reports, namely;

(1) Lack of specific investigation on Key Performance Measures (KPI)

(2) Lack of adopting a KPI approach in practice;

(3) Lack of availability of up to date KPIs data in terms of understanding of any current and future productivity and performance improvements.

Indeed, these gaps identify the need for further investigation, in order to guide and inform decisions, strategies, and policies, to support opportunities to encourage greater long-term planning of resources and achieve a suitably up-skilled workforce. Furthermore, having the availability of up-to-date demographic and KPI data could help identify areas for *"process management and improvement"* to support continual improvement and offer the chance to better predict the value and cost of projects; for example, by allowing the measurement of specified workmanship and product performance, in comparison to, actual performance in terms of effectiveness, efficiency and quality. Thus, these identified research gaps further relates to the research problem, that is; despite overall, the Historic Building repair and maintenance sector, being a professional, and highly-skilled, with vast experience and expertise, the efficiency of current processes leaves much to desire. Many projects, are in fact, still running over time and therefore over budget, with many instances of projects experiencing poor performance in historic building repair and maintenance practice, as a result of a deficiency in comprehension and application of Project Management.

In relation to the 14 MSME and SME semi-structured interviews, in essence, they resonated with the literature, as they surrounded similar topics, as mentioned in the academic studies and the periodical industrial intelligence reports. Thus, the analysis of the data and the pilot study semi-structured interview findings validated the results of the literature review, which in turn, constructed more robust evidence, by acknowledging that, the frequent project process and practice deficiency issues identified in the literature review, are perceived to be the same by sector practitioners. For example, employing the method of thematic analysis, revealed the complexity of current historic building R&M practice, and identified 16 key issues classified under the three key themes; (i) senior management issues*;* (ii) human resource issues; and (iii) technical issues. Within these three key themes, all 14 respondents highlighted the following four key issues: (i) *No Defined Process;* (ii) *Silo working resulting in a lack of a multi-disciplinary approach and communication and collaboration between project stakeholders*; (iii) *Lack of expertise of the design team*; and (iv) *Lack of sufficient time for investigation and lack of understanding about the condition of the building.*

It is clear that, the comments and attitude from the 14 semi-structured interviews, that current industry processes need to improve, allied to the demand for higher-skilled operatives and technical advances, to support and/or influence practice. Yet, for *"process management and improvement",* such need and demand, has tended to drive any development of the sector, towards focusing on technical improvement rather than Project Management improvements. Permitting the viewpoint, to aid *"process management and improvement"* within the sector, as well as, being critical to develop new frameworks, models and theories, fundamentally, it is imperative to review current conventional Project Management strategies and on-site processes. Hence, based on the literature review, combined with anecdotal experience and knowledge, allied to the lack of a defined process map, or how such a map, can be used to improve the delivery of projects., and as part of the study's action research strategy, a conceptual Historic Building R&M process map was developed. The initial generic model was presented to the respondents during the interview process, who evaluated and modified the graphical representation, to develop a high-level generic model that represented the main activities followed by specialist MSME and SME organisations. Moreover, the development of a high-level conceptual process map provides the opportunity to allow MSME and SMEs (professionals and contractors), to visually observe all the strategic steps and decisions, Therefore, it can be seen that adopting an action-research methodology is justifiable in order to support effective SME practice for historic building R&M project processes.

Thus, from the overall findings of the literature review (various industrial intelligence reports and documents) and the exploratory pilot study (14 semi-structured interviews), the main conclusion, and lesson, that can be drawn, in terms of this research objective; is that, in reality, the plethora of sector-wide and project level challenges offered, are inextricably linked, very much like the complex, multi-disciplinary and bespoke nature of historic building repair and maintenance projects. Therefore, the key challenges remain; to determine specific repair requirements, establish specialised skill requirements and ultimately enhance historic building R&M practice, by using a structured and multi-disciplinary integrated approach, in the historic building R&M project delivery process.

10.2.2 Research Objective 2: *To appraise current frameworks for construction process management and examine their suitability in terms of supporting and enhancing Project Management and on-site construction process management practice.*

Research objective 2, was correspondingly achieved, under the same conditions as Objective 1 (see 10.1), whereby, the review of the literature, pertaining to Project Management and current frameworks for construction process management, revealed a gap in the literature, identifying a; (1) paucity of specific investigation on "*process management and improvement*"; (2) a distinct lack of in-depth studies on historic building Project Management (PM) process and its ability to support optimised project delivery; and (3) an absence of research related to providing a structured, holistic and integrated framework, for guiding Project Management and on-site processes practice. For example, the few relevant pieces of literature, which exist to support project delivery, are either Government legislatory guidance, or standard documents (British Standard 70913:2013; SHEP, 2011), or alternatively wider construction sectoral practical guidance documents, produced by several professional organisations (RIBA, 2013; RICS, 2013). The review of the literature revealed; each current industry Construction Process Management Framework (CPMF), has their own individual merits and benefits; and whilst they provide valid guidance, in reality, they provide broadly generic guidance on procedure; as they have a tendency to promote silo working, as they do not specify a defined Project

Management process for historic building repair and maintenance, resulting in SMEs operating as groups of disparate organisations across the supply chain. Moreover, these current Project Management frameworks, have lack of correlation with the sector and its specialist MSME and SMEs, as they are: not explicit, only infer that they can be adapted for the sector, and do not reflect the terminology and work-processes that are undertaken by the majority of historic building repair and maintenance SMEs. Hence, in the absence of specific guidance and standards targeted for carrying-out and managing on-site operations, direct impacts can be felt on the project schedule, cost and overall performance, whereby, MSME and SMEs have a tendency to adopt an ad hoc approach, relying heavily on subjective knowledge, expertise and subsequent judgement of both professional and contractor. Furthermore, current frameworks have a specific focus on BIM, rather than the concept of historic building repair and maintenance digitisation, nonetheless, a small number of studies, which have developed conceptual HBIM frameworks were also reviewed, and whilst, the developed conceptual HBIM frameworks are a major step forward, they suffer from the same concurrent issues.

In relation to the 14 MSME and SME semi-structured interviews, with regards, all the responses provided by the interviewees, surrounding understanding, knowledge and implementation of CPMFs, when being involved in historic building R&M delivery. For example, they identified 8 key issues within the same three key themes, highlighted in 10.2.1; firstly, senior management issues; *lack of uptake from a contracting SME stance, raising awareness and resistance to change;* secondly, human resource issues; *skills development, education and training*; and thirdly technical issues; *the need for an up to date technical CPMF handbook/guide for SMEs and the need to create a raft of demonstration projects showcasing the benefits.* The responses confirmed there is a wide consensus among respondents, of not only the lack of understanding, knowledge, and implementation of CPMFs, but also an absence of specific guidance and standards targeted for carrying-out and managing on-site operations. This in part, could explain why an ad-hoc approach to the collection of project data, supported by the lack of communication and collaboration between project stakeholders', results in silo working and that SMEs lack awareness of these Project Management frameworks and question their relevance for true collaboration, given the sector's risk-averse culture seems to be plausible. The findings correlate with the literature review, suggesting that, in order to achieve, the combined delivery performance objectives of time, cost, safety, technical and quality on projects, MSME and SMEs, need to not only look for new management paradigms and practices, that lead to real improvement, but also be aware of the benefits and advantages of such tools (Loforte and Fernandes, 2010).

A key conclusion, and lesson, that can be drawn, in terms of this research objective; is there needs to be not only an integrated methodology but also a move towards a more structured and coherent approach, indeed, an evolution towards, a co-ordinated and standardised flow of the sequence of activities/works performed, all within a context of a centralised and streamlined workflow. In turn, this would also be useful in driving historic building *"process improvement and management",* allowing all project stakeholders to understand these complex processes and realise potential tactics to be catalysts for improvement. Moreover, given projects are heavily reliant on specialist MSME/SME contractors and professionals, there is need for a simple, yet appropriate and systematic methodology, which is structured and holistic, tailored to MSME/SME historic building R&M practice. Thus, accordingly, the development of a process model, map and a management tool, that enables a structured management approach to the historic building R&M process, is justifiable in supporting effective and efficient SME professional and contractor practice.

10.2.3 Research Objective 3: *To develop an in-depth comprehension of digital technologies suitable for historic stone building repair and maintenance projects, as well as an in-depth understanding of Integrated Project Delivery's concepts and principles.*

To achieve this third objective of the research, a comprehensive review of suitable digital technologies for historic building repair and maintenance and an overview of Integrated Project Delivery (IPD) concepts and principles has been undertaken. Firstly, focusing on Historic Building R&M Digitisation; an extensive literature review identified much of the work and application of the technologies in the built heritage sector, has to date has tended to focus on conservation practice, within culturally important historic buildings. Whereby, digitisation trends tend to focus on digital workflows surrounding spatial documentation, modelling, surveying, and monitoring of historic stone buildings. Yet, despite the lack of research in the area of R&M construction practice, several studies, (Bednarik et al., 2012; Bisenga et al., 2014; Bosché, Forster and Valero, 2017; Brunetaud et al., 2012; Ercoli, 2013; Hayes et al., 2015; Hallermann and Morgenthal, 2015; Janvier-Badosa et al., 2015; Kordatos et al. 2013; Kottke, 2009; Moropoulou et al., 2013; Oses et al., 2014; Ouimet, 2015; Paoletti et al., 2013; Shaughnessy, 2015; Spodek & Rosina, 2009 Stefani et al, 2014; Sun, 2012 ; Xi et al., 2015; Yajing and Cong, 2011), focussing on historic stone structures, have developed avenues relevant for Project Management, project surveying, building diagnostics, and monitoring and evaluation, providing highly valuable insights into the relevant digital technologies required to enhance practice. Indeed, clarifying that, for example, embracing such tools as; the integration of 3D reality data capture technologies, mobile computing and web-based platforms, can support and facilitate new digital workflow methodology approaches to historic project data capture, as a, consequence of which, can enhance project performance and realise process efficiencies for historic building repair and maintenance.

Secondly, focusing on Integrated Project Delivery (IPD), the literature review observed; such an innovative project delivery process can provide project stakeholders with detailed processes to; effectively implement collaborative working practices; and serve the interests of project transparency and communication; along with providing the mechanics for managing project data management and underpinning continuous improvement. Although, the literature argued IPD and its concepts cannot be practiced without sufficient knowledge and understanding of the mechanism itself. Nonetheless, if historic building repair and maintenance projects adopted an IPD approach (professionals and SME contractors), early in the planning phase, where it is essential to have the knowledge and skills necessary to help identify and explore all the issues surrounding the project in order to mitigate risks, it could offer not only improving project performance but also workforce performance; reducing schedule delays, cost overruns, conflicts, and other issues often associated with historic building projects.

In terms of the fourteen key industry players who participated in the interview process, with regards, historic building digitisation and adopting an IPD approach in practice, the level of understanding and knowledge, was as expected; varying from low to high, with the majority of responses typically only providing one or two examples, predominantly surrounding digital technologies and their ability to support practice, suggesting there was a consensus, as to familiarity of the concept of IPD. Hence, it can be seen that whilst practitioners reported the possible need for adopting such tools and processes, in the majority, there was a general lack of awareness as to; what these digital technologies were, what is involved in IPD and what are the benefits they brought. Unsurprising, as SMEs have yet to embrace the application of digital technologies, never mind innovative approaches to project delivery such as IPD, given that respondents, indicated, they have challenges in maintaining current with the latest digital tools, equipment and project delivery processes. However, they suggested the following three key components; *attending workshops/seminars, case studies, and learning from peers,* as an opportunity to reflect on practice and learn through evaluation of the outcomes (issues and successes) of completed projects which have employed digital technologies and adopted an IPD based approach.

The main conclusion, and lesson, that can be drawn, in terms of this research objective, is there is a need to raise MSME and SME awareness and highlight the benefits of the most relevant key digital technologies and of adopting an IPD approach. For this to transpire in reality, underscoring their capabilities in reducing process inefficiencies will require implementing practical research, in order to understand; what new technologies could likely be used and how IPD could be adopted; as well as determine what investments in skills will be required to make this achievable; and identify the most appropriate technological mix to address the specific project challenges. Hence, adopting a project-based approach, and generating a database of demonstration case studies, focusing on repair and maintenance works and the associated work processes and practices (e.g. surveying, logistics, on-site works, QA etc.), can not only help support Project management and construction practice modernisation and innovation, but also encourage the sector towards *"process improvement and management",* in historic building R&M project processes and practice.

10.2.4 Research Objective 4: *To develop a common structured collaborative industry framework for process improvement and management to support a collaborative, multidisciplinary approach which will facilitate an Integrated Project Delivery (IPD) based approach, whilst inform digital technology application.*

To achieve the fourth objective of the research, the development of the framework, was founded on the principles outlined in section 7.3; for example, combining the concepts of framework development and process improvement, and for the developed framework to be grounded in an existing industry framework. In terms of the framework development, the results from the thematic analysis, surrounding the exploratory pilot study, presented in Chapter 5 & 6, and concurrently, through co-operative industry engagement, the generation of a best practice historic building SME historic building repair and maintenance process map was undertaken, allowing to, accurately capture and reflect the work phases of SMEs, operating in the sector, as part of the action research methodology, to provide validity to the framework development.

Thus, this map allowed the development of a four-phase process model, with a further 8 sub-phases, which acknowledged delivering a historic building repair and maintenance project, is an iterative, yet systematic process, which requires adopting a multi-disciplinary, structured, collaborative approach, throughout a project lifecycle (from planning to completion), fundamental for effective repair and maintenance. The 4-phase process model was mapped, formatted and compared against three existing wider UK construction industry Construction Process Management Frameworks (CPMF), as well as three relevant UK Project Management British Standards and regulations, to provide validity of industry best practice. From the 4-phase process model, the framework was developed further, whereby, through an iterative process, employing; Business Process Mapping Notation (BPMN) process mapping, as a simple yet standardised visual communication tool, provided an improved clarity, in terms of an overview of the whole process, as there was scope, to create a series of four process levels (level 0, 1, 2, and 3) maps; and to satisfy academic rigour, employing the Generic Design and Construction Process Protocol (GDCPP) principles (Cooper et al., 1998), to support the framework, its content generation, and maintain the aim to support integrated project delivery (IPD) and inform digital technology application.

The developed *CrOsS* framework consists of four interdependent phases: *Phase 1, Project Appraisal; Phase 2, Project Set-Up; Phase 3, Project On-site Practice; Phase 4, Project Completion*, representing a framework for Project Management and on-site practice process management, within historic building repair projects; aimed at providing a cross-cutting, integral, yet simple and straightforward to use, SME process standard and guide. Thus, the framework potentially should provide a more industry relevant framework, that promotes, not only a multi-disciplinary collaborative approach, but also provides, a defined delivery structure that accurately reflects the intricacies and complexities of repair and maintenance practice, to help support optimised project delivery. Hence, what can be drawn from this stage of the research study; is that employing an iterative action research-based process approach, was a significant framework development element, as it allowed content development to occur, grounded in a conceptual model of practice, whereby it permitted addressing the issues identified in the literature and the exploratory pilot study. Therefore, it can be seen that a SME tailored process standard framework development is a logical step change, in order to enable a structured management approach to the historic building repair and maintenance process, whilst supporting effective and efficient MSME and SME professional and contractor practice.

10.2.6 Research Objective 5*: To evaluate and validate the newly developed process management framework (process road map and tool) capability for undertaking historic building R&M PM and on-site practice.*

Accomplishing this fifth and final objective relied on performing a multi-method qualitative study, which involved three key components; (1) a practical project-based demonstration case study project, to observe the framework in a *"real-world"* context; (2) along with performing 4 semi-structured interviews with key case study project participants (SME consultants and contractor); and (3) two focus group sessions in which 12 practitioners (a mixture of professional, consultant, and supply chain MSME and SMEs).

For the demonstration project, the process framework was not piloted in its entirety, due to various factors, such as; research resource, budget and time constraints (both, in terms of the PhD and case study project), resulting in focusing on the project appraisal phase (preliminary services sub phase; integrated survey process). Nonetheless, grounded in case study research design, despite not being able to demonstrate the whole framework, this still allowed, highlighting varying potential benefits and sector practice challenges in framework application. For example, to highlight the benefits accrued from the integrated project appraisal phase, in particular the on-site survey process; a comparative cost-benefit analysis of five Key Performance Indicators (KPIs) (quality, time, cost and health and safety) was carried out. Thus, through the use of a *"structured process-workflow"*, in comparison to conventional on-site processes, resulted in a 25-30 percent estimated time and cost-saving (figures assumed both consultant and contractor rates were similar in nature). Whilst, for potential sector practice challenges in framework application, the findings from the four semi-structured interviews, indicated a number of areas for investigation; for example, a key challenge was to embed education and training within the framework, to alleviate any concerns surrounding framework understanding, its concepts and terminology, behind the tool, whilst it was offered, an increase in documentation as a result of framework use, would be time consuming and require the need for an additional project delivery team role to be created. Nonetheless, the findings from the four semi-structured interviews indicated that the framework was practical, rational and reliable, as a means for attaining a multi-disciplinary and collaborative approach for building repairs. Although, they suggested to improve the framework was the need for; increasing awareness and distribution of the framework through a *"Repair & Maintenance hub"*, to align the framework with appropriate and suitable UK recognised forms of contracts for adopting an integrated approach, and above all the main key recommendation was the continuing need for similar demonstration project-based data.

In relation to the focus group findings, they echoed the demonstration project and the four semi-structured interviews identifying; that the framework had a very clear, systematic and structured explanatory structure, which allows for integration and commonality. The Focus Group Sessions (FGS), also corroborated the high-level generic *CrOsS* framework process model was a valid and credible guidance tool, for supporting the implementation of the framework within the historic building sector. With regards the FGS questionnaire, it allowed the research study to reach some indicative conclusions about the whole sector's perspective on the credibility, appropriateness, applicability, and clarity of the framework, suggesting, that if the framework was presented to industry practitioners, they would consider the framework as a logical and legitimate addition to their practice. However, whilst the Focus Group industry practitioners reported potential benefits to both professional and contractor practice; by providing a good basis for process improvement, through several performance and productivity benefits (enhanced data quality capture, improved project collaboration, and communication, increased Health & Safety, time and cost improvements), there were a number of adoption challenges raised towards industry practice, such as; resistance to change of current practice and hindered by existing procurement methods, whilst it is limited by not able to be tested in its entirety, resulting in difficulty in determining its limitations/weaknesses. The main conclusion, and lesson, that can be drawn, in terms of this research objective, indicated that the framework was pragmatic, valid, and credible as a means for attaining a multi-disciplinary and collaborative approach for building repairs.

10.3 Research Contribution

The research study acknowledges, that a paucity of research surrounding historic building R&M *"process improvement and management"*, has resulted in little interest in the current body of knowledge, both theoretically and in practice, across the UK and internationally. The following sub-sections provide an overview of the study's contribution to the field.

10.3.1 Theory Contribution

Currently, no single overarching theory explains the role of *"process improvement and management"* as a means for modernisation of the historic building R&M sector. Thus, as illustrated in Figure 10.2 this study, has shown how knowledge from the field of; CM (GDCPP), business process improvement (BPMN) and architectural conservation (structured documentation, working with evidence, minimal intervention, and sustainability) has contributed to the existing historic building R&M body of knowledge, whereby a theoretical framework was generated to support the for understanding the process required to modernise the historic building R&M sector and contribute to the productivity and performance of historic building R&M projects.

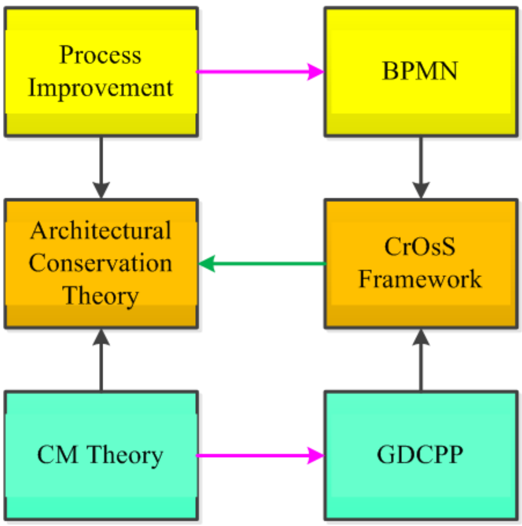


Figure 10.2: Theoretical Contribution to Knowledge

Furthermore, by adopting a pragmatic viewpoint, this research study has also contributed to the growing body of research methodology knowledge by supporting the argument that a qualitative action research strategy can generate tangible findings that helps provide solutions to problems practitioners experience in the real world (Denscombe, 2010). Whereby, adopting an action research strategy is a meaningful and effective way of reducing the gap between academia, research and industry practice. By drawing strength from its convergence towards transformation, and the realisation of the need to diagnose, plan, act, evaluate and involve industry practitioners throughout the research process (Fellows and Liu, 2015; Saunders et al., 2016).

10.4 Practice Contribution

On the subject of *"process management and improvement"*, the researcher believes that this is the first research project undertaken within the historic building repair and maintenance sector, thus provides valid contribution and adds to the growing body of UK Construction Project Management practice knowledge, achieved through the delivery of the following outputs:

(i) Integrating and employing existing construction process management frameworks (GDCPP) and process modelling and mapping techniques (BPMN) to generate a best practice protocol/process map for historic building repair and maintenance. Until now, there has been no simple yet standardised and structured visual communication tool to provide a clear overview of the complete historic building repair and maintenance process.

(ii) Development of a common structured collaborative (CrOsS) framework, designed to offer a process model, map, and a management tool that supports integrated working and inform the use of digital technology.

(iii) Provide a deeper understanding of the applicability and effectiveness of a "process management and improvement" framework, and contribute to the knowledge of digital technologies and IPD implementation awareness in the historic building repair and maintenance sector.

(iv) Essentially, the developed integrated process-based framework tool is aimed at supporting and assisting MSME and SMEs to develop an enhanced comprehension of the action required for change, whilst identifying the key processes that require modernisation.

10.5 Limitations of the Research

Throughout the study, the research bounded by limitations, in terms of its conduct and scope are briefly outlined, in the following;

(i) Scope orientated towards MSMEs and SMEs, at consultant and contractor level, in particular, stonemasonry specialists (Professionals, Contractors, Sub-Contractors, and Suppliers)

(ii) Complexity in arranging a suitable demonstration project due to several factors, namely; industry fragmentation and the prevalent practice of silo-working. These presented difficulty in terms of full agreement from all project stakeholders, whereby on two occasions, at a very late stage, the research had to seek alternative options, which in turn placed the project under pressure, given part of the research methodology was an action research-based case study and would have compelled the study to investigate an alternative research methodology.

(iii) Only the preliminary services sub-phase of the project appraisal phase of the framework could be demonstrated (i.e. integrated surveying process), due to limited resources of the study (timescale and budget).

(iv) Given the developed framework and some its findings, may be applicable to the UK, difficulty may arise in attempting to generalise the findings to historic building repair and maintenance Project Management practice in international countries. Thus, similar studies need to be conducted to validate the framework for use in such countries.

(v) The developed process management framework represents a specific theoretical and practical application of existing Construction Project Management and process management principles.

(vi) From the industry expert practitioner validation and evaluation process, several external factors were offered, which could possibly hinder the successful application of the developed Project Management framework, such as; framework buy-in, responsibility, distribution and management; fidelity of using digital technologies, project team competence, etc., however, these distinct issues were beyond the study scope.

10.6 Recommendations for future research

Whilst the research has developed an innovative framework for historic building repair and maintenance *"process management and improvement"*, substantiated in its industrial frame of reference, which confirms the ability of research to add value and provide practical recommendations to the historic building R&M sector. In order to, help support modernisation within historic building R&M projects, further complementary work would be beneficial, based on a three main factors; firstly, developing a common structured collaborative integrated approach and digital technology implementation are vehicles for enhancing industry performance and productivity; secondly, the size and scale of growth opportunity that the historic building R&M sector represents in Scotland and the UK; and thirdly, the industry's current capacity to improve the condition of not only the UK but also Europe's existing building stock. Thus, the following recommendations, for the improvement of knowledge in this subject area, are made:

(*1) Additional framework development and efficacy demonstration across individual phases, as well as the whole project lifecycle.*

(2) Establishment of a series of practice-based demonstration case studies, to provide the opportunity to generate a database of evaluated example projects, as a reference guide, in terms of, framework challenges and benefits, whilst they would enable a feedback loop system, to determine the influence and value of adopting the framework, with its contemporary Project Management approach, supported by digital technologies employment.

(3) The high-level generic framework process diagrams for each phase of the project only present strategic processes and their associated key sub-processes. Thus, further hierarchical decomposition of the specific level detail of the processes performed is required. For example, provide additional process maps of each Phase's processes, to a similar level as produced for the surveying process within the sub phase of preliminary services of Phase 1: Project Appraisal.

(4) Corresponding international research studies require to be performed; identifying and analysing the value impact, and effectiveness of the framework, to make cross-country comparisons.

(5) A multi-methods qualitative exploratory action research strategy was employed for the current research. For future research, it would be prudent to adopt a mixed-methods approach (possibly a sequential exploratory or explanatory research design), for example allowing the capturing of quantitative data regarding critical success factors of adopting the framework, to build and expand on the initial set of findings.

It should be noted that the domain of Historic Building R&M, also encompasses aspects of design, risk, and procurement process management system. As such, the developed framework can be applicable to these processes, suggesting the exploration of the design, risk, procurement management workflow emerges as several other possible future areas of research.

References/Bibliography

Abdel-Wahab, M.S., Dainty, A.R., Ison, S.G., Bowen, P. and Hazlehurst, G., (2008) Trends of skills and productivity in the UK construction industry. *Engineering, Construction and Architectural Management*, *15*(4), pp.372-382.

Abdel-Wahab, M. Dainty, A. and Ison, S. (2010) A review of the case of a Levy-Grant Scheme (LGS) in the UK construction industry *Journal of Vocational Education and Training*, v62 n3 p273-283 Sep 2010. Routledge Taylor & Francis, Ltd. Philadelphia

Abdel-Wahab, MS (2012). 'Rethinking apprenticeship training in the British construction industry' *Journal of Vocational Education and Training*, vol 64, no. 2, pp. 145-154., 10.1080/13636820.2011.622450

Abdel-Wahab, M., & Bennadji, A. (2013). Skills development for retrofitting a historic listed building in Scotland. *International Journal of Low-Carbon Technologies*, ctt043.

Adamson, R.H., (2014) Stonemasons' Drawings on Building Fabric: Diversity, Form and Function. *Archaeological Journal*, *171*(1), pp.258-288.

Aquil, M.A., 2013. Project Management in SMEs. *Journal of Strategy and Performance Management*, 1(1), p.8.

Al-Kheder, S., Al-Shawabkeh, Y., & Haala, N. (2009). Developing a documentation system for desert palaces in Jordan using 3D laser scanning and digital photogrammetry. *Journal of Archaeological Science*, *36*(2), 537-546.

Al-Omari, A., Brunetaud, X., Beck, K. and Al-Mukhtar, M., (2015) Preliminary digital health record of limestone walls in Al-Ziggurat, Al-Nimrud city, Iraq. *Journal of Cultural Heritage*, *16*(5), pp.737-740.

Alreshidi, E., Mourshed, M. and Rezgui, Y., (2018) Requirements for cloud-based BIM governance solutions to facilitate team collaboration in construction projects. Requirements engineering, 23(1), pp.1-31.

Antonopoulou, S.; Bryan, P. Historic England (2017) BIM for Heritage: Developing a Historic Building Information; Historic England: Swindon, UK, 2017.

American Institute of Architects (AIA) (2017). Integrated Project Delivery (IPD): A Guide: The American Institute of Architectures, Sacramento, CA.

American Institute of Architects (AIA) (2014) Integrated Project Delivery: An Updated Working Definition, American Institute of Architects (AIA), Sacramento, CA.

American Institute of Architects (AIA) (2007). Integrated Project Delivery: A Working Definition (2 ed.). The American Institute of Architectures, Sacramento, CA.

Anjard, R., (1998) Process mapping: a valuable tool for construction management and other professionals. *Facilities*, *16*(3/4), pp.79-81.

Arayici, Y., (2008) Towards building information modelling for existing structures. *Structural Survey*, *26*(3), pp.210-222.

Armesto-González, J., Riveiro-Rodríguez, B., González-Aguilera, D., & Rivas-Brea, M. T., (2010) Terrestrial laser scanning intensity data applied to damage detection for historical buildings. *Journal of Archaeological Science*, *37*(12), 3037-3047.

Association for Project Management (API). (2012) APM Body of Knowledge, 6th edition. Bucks, England.

Atakul, N., Thaheem, M.J. and De Marco, A., (2014) Risk management for sustainable restoration of immovable cultural heritage, part 1: PRM framework. *Journal of cultural heritage management and sustainable development*, *4*(2), pp.149-165.

Awadid, A. and Nurcan, S., (2016) A systematic literature review of consistency among business process models. In *Enterprise, Business-Process and Information Systems Modeling* (pp. 175-195). Springer, Cham.

Aziz, R.F. and Hafez, S.M., (2013) Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, *52*(4), pp.679-695.

Azhar, S., Ahmad, I., and Sein, M. (2010) Action research as a proactive research method for construction engineering and management. *Journal of Construction Engineering Management* 136(1), 87–98.

Azhar, S., Jackson, A. and Sattineni, A., (2015) Construction apps: a critical review and analysis. In *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction* (Vol. 32, p. 1). IAARC Publications.

Australia International Council on Monuments and Sites (ICOMOS) (1999) *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance*. Victoria: Australia.

Baars, P., (2012) *Financing and Maintenance of Historic Buildings in the Netherlands*, Communication and Strategy Department of Nationaal Restauratie Fonds.

Baccarini, D., (1996) The concept of project complexity—a review. *International journal of project management*, 14(4), pp.201-204.

Baccarini, D., (1999) The logical framework method for defining project success. *Project management journal*, *30*, pp.25-32.

Baik, A., Alitany, A., Boehm, J. and Robson, S., (2014) Jeddah Historical Building Information Modelling" JHBIM"-Object Library. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *2*(5), p.41.

Baiden, B. K., Price, A. D. F. & Dainty, A. R. J. (2006) The extent of team integration within Construction projects. *International Journal of Project Management*, 24, 13-23.

Baiden, B.K. and Price, A.D., (2011) The effect of integration on project delivery team effectiveness. *International Journal of Project Management,* 29(2), pp.129-136.

Baker, P. (2011). Technical Paper 10 – U-values and Traditional Buildings, Edinburgh: Historic Scotland

Balaras, C.A., Droutsa, K., Dascalaki, E. and Kontoyiannidis, S. (2005) Deterioration of European apartment buildings, *Energy and Buildings*, 37: pp. 515-527.

Barber, D.M., Dallas, R.W. and Mills, J.P., (2006) Laser scanning for architectural conservation. *Journal of Architectural Conservation*, *12*(1), pp.35-52.

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M.J., Sridhar, M., Parsons, M., Bertram, N. and Brown, S., (2017) *Reinventing construction: A route to higher productivity*. McKinsey Global Institute. New York, United States

Bassioni, H.A., Price, A.D. and Hassan, T.M., (2005) Performance measurement in construction. Journal of management in engineering, 20(2), pp.42-50.

Beckmann, P., and Bowles, R. (2004). *Structural Aspects of Building Conservation* (2nd ed.). Elsevier Butterworth. Oxford

Bednarik, M., Kovářová, K., Holzer, R. and Laho, M., (2012) Natural Ashlars of Historical Monument-Modern Methods of Data Processing and Storage. *Engineering Mechanics*, p.320.

Bennett, F.L., (2007) *The management of construction: A project lifecycle approach*. Routledge.

Bernard, H.R., Wutich, A. and Ryan, G.W., (2016) *Analyzing qualitative data: Systematic approaches*. Sage Publications, Thousand Oaks, CA:USA

Bisegna, F., Ambrosini, D., Paoletti, D., Sfarra, S., & Gugliermetti, F. (2014) *A qualitative method for combining thermal imprints to emerging weak points of ancient wall structures by passive infrared thermography–A case study*. Journal of Cultural Heritage, 15(2), 199-202.

Biton, N. and Howell, G., (2013) The journey of lean construction theory review and reinterpretation. *Proceedings IGLC-21, July*, pp.125-132.

Bosché, F., Forster, A. and Valero, E., (2015) 3d Surveying Technologies and Applications: Point Clouds and beyond'a Technical Report for Historic Scotland'. Available at: *https://web. sbe. hw. ac. uk/fbosche/publications/report/Bosche-2015-Report. pdf*. (accessed 10/01/2017)

Braun, V. and Clarke, V., (2006) Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), pp.77-101.

Brightman, M. (2012) Is the Conservation of the United Kingdom's Built Heritage Sustainable? *Reinvention: a Journal of Undergraduate Research*, British Conference of Undergraduate Research 2012 Special Issue.

Brightman, M. (2013) The Function of Government in times of Economic Crisis, *Diffusion*, 5 (2).

British Standards Institute (2012) *BSI 8210:2012: guide to facilities maintenance management*, BSI, London.

British Standards Institute (2013) *7913:2013 Guide to the Principles of the Conservation of Historic Buildings.* BSI, London
British Standards Institute (2013) *7913:2013 Guide to the Principles of the Conservation of Historic Buildings.* BSI, London
British Standards Institution., (2013) *PAS - 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using BIM*, London: BSi Limited.

Bryman A (2012) Social Research Methods. Fourth edition. Oxford University Press, Oxford.

Brumana, R., Oreni, D., Raimondi, A., Georgopoulos, A. and Bregianni, A., (2013) October. From survey to HBIM for documentation, dissemination and management of built heritage: The case study of St. Maria in Scaria d'Intelvi. In *Digital Heritage International Congress (DigitalHeritage), 2013* (Vol. 1, pp. 497-504). IEEE.

Brunetaud, X., Stefani, C., Badosa, S.J., Beck, K. and Al-Mukhtar, M., (2012) Comparison between photomodelling and laser scanning to create a 3D model for a digital health record. *European Journal of Environmental and Civil Engineering*, *16*(sup1), pp.s48-s63.

Bullen, P.A. and Love, P.E., (2010) The rhetoric of adaptive reuse or reality of demolition: Views from the field. *Cities*, *27*(4), pp.215-224.

Bullen, P.A. and Love, P.E., (2011). Adaptive reuse of heritage buildings. *Structural Survey*, *29*(5), pp.411-421.

Cartlidge, D., (2015) *Construction Project Manager's Pocket Book*. Routledge. Abingdon, UK

Carvalho, M.M.D. and Rabechini Junior, R., (2015) Impact of risk management on project performance: the importance of soft skills. *International Journal of Production Research*, *53*(2), pp.321-340.

Casula, G., Fais, S. and Ligas, P., (2009) An experimental application of a 3D terrestrial laser scanner and acoustic techniques in assessing the quality of the stones used in monumental structures. *International Journal of microstructure and materials properties*, *4*(1), pp.45-56.

Chabot, D., (2018) Trends in drone research and applications as the Journal of Unmanned Vehicle Systems turns five. *Journal of Unmanned Vehicle Systems*, *6*(1), pp.vi-xv.

Chalal, M. L., and Balbo, R. (2014) Framing Digital Tools and Techniques in Built Heritage 3D Modelling: The Problem of Level of Detail in a Simplified Environment. *International Journal of the Constructed Environment, 4(2).*

Chan, P.W. and Moehler, R.C., (2007) Developing a'Road Map'to Facilitate Employers' Role in Engaging with the Skills Development Agenda. *Association of Researchers in Construction Management*, *1*, pp.409-18.

Chang-Richards, Y., Wilkinson, S., Seville, E. and Brunsdon, D., (2017) Effects of a major disaster on skills shortages in the construction industry: Lessons learned from New Zealand. *Engineering, Construction and Architectural Management*, *24*(1), pp.2-20.

Chan, P.W. and Dainty, A.R., (2007) Resolving the UK construction skills crisis: a critical perspective on the research and policy agenda. *Construction management and economics*, 25(4), pp.375-386.

Chan, P. and Moehler, R.C., (2007) Developing a 'road map' to facilitate employers' role in engaging with the skills development agenda. *Association of Researchers in Construction Management*, *1*, pp.409-18.

Chartered Institute of Building (CIOB) (2014) *Code of practice for project management for construction and development*. 5th Edition. John Wiley & Sons.

Chartered Institute of Building (CIOB) (2017) Construction Manager Magazine, available at: http://www.constructionmanagermagazine.com/onsite/digital-makeover-17th-century-barns-complete/ (accessed 07/08/2017)

Chartered Institute of Procurement& Supply (CIPS), 2017).. For example, in the seasonally adjusted IHS Markit/CIPS UK Construction Purchasing Managers' Index (PMI) survey, available at:
https://www.markiteconomics.com/Survey/PressRelease.mvc/d27871f3c53a48d1ad8b0aa9aeb7409c (accessed 22/12/2017)

Cheng, H. M., Yang, W. B., and Yen, Y. N. (2015). BIM applied in historical building documentation and refurbishing. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1, 85-90.

Chinowsky, P., Diekmann, J., & Gallotti, V. (2008). Social network model for construction. *Journal of Construction Engineering and Management*, 134(10), 804-812.

Chong, W.K. and Low, S.P., (2005) Assessment of defects at construction and occupancy stages. *Journal of Performance of Constructed facilities*, *19*(4), pp.283-289.

Clarke, L and Herrmann, G (2007) *Divergent divisions of construction labour: Britain and Germany*. In: A. Dainty, S. Green, and B. Bagilhole, (eds.). "People and Culture in Construction: A reader": Taylor & Francis. Oxon

Chou, J.S. and Yang, J.G., (2012) Project management knowledge and effects on construction project outcomes: An empirical study. *Project Management Journal*, 43(5), pp.47-67.

Clarke, J.A. and Laefer, D.F., (2014) Systematic approach for large-scale, rapid, dilapidation surveys of historic masonry buildings. *International Journal of Architectural Heritage*, *8*(2), pp.290-310.

Colomina, I. and Molina, P., (2014) Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of photogrammetry and remote sensing*, *92*, pp.79-97.

Conference on Training in Architectural Conservation (COTAC) (2014) Integrating Digital Technologies in Support of Historic Building Information Modelling: BIM 4 Conservation (HBIM) http://www.cotac.org.uk/docs/COTAC-HBIM-Report-Final-A-21-April-2014-2-small.pdf (accessed 08/01/2016).

Connaughton, J. and Weller, S., (2013) Improving collaboration in construction: an opportunity for action research. In *Proceedings 29th Annual ARCOM Conference, Reading* (pp. 2-4).

Construction Industry Research and Information Association (CIRIA) (1994). Structural Renovation of

Traditional Buildings, Report 111 (reprinted 1986 ed. with update amendments), Construction Industry Research and Information Association, London.

Construction Industry Training Board (CITB) (2017) Industry Insights: Construction Skills Network Forecasts 2017–2021, available at:

https://www.citb.co.uk/documents/research/csn%202017-2021/csn-national-2017.pdf

(accessed 27/10/2017)Cooley, L. and Cholakis, P., (2013) Efficient project delivery: BIM, IPD, JOC, cloud computing and more. *Journal of Architectural Engineering Technology*, *2*(1), pp.1-5.

Cooper, R., Aouad, G., Lee, A., Wu, S., Fleming, A. and Kagioglou, M., (2005) *Process management in design and construction*. Oxford: Blackwell publishing.

Costanzo, A., Minasi, M., Casula, G., Musacchio, M., & Buongiorno, M. F. (2014). *Combined Use of Terrestrial Laser Scanning and IR Thermography Applied to a Historical Building*. Sensors, 15(1), 194-213.

Council on Training in Architectural Conservation (COTAC) (2016) Integrating HBIM Framework Report Part 1 and 2, available at: https://cotac.global/resources/HBIM-Framework-Part-1-February-2016.pdf and https://cotac.global/resources/HBIM-Framework-Part-2-February-2016.pdf (accessed 24/10/2016)

Crawford, L., Pollack, J. and England, D., (2006). Uncovering the trends in project management: Journal emphases over the last 10 years. *International journal of project management*, *24*(2), pp.175-184.

Creswell, J. W. (2012). Qualitative inquiry and research design: Choosing among five approaches. Sage Publications, Thousand Oaks, CA:USA

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications, Thousand Oaks, CA:USA

Crompton, L., Goulding, J.S. and Pour Rahimian, F. (2014) Construction partnering: moving towards the rationalisation for a dominant paradigm. ALAM CIPTA, *International Journal of Sustainable Tropical Design Research and Practice*, Vol. 7 No. 1, pp. 57-78.

Cunz, D., (2009) Integrated delivery: Forget about the contract, focus on the process. *Design Intelligence*, *7*.

Dainty, A.R., Ison, S.G. and Briscoe, G.H., (2005) The construction labour market skills crisis: the perspective of small–medium-sized firms. *Construction management and economics*, *23*(4), pp.387-398.

Dainty, A.R.J., Ison, S.G. and Root, D.S. (2005) *Averting the construction skills crisis: a regional approach.* Local Economy, 20(1), pp. 79–89.

Dainty, A (2008) *Methodological pluralism in construction management research. In: Knight, A and Ruddock, L (eds.) Advanced Research Methods in the Built Environment.* Wiley & Blackwell. Oxford. pp1-12

Dainty, A., Leiringer, R., Fernie, S. and Harty, C., (2017) BIM and the small construction firm: a critical perspective. *Building Research & Information*, 45(6), pp.696-709.

Daniels, C. (2012) *The Craft of Stonemasonry*. Crowood Press, Wiltshire

Dann, N., Worthing, D. and Bond, S. (1999) Conservation Maintenance Management – Establishing a Research Agenda, *Structural Survey*, 17 (3): pp. 143-153.

Dann, N. and Cantell, T. (2007) Maintenance in Conservation. In: Forsyth, M. (Ed) *Understanding Historic Building*, Oxford: Blackwell Publishing: pp. 185-198.

Dave, B., (2017) Business process management–a construction case study. *Construction Innovation*, *17*(1), pp.50-67.

Davey, A. (1988) *The Care and Conservation of Georgian Houses: a Maintenance Manual for Edinburgh New Town*. Butterworth Architecture. Oxford

Dawood, N.N., (2009) VR-roadmap: a vision for 2030 in the built environment. *Journal of Information Technology in Construction*.

Deloitte (2014) *Restoration and Renewal of the Palace of Westminster* http://www.restorationandrenewal.parliament.uk/joint-committee-report.html (accessed 07/11/2015)

Denscombe, M (2014) *The good research guide for small scale social science projects* Open University Press, Milton Keynes, UK

Denzin, N.K. and Lincoln, Y.S. (2011) *Handbook of Qualitative Research.* Sage. Thousand Oaks, CA

Department for Business, Innovation and Skills (2013a) *Supply Chain Analysis into the Construction Industry–A Report for the Construction Industrial Strategy.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/252026/bis-13-1168-supply-chain-analysis-into-the-construction-industry-report-for-the-construction-industrial-strategy.pdf accessed 1/11/2015

Department for Business, Innovation and Skills (2013b) UK CONSTRUCTION; An economic analysis of the sector. BSI. London, UK

Department for Business, Innovation & Skills (2015) *Policy paper; UK construction industry: digital technology.* https://www.gov.uk/government/publications/uk-construction-industry-digital-technology (accessed 27/10/2015)

Denzin, N.K. and Lincoln, Y.S. (2011), The Sage Handbook of Qualitative Research, Sage, Thousand Oaks, CA and London.

Dore, C. and Murphy, M., (2017) Current state of the art historic building information modelling.

Dubois, A. and Gadde, L.E., (2002) The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management & Economics*, *20*(7), pp.621-631.

Dyson, K., Matthews, J., and Love, P.E.D. (2016) Critical success factors of adapting heritage buildings: an exploratory study, *Built Environment Project and Asset Management*, Vol. 6 Issue: 1, pp.44-57, https://doi.org/10.1108/BEPAM-01-2015-0002

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S., 2015. A survey of current status of and perceived changes required for BIM adoption in the UK. *Built Environment Project and Asset Management*, 5(1), pp.4-21.

Eastman, C., Eastman, C.M., Teicholz, P., Sacks, R. and Liston, K., (2011) *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

Edum-Fotwe, F.T. and McCaffer, R., (2000) Developing project management competency: perspectives from the construction industry. *International Journal of Project Management*, *18*(2), pp.111-124.

ECORYS (Firm) (2013). *Review of estimates of the economic impact of Scotland's historic environment,* a report to Historic Scotland, available at: https://www.historicenvironment.scot/media/3916/economic-impact-ecorys.pdf/(accessed 08/01/2016).

ECORYS (Firm) (2012). *The Economic Impact of Maintaining and Repairing Historic Buildings in England (*a report to Historic Lottery Fund (HLF) and English Heritage available at:https://historicengland.org.uk/content/docs/research/economic-impact-maintaining-repairing-historic-buildings-england/ (accessed 08/01/2016).

Eckstein, H. (1975) *Case Study and Theory in Political Science*. In R. Gomm, M. Hammersley, and P. Foster (eds) Case Study Method. SAGE Publications Ltd: London.

Eight International (2017) The 2017 Competiveness Report, available at: https://www.8-international.com/flipbook/pdf/book-eight-advisory-the-2017-competitiveness-report.pdf (accessed 08/01/2016).

Egan, J. (1998) *Rethinking Construction. Report of the Construction Task Force*, DETR, London.

El Asmar, M., Hanna, A.S. and Loh, W.Y., 2013. Quantifying performance for the integrated project delivery system as compared to established delivery systems. *Journal of Construction Engineering and Management*, *139*(11), p.04013012.

Eleyan, D., and Loucopoulos, P., (2011) A dynamic model for project review in the construction industry, *ITcon* Vol. 16, pg. 577-600, http://www.itcon.org/2011/33

Elias, P. and Birch, M., (2010). SOC2010: revision of the Standard Occupational Classification. Economic & Labour Market Review, 4(7), pp.48-55.

Ellenberg, A., Kontsos, A., Bartoli, I. and Pradhan, A., (2014) Masonry crack detection application of an unmanned aerial vehicle. In *Computing in Civil and Building Engineering (2014)* (pp. 1788-1795).

Ercoli, L., Megna, B., Nocilla, A. and Zimbardo, M., (2013) Measure of a limestone weathering degree using laser scanner. *International Journal of Architectural Heritage*, *7*(5), pp.591-607.

Erdogan, B., Abbott, C., Aouad, G. and Kazi, A.S., (2009) Construction IT in 2030: a scenario planning approach, *ITcon Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning*, pg. 540-555.

Eurostat (2008) Statistical classification of economic activities in the European Union (EU) (NACE) available at: https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF (accessed 08/01/2016).

Fai, S. and Sydor, M., (2013) Building Information Modelling and the documentation of architectural heritage: Between the 'typical'and the 'specific'. In *Digital Heritage International Congress (DigitalHeritage)*, 2013 (Vol. 1, pp. 731-734). IEEE.

Fairclough, J., (2002) *Rethinking construction innovation and research-a review of the government's R&D policies and practices.*

Fakhimi, A.H., Sardroud, J.M. and Azhar, S., (2016) How can Lean, IPD and BIM Work Together?. In ISARC. *Proceedings of the International Symposium on Automation and Robotics in Construction (Vol. 33, p. 1).*

Farmer, M., (2016). The Farmer review of the UK construction labour model. Construction Leadership Council.

Feilden, B.M. (2003) *Conservation of Historic Buildings*, *3rd Ed*. Butterworth. Elsevier Butterworth. Oxford

Fellows, R. and Lui, A. (2015) *Research Methods for Construction*, 4th edn, Wiley, Oxford.

Fernández-Solís, J.L., (2008) The systemic nature of the construction industry. *Architectural Engineering and Design Management*, *4*(1), pp.31-46.

Fernandez-Solis, J.L., (2013) Building construction: A deterministic non-periodic flow–A case study of chaos theories in tracking production flow. *Architectural Engineering and Design Management*, 9(1), pp.21-48.

Fewings, P. and Henjewele, C., (2019) *Construction project management: an integrated approach*. Routledge.

Financial Times (2016) Britain's heritage renovations revive demand for old skills'. [ONLINE] Available at: https://www.ft.com/content/48936906-c8be-11e5-a8ef-ea66e967dd44 (accessed 20/08/17)

Fischer, M, Ashcraft, H, Reed, D and Khanzode, A (2017) *Integrating Project Delivery*. Hoboken: NJ: Wiley & Sons, Inc.

Flyvbjerg, B., (2006) Five misunderstandings about case-study research. *Qualitative inquiry*, *12*(2), pp.219-245.

Foni, A.E., Papagiannakis, G. and Magnenat-Thalmann, N., (2010) A taxonomy of visualization strategies for cultural heritage applications. *Journal on Computing and Cultural Heritage* (JOCCH), 3(1), p.1.

Forster, A. M, and Kayan, B (2009) Maintenance for historic buildings: a current perspective. *Structural Survey*, Vol. 27 Issue: 3,pp. 210-229,

Forster, A.M. (2010a), Building conservation philosophy for masonry repair: part 1 – "ethics". *Structural Survey*, Vol. 28, Iss: 2, pp.91 – 107.

Forster, A.M. (2010b), Building conservation philosophy for masonry repair: part 2 – 'principles'. *Structural Survey,* Vol. 28, Iss. 3, pp. 165-88.

Forster A.M., Carter, K., Banfill, P.F.G, Kayan B. (2011) Green Maintenance for historic buildings: an emerging concept. *Building Research and Information*, 39(6), pp. 656-664

Forster, A.M. and Carter, K. (2011) A framework for specifying natural hydraulic lime mortars for masonry construction, *Structural Survey*, Vol. 29 No. 5, pp. 373-96.

Forster, A. M., Carter, K., & Kayan, B. (2013). Greening maintenance. *Building Surveying Journal* (pp. 32-33). London: RICS

Forster, AM, Bosché, FN, & Valero, E. (2019) Digitally Surveying Damage. RICS Building Surveying Journal; 31-33. London, UK

Forster, AM, Bosché, FN, & Valero, E. (2019). The changing face of conservation. Built Environment Journal, 52-53

Froese, T.M., (2010) The impact of emerging information technology on project management for construction. *Automation in construction*, *19*(5), pp.531-538.

Fuller, A. and Unwin, L., (2008) *Towards expansive apprenticeships*. London: Teaching and Learning Research Programme.

Garcia, A.J., Manata, B., Mollaoglu, S. and Miller, V., (2015) Implementing IPD Method as Innovation: Project Coordination Influence on Information Sharing and Project Team Performance. *Engineering Project Organisation Conference*, Edinburgh, Scotland

Ganah, A.A. and John, G.A., (2014) Achieving Level 2 BIM by 2016 in the UK. In *Computing in Civil and Building Engineering (2014)* (pp. 143-150).

Ghassemi, R. & Becerik-Gerber, B., (2011) Transitioning to integrated project delivery: potential barriers and lessons learned." *Lean Construction Journal*, pp.32-52

Ghaffarianhoseini, A., Doan, D.T., Zhang, T., Ghaffarianhoseini, A., Naismith, N. and Tookey, J., (2016) A BIM Readiness & Implementation Strategy for SME Construction Companies in the UK. *In Proc. of the 33rd CIB W78 Conference.*

Ghose, A. and Han, S.P., (2014) Estimating demand for mobile applications in the new economy. *Management Science*, *60*(6), pp.1470-1488.

Gillespie, M.R.; Tracey, E.A.. (2016) *Scotland's building stone industry: a review*. Nottingham, UK, British Geological Survey, 46pp. (CR/16/026N) http://nora.nerc.ac.uk/513455/ (accessed 27/10/2015)

Glasgow City Council (2018) Report by Executive Director of Regeneration and the Economy, available at: http://www.glasgow.gov.uk/CouncillorsandCommittees/viewSelectedDocument.asp?c=P62AFQDN2UNT81Z3T1 (accessed 22/10/2018)

Glaser and Strauss (1967) *The Discovery of Grounded Theory*, Aldine Publishing Company, New York, USA

Gleick, J., (2011) *Chaos: Making a new science*. Open Road Media. New York, United States

Glendinning, M., MacInnes, R. and, MacKechnie, A (1996) *A History of Scottish Architecture: From the Renaissance to the Present Day*. Edinburgh University Press. Edinburgh

Gleick, J., (2011)Chaos: Making a new science. Open Road Media.

Golparvar-Fard, M., Bohn, J., Teizer, J., Savarese, S. and Peña-Mora, F., (2011) Evaluation of image-based modeling and laser scanning accuracy for emerging automated performance monitoring techniques. Automation in Construction, 20(8), pp.1143-1155.

Gray, D.E., (2013) *Doing research in the real world*. Sage Publications, Thousand Oaks, CA: USA

Greenhoot, A.F. and Dowsett, C.J., (2012) Secondary data analysis: An important tool for addressing developmental questions. *Journal of Cognition and Development*, *13*(1), pp.2-18.

Griffith, A. and Watson, P., (2003) Construction management: Principles and practice. Macmillan International Higher Education.

Guba, E.G. and Lincoln, Y.S., (1994) Competing paradigms in qualitative research. Handbook of qualitative research, 2(163-194), p.105.

Haddad, N.A., 2011. From ground surveying to 3D laser scanner: A review of techniques used for spatial documentation of historic sites. *Journal of King Saud University-Engineering Sciences*, *23*(2), pp.109-118.

Morgenthal, G. and Hallermann, N., (2014) Quality assessment of unmanned aerial vehicle (UAV) based visual inspection of structures. *Advances in Structural Engineering*, *17*(3), pp.289-302.

Hallermann, N., Morgenthal, G. and Rodehorst, V., (2015) Vision-based monitoring of heritage monuments: Unmanned aerial systems (uas) for detailed inspection and high-accuracy survey of structures. *WIT Transactions on The Built Environment*, *153*, pp.621-632.

Hardie, M. and Newell, G., 2011. Factors influencing technical innovation in construction SMEs: an Australian perspective. *Engineering, Construction and Architectural Management*, *18*(6), pp.618-636

Harrison, F. and Lock, D., (2017) *Advanced project management: a structured approach*. 4th Edition. Routledge, London.

Harty, C., Goodier, C.I., Soetanto, R., Austin, S., Dainty, A.R. and Price, A.D., (2007) The futures of construction: a critical review of construction future studies. *Construction Management and Economics*, *25*(5), pp.477-493.

Harty, C. and Leiringer, R., (2017) The futures of construction management research. *Construction management and economics*, *35*(7), pp.392-403.

Hayes, J., Fai, S., Kretz, S., Ouimet, C. and White, P., (2015) Digitally-Assisted Stone Carving of a Relief Sculpture for the Parliament Buildings National Historic Site of Canada. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *2*(5), p.97.

Hellmund, A., Van Den Wymelenberg, K. and Baker, K., (2010) Facing the challenges of integrated design and project delivery. *IEEE Engineering Management Review*, *2*(38), pp.8-14.

Henao, F. and Franco, L.A., (2016) Unpacking multi-methodology: Impacts of a community development intervention. *European Journal of Operational Research*, *253*(3), pp.681-696.

Heng Li , Hongling Guo , Miroslaw J. Skibniewski & Martin Skitmore (2008) Using the IKEA model and virtual prototyping technology to improve construction process management, *Construction Management and Economics*, 26:9, 991-1000, DOI:10.1080/01446190802290477

Henry, A. (2007) *Stone Conservation; Principles and Methods.* Donhead Publishing Ltd, Dorset

Health and Safety Executive (HSE) (2015). The Construction (Design and Management) (CDM) Regulations. *London: The Stationery Office*, UK

Hill, P.R., and David, J.C.E. (1995) *Practical Stone Masonry.* Donhead Publishing Ltd, Dorset

Historic Scotland (2011) *Scottish Historic Environment Policy.* APS Group Scotland

Historic Scotland (2012a) *Focus; Informing the Conservation of the Built Environment*. Historic Scotland. Edinburgh. http://www.historic-scotland.gov.uk/es/focus-magazine-2012.pdf (accessed 08/01/2016).

Historic Scotland (2012b) *Traditional Building Skills Strategy.* APS Group Scotland

Historic Scotland (2012c) *Establishing the Need for Traditional Skills*. Historic Scotland. Edinburgh

Historic Scotland (2013) *Guide to the Protection of Scotland's Listed Buildings. What listing means to owners and occupiers.* Edinburgh, Historic Scotland

Historic Scotland (2014) *Short Guide Maintaining Your Home.* Edinburgh, Historic Scotland

Historic Scotland (2015) *Annual Report - Our Place in Time - Historic Environment Strategy*. Historic Scotland, Longmore House, Salisbury Place, Edinburgh EH9 1SH

Historic Environment Scotland (2016) *Scotland's Historic Environment Audit (SHEA).* APS Group Scotland

Historic Environment Scotland (2018) *Scotland's Historic Environment Audit (SHEA).* APS Group Scotland

HM Government (2013) Construction 2025: Industrial Strategy: government and industry in partnership. Available at:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf (accessed 11/02/ 2016)

Hyslop, Ewan K. (2004) *The performance of replacement sandstone in the New Town of Edinburgh. Historic Scotland Research Report*. Historic Scotland. Edinburgh

Hyslop, E. K., McMillan, A. A., and Maxwell, I. (2006b) *Stone in Scotland. Earth Science Series.* Paris: UNESCO Publishing, International Association of Engineering Geology, Queen's Printer for Scotland, British Geological Survey.

Hughes, W.P., (2003) A comparison of two editions of the RIBA Plan of Work. *Engineering, Construction and Architectural Management*, *10*(5), pp.302-311.

Hughes J.J. (2012), RILEM TC 203-RHM: Repair mortars for historic masonry. The role of mortar in masonry: an introduction to requirements for the design of repair mortars. *Materials and Structures, 45, pp.1287–1294.*

Hutton and Rostron (1997) *Report: A Future for Stone in Scotland*. Historic Scotland. Edinburgh.

Ibem, E.O. and Laryea, S., (2014) Survey of digital technologies in procurement of construction projects. *Automation in Construction*, *46*, pp.11-21.

ICOMOS-ISCS (2008) *Illustrated glossary on stone deterioration patterns.* ICOMOS-International Documentation Centre, Paris, France

ICOMOS-ISCS (1993) *Guidelines for Education and training in the conservation of Monuments, Ensembles and Sites.* ICOMOS-International Documentation Centre, Paris. http://www.icomos.org/en/what-we-do/disseminating-knowledge/publicationall/179-articles-en-francais/ressources/charters-and-standards/187-guidelines-for-education-and-training-in-the-conservation-of-monuments-ensembles-and-sites

Infrastructure and Projects Authority (2016). UK Government Construction Strategy 2016–20

Institute of Historic Building Conservation (IHBC) (2014) Scotland's Local Authority Conservation Services First 'scoping' report: 2013, available at: http://www.ihbc.org.uk/news/docs/Scotland%27s%20Local%20Authority%20Conservation%20Services%20%20First%20%27Scoping%27%20Report%202013%20IHBC.pdf (accessed 11/10/ 2017)

Janvier-Badosa, S., Stefani, C., Brunetaud, X., Beck, K., De Luca, L. and Al-Mukhtar, M., (2015) Documentation and analysis of 3D mappings for monument diagnosys. In Built Heritage: Monitoring Conservation Management (pp. 347-357). Springer, Cham.

Jordan-Palomar, I., Tzortzopoulos, P., García-Valldecabres, J. and Pellicer, E., (2018) Protocol to Manage Heritage-Building Interventions Using Heritage Building Information Modelling (HBIM). Sustainability, 10(4), p.908.

Kagioglou, M. Cooper, R. Aouad, G. Hinks, J. Sexton, M. and Sheath, D. (1998) Generic Design and Construction Process Protocol: final report, The University of Salford.

Kagioglou, M., Cooper, R., Aouad, G. and Sexton, M., (2000). Rethinking construction: the generic design and construction process protocol. *Engineering, Construction and Architectural Management*, 7(2), pp.141-153.

Kahloun, F. and Ghannouchi, S.A., (2018) Improvement of Quality for Business Process Modeling Driven by Guidelines. *Procedia Computer Science*, *126*, pp.39-48.

Kayan, B.A., (2013) *Green maintenance for historic masonry buildings: a life cycle assessment approach* (Doctoral dissertation, Heriot-Watt University).

Kayan, B.A., (2015) Conservation plan and "green maintenance" from sustainable repair perspectives. *Smart and Sustainable Built Environment*, *4*(1), pp.25-44.

Kayan, B.A., Forster, A.M. and Banfill, P.F., 2016. Green Maintenance for historic masonry buildings: an option appraisal approach. *Smart and Sustainable Built Environment*, 5(2), pp.143-164.

Kayan, B.A., Halim, I.A. and Mahmud, N.S., (2017) Green maintenance for heritage buildings: low carbon repair appraisal approach on laterite stones. *Chemical Engineering Transactions*, 56, pp.337-342.

Kayan, B.A., (2019) Sustainable built heritage: maintenance management appraisal approach. *Journal of Cultural Heritage Management and Sustainable Development*.

Khan, S., (2016) Leadership in the digital age: A study on the effects of digitalisation on top management leadership.

Available at: http://www.diva-portal.org/smash/get/diva2:971518/FULLTEXT02 (accessed 24/04/2016)

Kim, C., Park, T., Lim, H. and Kim, H., (2013) On-site construction management using mobile computing technology. *Automation in construction*, *35*, pp.415-423.

Kissi, E., Ahadzie, D.K. and Badu, E., (2014) Constraints to the development of professional project management practices in the Ghanaian construction industry. *Journal of Construction Project Management and Innovation*, 4(1), pp.791-808.

Knight, J. (1995) *The repair of historic buildings in Scotland; advice on the principles and methods.* Edinburgh: Historic Scotland

Kordatos, E.Z., Exarchos, D.A., Stavrakos, C., Moropoulou, A. and Matikas, T.E., (2013) Infrared thermographic inspection of murals and characterization of degradation in historic monuments. *Construction and Building Materials*, *48*, pp.1261-1265.

Koskela, L. (1992). “Application of the New Production Philosophy to Construction”. Tech.Report No. 72, CIFE, Stanford Univ., CA

Koskela, L. and Howell, G.A. (2002). The theory of project management – problem and opportunity, VTT Research Note, VVT Technical Research Centre of Finland.

Koskela, L.J., (2008) *Which kind of science is construction management?.* In Proceedings for the 16th Annual Conference of the International Group for Lean Construction (pp. 51-60). The University of Salford.

Kolev, K., Tanskanen, P., Speciale, P., & Pollefeys, M. (2014) Turning mobile phones into 3D scanners. In Computer Vision and Pattern Recognition (CVPR), 2014 *IEEE Conference on (pp. 3946-3953). IEEE*

Kottke, J., Matero, F. and Hinchman, J., (2011) Terrestrial laser scanning: imaging, quantifying, and monitoring microscale surface deterioration of stone at heritage sites. *Change Over Time*, 1(2), pp.268-287.

Kuhn, T. H. (1996). The structure of scientific revolutions (3rd ed.). Chicago: University of Chicago Press.Kylili, A., Fokaides, P. A., Christou, P., and Kalogirou, S. A. (2014) *Infrared thermography (IRT) applications for building diagnostics: A review*. Applied Energy, 134, 531-549

Laing, R., Leon, M., Isaacs, J. and Georgiev, D., (2015) Scan to BIM: the development of a clear workflow for the incorporation of point clouds within a BIM environment. *WIT Transactions on The Built Environment*, *149*, pp.279-289.

Laing, R., Leon, M., Mahdjoubi, L. and J. Scott (2014) Integrating Rapid 3D Data Collection Techniques to Support BIM Design Decision Making, *Procedia Environmental Sciences, 22, 120-130.*

Laing, R. and Scott, J., (2011) 3D high-definition scanning: Data recording and virtual modelling of the built heritage. *Journal of Building Appraisal*, *6*(3-4), pp.201-211.

Latham, S.M., (1994) *Constructing the team*. London: HM Stationery Office.

Leitch Review of Skills (2006), *Prosperity for all in the global economy – world class skills.* H M Treasury

Levy, J. S. (2008) 'Case Studies: Types, Designs, and Logics of Inference', *Conflict Management and Peace Science*, 25, 1-18.

Liu, Z., Osmani, M., Demian, P. and Baldwin, A., (2015) A BIM-aided construction waste minimisation framework. *Automation in construction*, *59*, pp.1-23.

Lock, D., (2016) Project management in construction. Routledge. Abingdon, UK

Logothetis, S., Delinasiou, A., and Stylianidis, E. (2015). Building Information Modelling for Cultural Heritage; A review. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1, 177-183Loosemore, M., 2013. *Innovation, strategy and risk in construction: Turning serendipity into capability*. Routledge.

Loosemore, M., (2013) *Innovation, strategy and risk in construction: Turning serendipity into capability*. Routledge.

López, F.J., Lerones, P.M., Llamas, J., Gómez-García-Bermejo, J. and Zalama, E., (2018) June. Linking HBIM graphical and semantic information through the Getty AAT: Practical application to the Castle of Torrelobatón. *In IOP Conference Series: Materials Science and Engineering (*Vol. 364, No. 1, p. 012100). IOP Publishing.

Lor, P.J., (2017) International and comparative librarianship. In *Encyclopedia of library and information sciences* (pp. 2404-2412). CRC Press.

Lott, G. (2013) *The Sands of Time, Britain's Building Sandstones,* The Building Conservation Directory http://www.buildingconservation.com/articles

Love, P.E., Holt, G.D., Shen, L.Y., Li, H. and Irani, Z., (2002) Using systems dynamics to better understand change and rework in construction project management systems. *International journal of project management*, *20*(6), pp.425-436.

Love, P.E.D. and Bullen, P.A. (2009) Toward the sustainable adaption of existing facilities. *Facilities,* Vol. 27 No. 9, pp. 357-67.

Love, P.E., Edwards, D.J., Irani, Z. and Sharif, A., (2011) Participatory action research approach to public sector procurement selection. *Journal of Construction Engineering and Management*, *138*(3), pp.311-322.

Lourenço, P.B., Peña, F. and Amado, M., (2010) A document management system for the conservation of cultural heritage buildings. *International Journal of Architectural Heritage*, *5*(1), pp.101-121.

Lu, X., Clements-Croome, D., & Viljanen, M. (2010a). Integration of chaos theory and mathematical models in building simulation. Part I: Literature review. *Automation in Construction*, 19, 447–451.

Lu¨, X., Clements-Croome, D., & Viljanen, M. (2010b). Integration of chaos theory and mathematical models in building simulation. Part II: Conceptual frameworks. *Automation in Construction*, 19, 452–457.Lucko, G. and Rojas, E.M., (2009) Research validation: Challenges and opportunities in the construction domain. *Journal of construction engineering and management*, *136*(1), pp.127-135.

Maguire, M. and Delahunt, B., (2017) Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education*, *9*(3).

Mandelbrot, B., (2013) *Fractals and chaos: the Mandelbrot set and beyond*. Springer Science & Business Media. Berlin, Germany

Martínez-Molina, A., Tort-Ausina, I., Cho, S. and Vivancos, J.L., (2016) Energy efficiency and thermal comfort in historic buildings: A review. *Renewable and Sustainable Energy Reviews*, *61*, pp.70-85.

Maxwell, I. (2007) *Repointing Rubble Stonework*; *Inform Guide*. Historic Scotland. Edinburgh

Maierhofer, Ch.; Krankenhagen, R.; Röllig, M.; Schlichting, J.; Schiller, M.; Seidl, Th.; Mecke, R.; Kalisch, U.; Hennen, Ch.; Meinhardt, J. (2011) Investigating historic masonry structures with a combination of active thermography and 3D laser scanner. *Quant. Infrared. Thermogr. J. 8, 115–118*

Maintain our Heritage. (2004) *Putting it Off: How Lack of Maintenance Fails our Heritage,* Maintain our Heritage: Bath, UK. McCabe, S., (2014) *Quality improvement techniques in construction: principles and methods*. Routledge. Abingdon, UK

Megahed, N., (2015) Towards a theoretical framework for HBIM approach in historic preservation and management. *International Journal of Architectural Research: ArchNet-IJAR*, *9*(3), pp.130-147.

Meredith, J.R., Mantel Jr, S.J. and Shafer, S.M., (2017) *Project management: a managerial approach*. John Wiley & Sons.

Mihic, M., Sertic, J. and Zavrski, I., 2014. Integrated project delivery as integration between solution development and solution implementation. *Procedia-Social and Behavioral Sciences*, *119*, pp.557-565.

Mitka, B. and Pluta, M., (2016). COMPARATIVE ANALYSIS OF THE PROCESS OF CREATING A 3D MODEL OF ARCHITECTURE OBJECT WITH USING LASER SCANNING AND STRUCTURE FROM MOTION TECHNOLOGIES *Surveying Geology & mining Ecology Management*, 2, pp.847-854.

McGibbon, S. and Abdel-Wahab, M. (2016) Stonemasonry Skills Development: Two Case Studies of Historic Buildings Repair and Maintenance. *Structural Survey; Journal of Building Pathology and Refurbishment,Volume 34, Issue 3.*

Michiels, E. (2013) Monumentenwacht: an efficient preventive conservation strategy. *Presentation at Built Environment Forum Scotland Congress*, Linlithgow, Scotland .

Monumentenwacht Netherlands. (2000) *Prevention Better than Cure*, Amersfoot: Stichting Federatic Monumentenwacht Nederland.

Mukherjee, A., Hoare, D. and Hoare, J., (2000). Selection of Research Methodology for PhD Researchers Working with an Organisation. 18th Annual ARCOM Conference. University of Northumbria, England.

Munns, A.K. and Bjeirmi, B.F., (1996) The role of project management in achieving project success. *International journal of project management*, *14*(2), pp.81-87.

Murphy, M., McGovern, E., & Pavia, S. (2013). Historic Building Information Modelling–Adding intelligence to laser and image based surveys of European classical architecture. *ISPRS journal of photogrammetry and remote sensing, 76, 89-102.*

Myers, M.D., (2013) Qualitative research in business and management. Sage Publications, Thousand Oaks, CA: USA

Naoum, S.G., (2013) *Dissertation Research and Writing for Built Environment Students*.£rd Edition. Routledge. Abingdon, UK

National Heritage Training Group (NHTG) (2007) *Traditional building Skills-assessing the Need. Meeting the Challenge. Scotland.* NHTG, London

National Heritage Training Group (2008) *Built Heritage Sector Professionals: Current Skills,Future Training*, NHTG, London.

Natural Stone Institute (2005) *Building with Scottish stone*. Arcamedia, Edinbur

Neve, H.H., Wandahl, S., Kaeseler, S.M. and Tandrup, A., (2017) Integrating IPD and Exploring Potentials. In *33rd Annual ARCOM Conference Association of Researchers in Construction Management (ARCOM) Annual Conference* (pp. 154-163). Association of Researchers in Construction Management.

Nofera, W., Korkmaz, S., Miller, V.D. and Toole, T.M., (2011) Innovative features of integrated project delivery shaping project team communication. *In The 2011 Engineering Project Organizations Conference*. Estes Park, Colorado, USA.

Nowell, L.S., Norris, J.M., White, D.E. and Moules, N.J., (2017) Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*(1), p.1609406917733847.

Office for National Statistics (ONS) (2010) SOC 2010: The current Standard Occupational Classification for the UK, volumes 1-3, available at: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2010 (accessed 7/03/2016)

Odgers, D. and Henry, A. (2012), *English Heritage Practical Building Conservation, Stone*. Farnham: Ashgate Publishing Limited.

Ouimet, C., Gregg, J., Kretz, S., Chandler, C. and Hayes, J., 2015. Documentation and dissemination of the sculptural elements of Canada's Parliamentary Buildings: Methodology development and evolution, a case study. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *40*(5), p.347.

Oesterreich, T.D. and Teuteberg, F., (2016) Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, *83*, pp.121-139.

Oreni, D., Brumana, R., Della Torre, S., Banfi, F. and Previtali, M., (2014) Survey turned into HBIM: the restoration and the work involved concerning the Basilica di Collemaggio after the earthquake (L'Aquila). *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *2*(5), p.267.

Oses, N. and Dornaika, F., (2013) June. Image-based delineation of built heritage masonry for automatic classification. In *International Conference Image Analysis and Recognition* (pp. 782-789). Springer Berlin Heidelberg.

Pajares G. (2015) Overview and current status of remote sensing applications based on unmanned aerial vehicles (UAVs) Photogramm. Eng. Remote Sens. 81: 281-330 Crossref, Google Scholar.

Paoletti, D., Ambrosini, D., Sfarra, S., & Bisegna, F. (2013). *Preventive thermographic diagnosis of historical buildings for consolidation.* Journal of Cultural Heritage, 14(2), 116-121

Paolillo, W., Olson, B.V. and Straub, E., (2016) People centered innovation: Enabling lean integrated project delivery and disrupting the construction industry for a more sustainable future. *Journal of Construction Engineering*

PinsentMason, (2017) Collaborative-Construction: A critical review of the theory and practice of collaborative working in construction, available at:http://www.pinsentmasons.com/PDF/2016/Collaborative-Construction.pdf (accessed 20/11/2017)

Pomponi, F., Farr, E.R., Piroozfar, P. and Gates, J.R., (2015) Façade refurbishment of existing office buildings: do conventional energy-saving interventions always work?. *Journal of Building Engineering*, *3*, pp.135-143.

Popper, K., (2005) *The logic of scientific discovery*. Routledge. Abingdon, UK

Poole, P. N. (2010). *The Cost of Digitising Europe's Cultural Heritage A Report for the Comité des Sages of the European Commission.* http://nickpoole.org.uk/wp-content/uploads/2011/12/digiti_report.pdf accessed 1/11/2015

Project Management Institute (PMI) (2013) A Guide to the *PM* Body of *Knowledge*: PMBOK Guide (Fifth Edition). Project Management Institute, Pennsylvania, United StatesPurchase, W.R. (2009) *Modern Practical Masonry*. Donhead Publishing Ltd. Dorset

Quattrini, R., Malinverni, E.S., Clini, P., Nespeca, R. and Orlietti, E., (2015) From TLS to HBIM. High quality semantically-aware 3D modeling of complex architecture. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *40*(5), p.367.

Pye Tait Consulting Limited (Firm) (2013) *Skills needs analysis 2013 repair, maintenance and energy efficiency retrofit of traditional (pre-1919) buildings in England and Scotland*. English Heritage, Historic Scotland and Construction Industry Training Board, Harrogate.

Quattrini, R., Malinverni, E., Clini, P., Nespeca, R., & Orlietti, E. (2015). From Tls to Hbim. High Quality Semantically-Aware 3d Modeling of Complex Architecture. ISPRS

-*International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-5/W4. pp.367-374

Raadvad Bygningssyn. (2011) *Center for Building Conservation, Raadvad* (available at: http://www.bygningsbevaring.dk/) (accessed 24 July 2011).

Ramazani, J. and Jergeas, G., (2015) Project managers and the journey from good to great: The benefits of investment in project management training and education. *International Journal of Project Management*, *33*(1), pp.41-52.

Ranns, R.H.B. and Ranns, E.J., (2016) *Practical construction management*. Routledge. Abingdon, UK

Remondino, F., 2011. Heritage recording and 3D modeling with photogrammetry and 3D scanning. *Remote Sensing*, *3*(6), pp.1104-1138.

Rodwell, D., (2008). Conservation and sustainability in historic cities. John Wiley & Sons. New Jersey, USA.

Rohani, M., Fan, M. and Yu, C., (2014) Advanced visualization and simulation techniques for modern construction management. Indoor and Built Environment, 23(5), pp.665-674.

Rosemann, M. and vom Brocke, J., (2015) The six core elements of business process management. In *Handbook on business process management 1* (pp. 105-122). Springer, Berlin, Heidelberg.

Royal Institution of Chartered Surveyors (RICS) (2009) RICS Practice Standards, UK: Historic building conservation; RICS guidance note; 1st edition, available at: https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/building-surveying/historic-building-conservation-1st-edition-rics.pdf (accessed 08/02/2016)

Royal Institute of British Architects (RIBA) (2013) RIBA Plan of Work 2013. Newcastle, UK

Royal Institute of British Architects (RIBA) (2013) *Conservation: RIBA Plan of Work 2013*; Newcastle, UK

Russell, R., Ormerod, M. and Newton, R., (2018) The development of a design and construction process protocol to support the home modification process delivered by occupational therapists. *Journal of aging research*, *2018*.

Rye, C. and Scott, C., (2012) The SPAB research report 1. U-value report. Society for the Protection of Ancient Buildings: London, UK.

Sabrina, B., & Wärmländer, S. K. (2013). 3D laser scanning as a tool for Viking Age studies. *The First International Conference held at the State Hermitage Museum*; 4–6 June 2012; St. Petersburg, Russia (pp. 170-184).

Sala-i-Martín, X., Bilbao-Osorio, B., Blanke, J., Crotti, R., Hanouz, M. D., Geiger, T., and Ko, C. (2017). The Global Competitiveness Index 2017–2018, available at:

Saldaña, J., (2015) *The coding manual for qualitative researchers*. Sage Publications, Thousand Oaks, CA:USA

Saluja, C., (2009) A process mapping procedure for planning building information modelling (BIM) execution on a building construction project. Master Thesis, Pennsylvania State University, University Park, PA.

Sarhan, S. and Fox, A., (2013) Performance measurement in the UK construction industry and its role in supporting the application of lean construction concepts. *Construction Economics and Building*, 13(1), pp.23-35.

Saunders, M., Lewis P. and Thornhill, A. (2016). Research Methods for Business 5th Edition. Students. Financial Times Prentice Hall Inc., London.

Schweber, L. and Harty, C., 2010. Actors and objects: a socio-technical networks approach to technology uptake in the construction sector. *Construction Management and Economics*, *28*(6), pp.657-674.

Schöps, T., Sattler, T., Häne, C. and Pollefeys, M., (2015) *3D modeling on the go: Interactive 3D reconstruction of large-scale scenes on mobile devices.* In 2015 International Conference on 3D Vision (pp. 291-299). IEEE.

Scott, J., Laing, R., & Hogg, G. (2013) *Built Heritage Digitization: Opportunities Afforded by Emerging Cloud Based Applications.* Cloud Computing Technology and Science (CloudCom), 2013 IEEE 5th International Conference, pp.88-93.

Scottish Government (2014) *Historic Environment (Amendment) (Scotland) Act 2014* http://www.legislation.gov.uk/asp/2014/19/contents/enacted (accessed 27/10/2015)

Scottish Stone Liaison Group (2006) *Safeguarding Glasgow's Stone-Built Heritage: Skills and Material Requirements.* Scottish Stone Liaison Group, Charlestown, Fife at: https://www.scotborders.gov.uk/.../id/.../scottish_small_towns_report_2007-2013.pdf

Sexton, M. and Lu, S.L., (2009) The challenges of creating actionable knowledge: an action research perspective. *Construction Management and Economics*, *27*(7), pp.683-694.

Shaughnessy, L., (2015) Cataloging Built Heritage: Methods of Recording Unit Masonry for the Future of Historic Preservation. Master's Thesis, University of Pennsylvania.

Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J. & Xue, H. (2010) Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced Engineering Informatics*, 24(2), 196-207.

Shenhar, A.J. and Dvir, D., (2007) Reinventing project management: the diamond approach to successful growth and innovation. *Harvard Business Review Press*.

Shipley, R., Utz, S. and Parsons, M., (2006) Does adaptive reuse pay? A study of the business of building renovation in Ontario, Canada. *International Journal of Heritage Studies*, *12*(6), pp.505-520.

Smith K. D. and Tardif M., (2009) *Building Information Modeling: A strategic Implementation Guide*. Wiley, Hoboken, NJ.

Spodek, J., & Rosina, E. (2009). Application of infrared thermography to historic building investigation. *Journal of Architectural Conservation*, *15*(1), 65-81.

Snow, J. and Torney, C. (2015) *Lime Mortars in Traditional Buildings*, Short Guide. Edinburgh: Historic Scotland.

Smits, J. (2011) Application of 3D Terrestrial Laser Scanning to Map Building Surfaces, *Journal of Architectural Conservation*, 17:1, 81-94, DOI: 10.1080/13556207.2011.10785083

Smith, B.J., Curran, J.M., Warke, P.A., Adamson, C., Stelfox, D. and Savage, J., (2013) Stone-built heritage inventory and 'performance in use'condition assessment of stonework. *Quarterly Journal of Engineering Geology and Hydrogeology*, *46*(4), pp.391-404.

Stefani, C., Brunetaud, X., Janvier-Badosa, S., Beck, K., De Luca, L. and Al-Mukhtar, M., (2012) October. 3D information system for the digital documentation and the monitoring of stone alteration. In *Euro-Mediterranean Conference* (pp. 330-339). Springer Berlin Heidelberg.

Stefani, C., Brunetaud, X., Janvier-Badosa, S., Beck, K., De Luca, L. and Al-Mukhtar, M., (2014) Developing a toolkit for mapping and displaying stone alteration on a web-based documentation platform. *Journal of Cultural Heritage*, *15*(1), pp.1-9.

Stewart, D.W. and Shamdasani, P.N., (2014) *Focus groups: Theory and practice* (Vol. 20). Sage Publications, Thousand Oaks, CA:USA

Stroeker, N., & Vogels, R. (2012). Survey Report on Digitisation in European Cultural Heritage Institutions 2012. *ENUMERATE Thematic Network*.Sun, T., Grattan, K.T., Srinivasan, S., Basheer, P.A.M., Smith, B.J. and Viles, H.A., (2012) Building stone condition monitoring using specially designed compensated optical fiber humidity sensors. *IEEE Sensors Journal*, *12*(5), pp.1011-1017.

Sun, C., Jiang, F. and Jiang, S., (2013) Research on RFID applications in construction industry. *Journal of Networks*, *8*(5), pp.1221-1228.

Sustainable Traditional Buildings Alliance (STBA) (2012) *Responsible Retrofit of Traditional Buildings* http://www.sdfoundation.org.uk/downloads/RESPONSIBLERETROFIT_FINAL_20_SEPT_2012.pdf (accessed 27/10/2015)

Swallow, P., Jackson, S., Godfrey, J., Dallas, R., Westman, A. and Watt, D., (2016) Measurement and recording of historic buildings. Routledge. Abingdin, UK

Tangkawarow, I.R.H.T. and Waworuntu, J., (2016) A Comparative of business process modelling techniques. In *IOP Conference Series: Materials Science and Engineering* (Vol. 128, No. 1, p. 012010).

Tapponi, O., Kassem, M., Kelly, G., Dawood, N. and White, B., (2015) October. Renovation of heritage assets using BIM: a case study of the Durham Cathedral. In Proceedings of the 32nd CIB W78 Conference, Eindhoven, The Netherlands (pp. 27-29).

Taylor, J.E. and Jaselskis, E.J., (2009) Introduction to the special issue on research methodologies in construction engineering and management. *Journal of Construction Engineering and Management* Vol. 136, Issue 1

TBR 2016 Heritage Economic Impact Indicator. Trends Business Research Ltd available at: https://historicengland.org.uk/research/heritage-counts/heritage-and-the- economy/ (accessed 08/01/2016).

The Royal Academy of Engineering (2010) Engineering a low carbon built environment the discipline of Building Engineering Physics. *The Royal Academy of Engineering, London*

Thornton, G. (2018). Future of Europe: A Region in Recovery: Grant Thornton International Business Report, available at:https://www.grantthornton.global/en/insights/articles/future-of-europe-2017/(accessed 22/10/2018).

Torney,C, Forster,A.M, Kennedy, C.J., Hyslop,E.K. (2012),"Plastic" repair of natural stone in Scotland: perceptions and practice", *Structural Survey*, Vol. 30 Iss: 4 pp. 297 – 311

Torney, C., Forster, A.M. and Szadurski, E.M., (2014). Specialist ‘restoration mortars’ for stone elements: a comparison of the physical properties of two stone repair materials. *Heritage Science*, *2*(1), p.1.

Torney, C., Forster, A.M., Banfill, P.F. and Szadurski, E.M., (2015). The effects of site practice on the physical properties of proprietary stone restoration mortar. *Construction and Building Materials*, 75, pp.359-367.

Torney, C. and Hyslop, E.K. (2015), *Repair and Replacement of Stone Masonry in Traditional Buildings, Short Guide.* Edinburgh: Historic Scotland.

Torney, C., (2016). Proprietary Mortars for Masonry Repair: Developing a Predictive Framework for Assessing Compatibility. *SCIENCE AND ART: A FUTURE FOR STONE*, p.607.

Torrance, H., (2012) Triangulation, respondent validation, and democratic participation in mixed methods research. *Journal of mixed methods research*, *6*(2), pp.111-123.

Turner, R., Ledwith, A. and Kelly, J., (2009) Project management in small to medium-sized enterprises: A comparison between firms by size and industry, *International Journal of Managing Projects i*n Business, Vol. 2 Issue: 2, pp.282-296, https://doi.org/10.1108/17538370910949301

Turner, R., Ledwith, A. and Kelly, J., (2010) Project management in small to medium-sized enterprises: Matching processes to the nature of the firm. *International journal of project management*, 28(8), pp.744-755.

Turner, R., Ledwith, A. and Kelly, J., (2012) Project management in small to medium-sized enterprises: Tailoring the practices to the size of company. *Management Decision*, 50(5), pp.942-957.

Tzortzopoulos, P., Sexton, M. and Cooper, R., (2005) Process models implementation in the construction industry: a literature synthesis. *Engineering, Construction and Architectural Management*, *12*(5), pp.470-486.

United Nations Department of Economic and Social Affairs (2010) International Standard Industrial Classification of All Economic Activities (ISIC) available at: https://www.bundesbank.de/resource/blob/612626/067f5294c6df434ea4528bdb62551f9b/mL/isic-rev-4-data.pdf (accessed 08/01/2016).

United Nations Educational, Scientific and Cultural Organisation (UNESCO) (2015). *Contribution of UK's UNESCO designations to UK government policy.* UK National Commission for UNESCO Secretariat. London, United Kingdom.

Umar, U.A., Shafiq, N., Malakahmad, A., Nuruddin, M.F., Khamidi, M.F., Farhan, S.A. and Gardezi, S.S.S., 2015 4D BIM Application in AEC Industry: Impact on Integrated Project Delivery. *Research Journal of Applied Sciences, Engineering and Technology*, 10(5), pp.547-552.

Urquhart, D. (2008) *Natural Stone Masonry in Modern Scottish Construction: A guide for designers and constructors.* Scottish Stone Liaison Group, Charlestown, Fife

Vähä, P., Heikkilä, T., Kilpeläinen, P., Järviluoma, M. and Gambao, E., (2013) Extending automation of building construction—Survey on potential sensor technologies and robotic applications. *Automation in Construction*, *36*, pp.168-178.

Vaismoradi, M., Turunen, H. and Bondas, T., (2013) Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences*, 15(3), pp.398-405.

Valero, E., Adán, A. and Cerrada, C., (2015) Evolution of RFID applications in construction: A literature review. *Sensors*, *15*(7), pp.15988-16008.

Valero, E., Bosché, F. and Forster, A., (2018) Automatic segmentation of 3D point clouds of rubble masonry walls, and its application to building surveying, repair and maintenance. *Automation in Construction*, *96*, pp.29-39.

Vandesande A., Michiels E., Van Balen K. (2016) From a working definition of preventive and planned conservation towards the innovative services of Monumentenwacht Vlaanderen; *International Conference Preventive and Planned Conservation*; Monza-Mantua; 5-9 May 2014; p.25-34.

Vogl, B. and Abdel-Wahab, M., (2015) Measuring the construction industry's productivity performance: critique of international productivity comparisons at industry level. *Journal of construction engineering and management*, *141*(4), p.04014085.

Vogler-Ludwig, K., Gienalczyk, H., Stock, L. and Hogarth, T., (2012). International Approaches to the Development of Intermediate Level Skills and Apprenticeships: Synthesis Report.

Vokes, C. and Brennan, J. (2013) *Technology and Skills in the Construction Industry*. Rotherham: UKCES.

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings—Literature review and future needs. *Automation in Construction*, *38*, 109-127.

Vrijhoef, R., Koskela, L.J. and Howell, G., (2001) Understanding construction supply chains: an alternative interpretation. In *Proceedings of 9th International Group for Lean Construction Conference.* (pp. 185-199).

Vrijhoef, R. and Koskela, L.J., (2005) Revisiting the three peculiarities of production in construction. In *Proceedings of 13th International Group for Lean Construction Conference.* (pp. 19-27).

Yin, R.K., (2013) *Case study research: Design and methods*. 5th ed. Sage publications. Newbury Park, CA

Warland, E.G, (2006) *Modern Practical Masonry*. Donhead Publishing Ltd, Dorset

Walker, J..(2011) Rosslyn Chapel Educational Materials http://81.21.76.62/index.html?domain=learning.rosslynchapel.org.uk (accessed 11/11/2016)

Wan, X., Wang, W., Liu, J. and Tong, T., (2014). Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC medical research methodology*, *14*(1), p.135.

Westney, R., (2017) Computerized Management of Multiple Small Projects: Planning, Task and Resource Scheduling, Estimating, Design Optimization, and Project Control. Routledge.

Wilson, L., Rawlinson, A., Mitchell, D.S., McGregor, H.C. and Parsons, R., (2013) The Scottish Ten project: collaborative heritage documentation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *5*, p.W2.

Wolstenholme (2009) *Never Waste a Good Crisis: A Review of Progress since Rethinking Construction and Thoughts for Our Future*, Constructing Excellence, http://www.constructingexcellence.org.uk/pdf/Wolstenhome_Report_Oct_2009 (accessed 27/10/2015)

Worthing, D., Dann, N. and Bond, S. (2002) Issues in conservation management. *Proceedings of the CIB W070 2002 Global Symposium: Applying and Extending the Global Knowledge Base, Glasgow, 18-20 September*, CIB, Glasgow, pp. 292-302.

Worthing, D., Dann, N. and Hills, S. (2003) *Best practice in maintenance management for listed buildings.* Project Report. Maintain Our Heritage. Available at: http://eprints.uwe.ac.uk/14842 (accessed 08/02/2016)

Wu, W. and Issa, R., (2013) Integrated process mapping for BIM implementation in green building project delivery. In *Proceedings of the 13th international conference on construction application of virtual reality, London* (pp. 30-31).

Wynarczyk, P. and Watson, R., (2005) Firm growth and supply chain partnerships: An empirical analysis of UK SME subcontractors. *Small Business Economics*, *24*(1), pp.39-51.

Wynarczyk, P., Piperopoulos, P. and McAdam, M., (2013) Open innovation in small and medium-sized enterprises: An overview. *International Small Business Journal*, *31*(3), pp.240-255.

Wua, T. C., Linb, Y. C., Hsuc, M. F., Zhenga, N. W., & Chen, W. L. (2013). Improving Traditional Building Repair Construction Quality Using Historic Building Information Modeling Concept. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1(2), 691-694.

Xi, X., Wang, C., Wan, Y.P. and Khuon, K.N., (2015) Ta Keo Temple Reconstruction Based on Terrestrial Laser Scanning Technology. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *40*(5), p.449.

Yang, L.R., (2012) Implementation of project strategy to improve new product development performance. *International Journal of Project Management*, *30*(7), pp.760-770.

Yarrow, T. and Jones, S., (2014). 'Stone is stone': engagement and detachment in the craft of conservation masonry. *Journal of the Royal Anthropological Institute*, *20*(2), pp.256-275.

Yajing, D. and Cong, W., (2011) Research on the Building Information Model of the stone building for heritages conservation with the outer south gate of the Ta Keo Temple as an example. In *Electric Technology and Civil Engineering (ICETCE), 2011 International Conference on* (pp. 1488-1491). IEEE.

Yee, L.S., Saar, C.C., Yusof, A.M., Chuing, L.S. and Chong, H.Y., 2017. An Empirical Review of Integrated Project Delivery (IPD) System. *International Journal of Innovation, Management and Technology*, 8 (1), pp.1-8.

Zou, P.X., Sunindijo, R.Y. and Dainty, A.R., (2014) A mixed methods research design for bridging the gap between research and practice in construction safety. *Safety science*, 70, pp.316-326.

Zulch, B.G., (2014) Communication: The foundation of project management. *Procedia Technology*, 16, pp.1000-1009.

Appendix A: HWU Ethics Committee Application

HERIOT-WATT UNIVERSITY

APPLICATION TO SCHOOL ETHICS COMMITTEE FOR ETHICAL APPROVAL FOR A RESEARCH PROJECT

Click on the grey boxes to insert text

Section A: Project Overview

1. Project Title: The Development of a Structured and Holistic Integrated Project Delivery (IPD)-Based SME Process-Standard Framework to Support the Scottish Historic Building Repair and Maintenance (R&M) Sector.

2. Approval sought: Full approval ■ Re-Submission ☐ In principle ☐
If 'in principle', when will full approval be sought?

Contact Information

3. Responsible Staff Member / Supervisor of student research:
   a) Name .... Mohamed Abdel-Wahab
   b) Telephone 451 4428
   c) Email .... m.abdel-wahab@hw.ac.uk

4. Investigator (if different from Responsible Staff Member) / Student:
   a) Name .... Scott McGibbon
   b) Telephone 451 4652
   c) Email .... sm604@hw.ac.uk

5. Duration of Proposed Project .... 24 months

6. Anticipated Start Date: 30/08/2016

7. Does the proposed research involve human participants or living animals in any way? Yes ■ No ☐

Note: Involvement of human participants includes obtaining information from people through methods such as experiments, observation, surveys or interview, or any use of previously obtained personal data, or any use of human tissue samples.

If your answer to Question 7 is 'yes' complete the rest of the form; if it is 'no', simply sign the declaration in section F at the end of the form.

8. Please provide a brief summary of the proposed study (if possible, in less than 300 words. Include an overview of the design, variables, and other ethically-pertinent considerations). Feel free to attach a document if convenient.

With the need to address the challenges of delivering high quality R&M, tackling climate change, energy efficiency and sustainability, as well as overcoming the heritage skills shortage, the built heritage is further challenged to maximise the quality, efficiency and value for money from a project management perspective. There is currently no defined process available for quality repair and maintenance (R&M)in historic buildings which puts a particular focus on the performance and productivity aspects of workers. We believes that enhancing existing processes of R&M in historic buildings is imperative to successful delivery of high quality,sustainable and cost effective solutions.

The research will be predominantly qualitative in design; a multi-stage mixed method approach and consist of three components: (1) semi- structured hour long interviews will take place with selected individuals from key SME stakeholders in industry; (2) a demonstration project; (3)focus groups will also be conducted with key stakeholders from industry (contractors and consultants) supplemented with a Quantitative questionnaire regarding framework validation/evaluation. With the research being carried out in four stages with an on-going literature review the methodological strategy consists of the combination of the following methods: literature reviews, semi-structured in-depth interviews, framework development, case study and focus group validation/evaluation.

The information in the study records will be kept strictly confidential. For example, comments will be coded electronically and the data will be stripped of identifying information. Data will be stored securely and made available only to persons conducting the study unless we specifically give permission in writing to do otherwise. No reference will be made in oral or written reports that will identify the individual. Once the research is completed, the information will be destroyed.

Section B: Administration

	Yes	No
1. Will participants be appropriately informed of: the aims of the study; their ethical rights; their expected contribution; and their subsequent debrief? For example, their right to withdraw, any deception employed or potential consequences of the study.	■	☐
2. Will consent be obtained from all appropriate parties?	■	☐
3. Will the Heriot-Watt University Code of Practice governing recruitment of research participants be followed? (Code of Practice available at Code of Practice governing recruitment of research participants)	■	☐

Section C: Ethical Considerations

	Yes	No
1. Will the study require participants to potentially experience stressful or unpleasant situations?	☐	■
2. Will the data collection and management (storage & disposal) potentially compromise the interests of the participants? For example, body fluids, tissue samples or other personally identifiable materials, such as visual, auditory or other data?	☐	■
3. Will payment or non-payment of participants have potentially negative implications in the study?	☐	■
4. Are there potential negative outcomes from the study for the participant? For example, compromise to or damage of, their physical, psychological, financial or social wellbeing.	☐	■
5. Are there any other potential negative outcomes from the study? For example, damage to property or risk of criminal or civil liability.	☐	■
6. Would you identify any other issues that may have potential ethical implications for your study?	☐	■

If you responded 'No' to any questions in section B, or 'Yes' to any questions in section C, please now complete section D & E. Otherwise, proceed to section F.

Section D: Further Information Regarding Ethical Considerations

If you responded 'No' to any questions in section B, or 'Yes' to any questions in Section C, please provide further information, indicating how you would address this issue. Please be as comprehensive as possible, as this will speed the process for the referees and may avoid the need to contact you for further information or clarification.

Section E: Potential Referees (Optional)

If you have completed Section D, this form and any appended information will be reviewed by the full EGIS Ethics Sub-committee. In addition, if you think it may be helpful for the review, you can suggest up to two staff members with appropriate expertise to review the submission.

1. Name .... Contact ....
2. Name .... Contact ....

Section F: DECLARATION

The information in this form is accurate to the best of my knowledge

Signature of Responsible Staff Member (PI or research supervisor) ....
Date 16/08/2016

Signature of Student (if applicable) S.McGibbon
Date 16/08/2016

Once completed this form should be returned to the Research & Knowledge Exchange Team egis-research-admin@hw.ac.uk. If the form is completed for PGR student research, it must be returned to egis-pgr-students@hw.ac.uk. If the form is completed for MSc/MRes student research, it must be returned to the Learning & Teaching Team egis-pgt@hw.ac.uk.

APPROVAL OF SECTIONS A.8, B, C & D (if completed)
I am satisfied that the researcher has properly considered the ethical implications of the intended study and has taken the appropriate action.

(Chair of EGIS Ethics Sub-committee or delegated representative) ....
Date 24/11/16

FINAL APPROVAL
I am satisfied that the researcher has properly considered the ethical implications of the intended study and has taken the appropriate action.

(Head of School / Director of Research) ....
Date 2.12.16

Appendix B- Pilot Study Interviewee Guide & Participant Interview Consent Form

HERIOT WATT UNIVERSITY

A Common Structured Integrated Collaborative Digitised (CrO₂S) Framework Development for the Historic Building Repair and Maintenance (R&M) Sector.

PhD. Research Project

1st October 2015 – 1st October 2019

Scott McGibbon

What is the purpose of this research?
This research is a study of a new innovative PM process for the Historic Building Repair and Maintenance (R&M) Sector. This study will be based on current evidence of the key challenges, barriers and drivers facing modernising and enhancing existing R&M practice of historic buildings. Along with current evidence of construction process management frameworks use and digitisation trends within historic masonry R&M practice and along with demonstration project "live" case study within Scotland, and field interviews/focus groups with highly experienced industry practitioners. It is anticipated that from analyses of this data, that proposals for future approaches to enhancing historic building R&M project delivery and performance may be set forth.

The basis of this research is to address the increasing demand for high quality economical and sustainable historic building R&M along with addressing the perennial problem of skills shortages (PM-project management and on-site practice). Given that the majority of historic building R&M is delivered by Small–Medium sized Enterprises (SMEs) (professional and contractor level), particularly micro SMEs. An absence of specific guidance for carrying-out and managing on-site operations for SMEs exists, resulting in piecemeal and disjointed Project Management. Therefore, in order to reduce improper repair decisions and interventions as well as combat the lack of knowledge and information, there is an urgent need for a common process management framework for modernising practice, directing objective data capture, collection and dissemination that engages all relevant project stakeholders to aid successful project delivery. Digitisation trends (such as laser scanning, virtual reality (VR) and cloud-computing) have the potential to revolutionise R&M practice of historic buildings, hence thereis also a need to have \ a framework which supports the use of such tools. In effect a structured digital workflow that is aimed at supporting Integrated Project Delivery (IPD). It is anticipated that through this research that SMEs (consultants and contractors) can enhance a multi-disciplinary and collaborative approach for historic building repairs and future approaches to enhancing historic building R&M project performance and on-site productivity can be achieved and be mutually beneficial for all stakeholders.

What is your potential role within this study?
You have been identified as a potential interview subject due to your role as an experienced industry practitioner and it is desired that you share your experiences and opinions on the current conditions and future of the field. Your insight into the issues facing practice will assist the researcher in developing a common digitised framework. The four main themes that will be discussed are as follows;

- The first theme is aimed to collect information concerning the key challenges, barriers and drivers facing modernising and enhancing existing R&M practice of historic buildings in Scotland.
- The second theme will explore your opinions about project-specific challenges and the common issues and problems that may arise at each stage of the overall project delivery process, and on the basis of your responses, the issues identified will be categorised into groups for analysis.
- The third theme will explore your current awareness of structured construction process management frameworks in general and specifically, the RIBA Plan of Work, 2013, CIOB Code of Practice, BS 7913, HBIM.
- The fourth theme will explore your current Awareness and Understanding of Digital Technologies and Integrated Project Delivery implementation within the historic building R&M sector.

You will be asked a series of questions regarding your practice. This interview session will be recorded via audio to assist the researcher in transcription. You will be informed when audio recording will begin and end during the interview. This research will ask you to participate in an interview that may last several hours, depending on the information you which to contribute. You will have the option to complete the interview in one sitting or over multiple sessions. You may also elect to withdraw from the research at any time. Due to financial constraints, the researcher cannot offer any payment for the time you have dedicated to the interviews. The researcher will make every effort to travel to you to conduct the interviews. If this is not possible, interviews will be carried out via video conferencing.

It is important to note that since the field of historic building masonry R&M practice is limited, it will be difficult to guarantee anonymity of your interview responses. Although, during the dissemination of this data, your name and role within the sector will not be identified. If you have concerns about this aspect of the research, please communicate these concerns to the researcher. The interview questions and format within this study have been subject to Heriot Watt University ethical review process under the guidance of the Chair of the Ethical Committee; Dr James Richards (j.richards@hw.ac.uk). The approval of this format has followed the guidelines of the University as well as the School of Energy, Geoscience, Infrastructure and Society (EGIS) ethical guidelines under the guidance of the Professor Chris Leishman (c.leishman@hw.ac.uk). This approval was obtained on (02/12/2016)

What will happen with the information you provide?
The information you provide the researcher will be kept for ten years to comply with University guidelines. Transcripts of your interview session will also be included in the appendices of the final report. Your interview transcript may be used by future researchers to conduct further studies within the field. No personal data, as defined by the Data Protection Act of 1998, will be shared within the research. You may also request transcripts of your interviews at any time by contacting the researcher. Should you choose to withdraw from the research, you will be provided with a form from the researcher stating your desire to no longer participant in the research. The form should be signed and dated and returned to the researcher as soon as possible. Once documentation is received, all data collected will be removed from the study.

What steps are needed to participant?
If you choose the participant the researcher will provide you with a consent form which you will need to complete and return to the researcher. You will then be contacted for to confirm an interview time which will be convenient for you. Once the research is complete, you will be provided with a copy of the study.
If you have any further questions about the research, you may contact;
The School of Energy, Geoscience, Infrastructure and Society
Centre of Excellence in Sustainable Building Design
Heriot Watt University
Scott McGibbon: sm604@hw.ac.uk
Professor Ming Sun: m.sun@hw.ac.uk
Dr Alan Forster: a.m.forster@hw.ac.uk

Participant Interview Consent Form

Name (Please Print):

Date:

Please answer the questions listed below and sign and date at the end of the questionnaire in the space provided.

Yes ☐ No ☐ Have you read the information sheet provided by the researcher?

Yes ☐ No ☐ Have you had the opportunity to ask questions to the researcher regarding this study?

Yes ☐ No ☐ Do you understand that the structure and composition of this interview has been approved by the Heriot Watt EGIS Ethics Committee?

Yes ☐ No ☐ Do you understand that you have the ability to withdraw your participation from this research at any time?

Yes ☐ No ☐ Do you understand that you reserve to right to not answer any questions posed by the researcher if so desired?

Yes ☐ No ☐ Do you understand how the data collected during your interviews will be compiled and stored under the Data Protection Act of 1998?

Yes ☐ No ☐ Do you understand that you will retain to right to access the information gathered about yourself during this research?

Yes ☐ No ☐ Do you consent to be video and audio taped for the purpose of this research?

Yes ☐ No ☐ Do you consent to the use of any photographic images taken by the researcher of yourself and/or your facilities during the course of the interview?

Yes ☐ No ☐ Do you understand that you will be identified during the dissemination of the research outcomes and there is no guarantee of anonymity?

Yes ☐ No ☐ Do you understand that the information you provide may be cited by future researchers?

Yes ☐ No ☐ Do you agree to participate in this research?

Participant Date Researcher (Scott McGibbon) Date

Appendix C - Pilot Study Interview Guide

Interview Schedule: Introduce myself; describe the nature of the study. Its aims and scope.
Questions: No more than five open-ended questions
Ethics: Confidentiality and data security. Explain Analysis of findings and how their answers will be used in the study. Feedback available in Winter 2019.

Methods	*Questions*	*Objective*
Section A- General Back ground of respondent	*Name:* *Profession:* *Qualifications:* *Current Job Designation: What are your assigned duties?* *Years of experience within the historic building R&M industry:* *Can you provide a brief overview of your knowledge + expertise?:*	*Semi-structured Questions:* *No more than 5 open-ended questions* *Ask factual before opinion* *Use probes as needed*

Section 1- Identification of the key challenges, barriers and drivers	*Qualitative Central Question* *1.0 What are the key challenges, barriers and drivers facing modernising and enhancing existing R&M practice of historic buildings? First at an industry wide level then at a project specific level*	*1+2*
Prompts/ Procedural Sub-Questions:	*What is the impact of the key challenges, identified above, on the performance and productivity of historic building R&M projects? What causes these key challenges and barriers to exist?* *When do these key challenges and barriers become problem/ issues for your company?* *How can we overcome these challenges and barriers?*	*1+2*

Section 2- Identification of project-specific challenges-	*Qualitative Central Question* *2.0 How would describe the typical performance of historic building R&M projects you have been involved in, based on of your knowledge, expertise + responsibility?*	*1+2*
Prompts/ Procedural Sub-Questions: (Hint: very high; high; moderate, low; very low)	*Procedural Sub-Questions:* *What are the typical key stages in historic building R&M project delivery?* *How has the performance of these projects been in terms of the following factors?* *Time; Cost; Quality; Sustainability; Health and Safety; Communication/collaboration* *In your opinion, what are the key factors affecting the performance of historic building R&M projects? Please explain* *What are the common problems (management, people and technical) affecting these factors?*	*1+2*

Section 3- Investigation of current processes and practices and their efficacy.	*Qualitative Central Question* *3.0 What are your thoughts on the current processes and conventional practices used in historic building R&M projects delivery? Do you think that they are efficient? How often in the project processes and conventional practices do you repeat work and why?*	*2+3*
Prompts	*Procedural Sub-Questions:* *In your opinion, what are the key project stages processes and practices that can potentially affect project performance? Please explain* *Please tell me more about the project processes and conventional practices you have used and the types of data you captured + collected?*	*2+3*

	How do we improve current processes and conventional practices? *In your opinion is there a need for a more formalised structured approach to historic building R&M projects?* *How can each of the key factors identified in section 2.0 be effectively managed to enhance the performance and productivity of historic building R&M projects*	

Section 4- Awareness, influence, implementation barriers Identification of CPMFs;	*Qualitative Central Question* *3.0 Are you aware of these CPMFS, their definition, application, methods and benefits? (RIBA Plan of Work 2013, CIOB Code of Practice, CDM 2015, BS 7913, HBIM, BS 6079:1:2010 etc.).*	*1+2*
Prompts	*Procedural Sub-Questions:* *What are your thoughts on using such frameworks for efficient project delivery+ practice?* *Do the named work stages accurately reflect current industry practice?* *Are they clear, accurate and unambiguous?* *Do you apply any of these structured construction process management frameworks in your projects?* *What frameworks, tools, etc, would you recommend be useful and/or effective? Please provide a justification for your response?* *In your opinion is there a need for a more specific CPMF for historic building R&M projects?* *What recommendations do you have for future efforts such as these?*	*1+2*

Section 5- Awareness & understanding of Digital Technologies and innovative PM processes	*Qualitative Central Question* *5.1 What are your thoughts on new technologies (laser scanning, cloud computing etc..) + innovative PM processes (IPD, Lean etc..) being able to help address the key factors, identified previously,? To what extent?*	*1+2+3*
Prompts	*Procedural Sub-Questions:* *In your opinion, what are the key project stages that can potentially affect the use of digital technology in projects? Please explain* 1. *From your experience, how effective would implementing a digital workflow be in enhancing potential performance benefits?explain* 2. *What do you think are the key challenges, barriers, opportunities and drivers to using digital technology in projects?*	*1+2+3*

Appendix D: Case Study and Focus Group Questions

The Development of a Common Structured Integrated Collaborative Digitised *(CrOsS)* Framework to Support SME Historic Building Repair and Maintenance (R&M) Sector.

By

Scott McGibbon

Supervisors:

Assistant Professor Alan M.Forster &

Assistant Professor Fred Bosche

Centre of Excellence in Sustainable Building Design, School of Energy, Geo-Science, Infrastructure & Society

Demonstration Project Interview guide- Key Informants

Interview Schedule:

Interview Schedule: Introduce myself; describe the nature of the study. Its aims and scope.
Questions: No more than five open-ended questions
Ethics: Confidentiality and data security. Explain Analysis of findings and how their answers will be used in the study. Feedback available in Winter 2019.

Methods	*Questions*	*Objective*
Introduction Key Components:	*Describe the nature of the study. Its aims and scope.*	*Semi-structured Questions:* *No more than 5 open-ended questions* *Ask factual before opinion* *Use probes as needed*
Section A- General Back ground of respondent	*Name:* *Profession:* *Qualifications:* *Current Job Designation: What are your assigned duties?* *Years of experience within the historic building R&M industry:* *Can you provide a brief description of this project?*	

Methods	*Questions*	*Objective*
Section 1- Project challenges and management efficacy	*Qualitative Central Question* *1.0 What are the key challenges, and how is the efficacy of the management of existing processes and conventional practices for this project?*	*1+2+3*

Prompts/ Procedural Sub-Questions:	*Can you provide the following; the project funding mechanism the subsequent procurement route chosen; the project timescale (estimated and actual); the project cost (estimated and the final cost)?* *How would describe the performance of the current project you are involved in, based on of your knowledge, expertise + responsibility of previous historic building R&M projects, in terms of the following KPI factors?* *Time; Cost; Quality; Sustainability; Health and Safety; Communication/collaboration*	*1+2+3*

Framework Evaluation Section 1: General background information _Focus Groups

Methods	*Questions*	*Objective*
Section A- General Back ground of respondent	*Name: (optional)* *Email address: (optional)* *Profession/Current Job Designation:* *Please state if you belong to any professional membership (e.g. RIBA, CIOB, RICS, CABE, ICE, etc.)* *Qualifications:* *Years of experience within the historic building R&M industry:* *Please indicate the type of organisation you are working for;* *Years of experience within the historic building R&M industry: Can you provide a brief overview of your knowledge + expertise?:*	*Semi-structured Questions:* *No more than 5 open-ended questions* *Ask factual before opinion* *Use probes as needed*

Section 2- clarity and comprehensiveness Identification	*Qualitative Central Question* *2.0 What are your thoughts on the clarity and comprehensiveness of the overall framework?*	*4+5*
Prompts	*Procedural Sub-Questions:* *Please kindly comment on the practical relevance and suitability of the framework to the Process Improvement Framework for Historic Building R&M Projects in Scotland On-site Operations management.*	*4+5*

Section 3- Identification of the key benefits.	*Qualitative Central Question* *3.0 What are the main benefits of the framework implementation or what do you particularly like about the framework?*	*4+5*
Prompts	*Procedural Sub-Questions:* *3.1 Based on of your knowledge, expertise + responsibility of previous historic building R&M projects, do you believe the framework would be effective in response to project performance and productivity challenges enhancing potential performance benefits??*	*4+5*

Section 4- Identification of the key barriers	*Qualitative Central Question* *4.0 What are the main challenges and barriers of the framework implementation?*	*4+5*
Prompts	*Procedural Sub-Questions:* *4.1 How can we overcome these challenges and barriers?*	*4+5*

Section 5- Identification of key limitations and the key improvements needed	*Qualitative Central Question* *5.0 What are the main limitations and weaknesses of the framework implementation?* *5.1 What improvements would you suggest for the framework?*	*4+5*
Prompts	*Procedural Sub-Questions:* *What is your view on each of the specific guidelines/instructions for the application of each of the phases of the framework?*	*4+5*

Focus Group; The Framework Validation Questionnaire

Code Validation	Factors	1 Poor	2 Satisfactory	3 Fair	4 Good	5 Excellent
V1	How useful would you rate the overall Process Improvement framework for On-site Operations management for Historic Building R&M Projects in Scotland?					
V2	How easy would it be to follow the BPM process in the framework (clarity of the framework)?					
V3	To what extent, can following the framework help in implementing On-site Operations management for Historic Building R&M Projects?					
V4	How effectively can the framework facilitate the overall success of historic building R&M projects?					
V5	How effectively does the framework focus on project management issues relevant to historic building R&M projects?					
V6	How well does the framework establish links between the stages of historic building R&M projects?					
V7	How would you rate the applicability of the framework in historic building R&M projects?					
V8	How would you rate the logical structure of the framework?					
V9	How would you rate the comprehensiveness of the framework?					
V10	How useful would you consider the framework in decision making?					
V11	How useful would you consider the framework in improving performance and productivity among On-site Operations management for Historic Building R&M Projects?					

Appendix E

Structured Document Pro-formas

PRO-FORMA FOR FACADE CONDITION ASSESSMENT AND RECOMMENDATION OF INTERVENTIONS

Property Address:
Client's name: Date of inspection:
Surveyor's name: Weather conditions:
Status of the property: Occupied /Unoccupied

Site Location	Façade Surveyed

About the property

Use: Choose an item.		**Type:** Choose an item.		**Regulatory:** Choose an item.

No. of Façades inspected: Choose an item.		**Façade Orientation/Environment:** Choose an item.	**No.of storeys:** Choose an item.	
Brief Description of Façade + Digital image: 360° Site Layout+ Logistics: refer to VR app				

Stone Composition- Visual Description

Stone Composition	**Visual Description**	Digital image:
Colour:	Choose an item.	
Grain Size:	Choose an item.	
Texture:	Choose an item.	
Bedding Orientation:	Choose an item.	
Bed heights		

Introduction to the report

This Condition Report is produced by a …….. Ltd. surveyor who provides an objective opinion about the condition of the stonework at the time of the inspection. We inspect the outside of the main building and all permanent outbuildings, but we do not force or open up the fabric. The Inspection/Condition report (based on TAN 25 Maintenance and Repair of Cleaned Stone Buildings, British Standards Institute (2012) BS8210: Building Maintenance Management, Standard RICS format + Standard BGS format) aims to tell you about:

- The construction and condition of the stonework on the date it was inspected
- Any defects that need urgent attention or are serious
- Areas that need further investigation to prevent serious damage to the fabric of the building
- Defects or issues which may be hazardous to safety and where further enquiries are needed
- Any extra services we provide are not covered by these terms and conditions and must be covered by a separate contract

To help describe the condition of the stonework, we give condition ratings to the main parts (the 'elements') of the stonework. Some elements can be made up of several different architectural features. The stonework condition rating is based on and in accordance with British standards and Historic Environment Scotland guidance;

BS 7913:2013 - Guide to the conservation of historic buildings
http://conservation.historic-scotland.gov.uk/publications-catalogue-2015.pdf

The condition ratings are described as follows:

Defects that are serious and/or need to be repaired, replaced or investigated urgently. (Immediate)	3
Defects that need repairing or replacing but are not considered being either serious or urgent. (within 1-5 years)	2
No repair is currently needed. (not structurally or functionally necessary at present)	1
Not inspected (see 'Important note').	**NI**

▪ Important note:

We carry out only a visual inspection aided with the means of 3D laser scanning and digital photography. This means we do not carry out invasive investigations and only carry out non-destructive techniques. We inspect chimneys, cornices, bay windows and other elements and surfaces on the outside of the building from ground level and, if necessary, from neighbouring public property and with the help of binoculars. We are not able to assess the condition of the inside of any chimney or flues. Basement areas are inspected if they are reasonably accessible. We note in our report if we are not able to check any parts of the property that the inspection would normally cover. If we are concerned about these parts, the report will tell you about any further investigations that are needed. We do not report on the cost of any work to put right defects or make recommendations on how repairs should be carried out.

Existing Stonework Characteristics

- **Stone Features**

Masonry Type:		**Surface Finish:**		**Element detail:**		**Façade location**	**Image No.**
Choose an item.		Choose an item.		Choose an item.		Choose an item.	

Mortar detail:		**Finish:**		**Width of Joint:**		**Façade location:**	**Image No.**
Choose an item.		Choose an item.		Choose an item.		Choose an item.	

- **Existing Stonework Condition**

Previous episodes of repair or maintenance	**Façade location**	**Digital Image No.**
Choose an item.	Choose an item.	
Choose an item.	Choose an item.	
Choose an item.	Choose an item.	
Choose an item.	Choose an item.	
Choose an item.	Choose an item.	
Choose an item.	Choose an item.	

Stonework features	Condition	Façade location	Digital Image No.
Choose an item.	Choose an item.	Choose an item.	
Choose an item.	Choose an item.	Choose an item.	
Choose an item.	Choose an item.	Choose an item.	
Choose an item.	Choose an item.	Choose an item.	

- **Type of Stonework Decay**

Decay features;	Possible Causes of stone decay or damage:	Façade location:	Image No.
Choose an item.	Choose an item.	Choose an item.	

http://www.icomos.org/publications/monuments_and_sites/15/pdf/Monuments_and_Sites_15_ISCS_Glossary_Stone.pdf

Are any further non-destructive tests or Investigations necessary to establish stonework façade condition e.g. Infrared Thermographic analysis

Proposed Test type	✓/✗	Purpose
Choose an item.	Choose an item.	Choose an item.
Choose an item.		Choose an item.

- **Recommended Action + Priorities**

Recommended actions:	Urgent: 3	Essential: 2	Desirable: 1	Area/Amount	Façade location:	Image No.
Choose an item.	Choose an item.				Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Future façade maintenance						
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	
Choose an item.					Choose an item.	

Choose an item.					Choose an item.	
Choose an item.					Choose an item.	

- ***Compatible materials should be used -** It is essential to obtain representative samples of the stone to address the relevant problem. The sample taken must be truly typical and if there are apparent variations in the stone for example in colour, texture or type of weathering, wherever possible samples will be collected of each variation.

Samples taken from the site will be in accordance with;

- **British Standard BS EN 12407:2000 (Natural Stone Test Methods — Petrographic Examination)**
- **European Standard prEN 12670:1997.**

The standard price shown provided by British Geological Survey (BGS) - **£400.00 – 750.00 + vat** is for a report that describes a **single stone type**. Extra charges will apply for reports describing multiple samples of different stone types, additional thin sections or site visits.

Detailed Stonework Repair Survey/Schedule/Strategy

Full stone Replacement	***Stone index Description***	***Quantity***	***Dimensions: L x B x H (mm)***	***Area/Amount; m/m²/m³***	***Façade location: Image No.***
			Total (m³)		

Partial stone Replacement (Indent)	***Stone index Description***	***Quantity***	***Dimensions: L x B x H (mm)***	***Area/Amount; m/m²/m³***	***Façade location: Image No.***
			Total (m³)		

Stonework Repair	***Repair Description Element detail:***	***Quantity***	***Dimensions: L x B x H (mm)***	***Area/Amount; m/m²/m³***	***Façade location: Image No.***
Structural Repair					
			Total (m³)		

Stonework Repair	***Repair Description***	***Area/m²***	***Façade location: Image No.***
Mortar Replacement			
		Total (***m/m²***)	

Stonework Repair	***Repair Description***	***Area/Amount; m/m²/m³***	***Façade location: Image No.***
Plastic Repair			
		Total (***m/m²***/ m³)	

Detailed Repair Survey/Schedule

Window Repair	***Repair Description Element detail:***	***Quantity***	***Dimensions: L x B x H (mm)***	***Area/Amount m/m²/m***	***Façade location: Image No.***
			Total (m³)		

Roof Repair	***Repair Description Element detail:***	***Quantity***	***Area/Amount m/m²/m***	***Façade location: Image No.***
			Total (***m/m²***)	

Rainwater Goods Repair	***Repair Description Element detail:***	***Quantity***	***Area/Amount m/m²/m***	***Façade location: Image No.***
			Total (***m/m²***)	

Appendix E

Phase 1: On-site operations management plan template for historic building R&M Projects (Based on the principles of: CIOB, 2014; Griffith and Watson, 2004; PMI, 2008)

This explains how on-site operations management will be implemented for a particular historic building R&M project in Scotland focusing on how to approach, plan and implement all activities regarding on-site operations management. **Frequency of on-site operations management meetings and review of the project on-site operations**

Meetings for the purpose of discussing and making decisions on the project on-site operations are scheduled as: Weekly-Bi-weekly-Monthly--others

The on-site operations management identification, analysis, responses, review and monitoring process shall occur throughout the whole phases of the project life cycle. A full review and update of potential digital technologies for on-site operations will occur at the commencement of each successive phase of the project.

On-site operations identification Tools & Techniques

The historic building R&M project delivery team and project on-site operations management team should use any combination of: checklists, brainstorming, and historical data along with interviewing and consulting experts to identify potential digital technologies that might enhance the objectives of the project at its stage of development.

On-site operations analysis methods

Qualitative on-site operations analysis will be used to analyse the identified on-site operations affecting the performance of historic building R&M projects in Scotland

On-site operations reporting format

State how the outputs of the On-site operations management processes will be documented analysed and communicated. It explains the content and format of the on-site operations register as well as any other on-site operations reports needed. It also explains on-site operations related reports and their format that will be adopted to communicate the project on-site operations to the interested project stakeholders. It is recommended that a copy of on-site operations register template should be attached to the risk management plan.

On-site operations management plan

This document explains how on-site operations management will be structured and undertaken for historic building R&M Projects in Scotland. The on-site operations management plan consist of but not limited to defining: on-site operations management objectives, roles and responsibilities, process and procedure, frequency of review and reporting, budgeting, on-site operations categories, definitions of on-site operations digitisation possibility of occurrence and consequences, reporting format and tracking.

Project name:
Project ID:
Project Location:
Project Sponsor:
Main Contractor:
Consultant:
Project Manager:
Date:
Version:

On-site operations management plan approval

The signatories below confirmed they have reviewed the on-site operations management plan for the above named historic building R&M Projects in Scotland. Any amendments to this on-site operations management plan will be coordinated with and approved by the same signatories or their assigned representative. Project manager, project sponsor, contractor and consultant are recommended to be the authorised signatories.

Signature:	Signature:
Print Name:	Print Name:
Title:	Title:
Role:	Role:
Date:	Date:
Signature:	Signature:
Print Name:	Print Name:
Title:	Title:
Role:	Role:
Date:	Date:

On-site operations management objectives

On-site operations management encourages the project team to take suitable actions to:

- Decrease the negative impacts on project scope, cost, schedule and quality
- Exploit opportunities to utilise digital technologies to improve the project's objectives with lower cost, shorter duration, enhanced scope and higher quality
- Reduce management crisis

Roles and responsibilities

Roles and responsibilities of the historic building R&M project delivery team regarding on-site operations management planning, identification, analysis, responses strategies; review and monitoring will be explained in this section. The project managers, project delivery team members (including contractors, consultants & the client) and the project on-site operations manager should be involved in the on-site operations management activities.

Project on-site operations management roles and responsibilities

Roles	Responsibilities
Project Managers	▪ Integrate resources and time needed to implement the on-site operations management plan in the project budget and schedule ▪ Develop, communicate and implement on-site operations management plan ▪ Develop and update the on-site operation digitisation register with the support of the Project Team and integrate it into the work plan ▪ Ensure proactive response to all on-site operations management and digitisation opportunities that will impact the successful delivery of the project. ▪ Produce on-site operations management reports for project stakeholders ▪ Schedule and conduct project on-site operations management meetings. ▪ Monitor and update on-site operations management. ▪ Ensure quality of the on-site operations management data in the on-site operation digitisation register. ▪ Track and monitor the effectiveness of digital on-site operations management response actions. ▪ Recommend training on digital on-site operations management skills for project team as often as required
Project Delivery Team Member	▪ Identify the on-site operations and describe them (e.g., condition survey, stone replacement, etc.) ▪ Evaluate the possibility of digitisation occurrence & assign descriptive rating (very low, low, medium, high, very high) ▪ Evaluate the consequences of digitisation on project cost, time, quality, environmental sustainability and on-site operation management & assign descriptive rating as above ▪ Assist to identify on-site operation digitisation owner and develop on-site operation response strategies ▪ Document on-site operation response strategies and report to project manager for integration in on-site operation management updates. ▪ Communicate with project manager about newly-identified on-site operation, analysis, and decision.
Project on-site operations Manager	▪ Support the project manager to develops and updates the on-site operations management plan and the on-site operations register ▪ Promote and direct on-site operations management for the project. ▪ Schedule and conduct project on-site operations meetings ▪ Perform on-site operations monitoring and updating ▪ Ensure quality of the on-site operations data in the on-site operations Register ▪ Document on-site operations response actions ▪ Track and monitor the effectiveness of digitisation of on-site operations response actions ▪ Track and monitor the effectiveness of on-site operations response actions. ▪ Produce on-site operations management reports for the project manager ▪ Report to the project manager on all matters related to on-site operations management ▪ Compile the lessons learned in the area of on-site operations management

Processes and procedures

Tracking

Document how on-site operations activities will be recorded for the benefit of the current project as well as for future needs and lesson learned.

Budgeting

This section explains how to allocate resources, estimate funds required for the management of on-site operations by the project on-site operations management team.

On-site operations categories

On-site operations category provides a structure that ensures a comprehensive procedure of systematic on-site operations identification to a consistent level of details and contributes to the efficiency and quality of the identifying potential digital technologies process. On-site operations categorisation framework in form of a simple list of on-site operations categories or an on-site operation Work Breakdown Structure (WBS) can be used to describe on-site operations categories.

Appendix E - Phase 2: On-site operations site logistics plan template for historic building R&M Projects (Based on the prnciples of: CIOB, 2014; Griffith and Watson, 2004; PMI, 2008)

Site Logistics

Project: Client's name:

Date:

Site Location + Façade Surveyed

360° Site Layout+ Logistics

MATERIAL REQUIREMENTS

2.0 Identify the types and quantities of materials which will be required at all stages of the work programme and how they will be delivered. The information generated to complete section 2 should be linked to the On-site operations management plan (OPMP). The OPMP should detail the procedures of how to approach, plan and implement R&M management tasks for historic building R&M projects.

2.1. Each responsible person should complete the relevant sections of the following table based on the materials used in the project. The method of delivering the materials impacts on the three key reasons for generation of design waste (i.e. off cuts), construction process wastage (i.e. over-ordering, design and programme change, and damage). Justifications for contingency / wastage should include expected levels of wastage through actual use, accidental damage etc. Please duplicate the table for each person / work programme stage as required.

Completed By:								
Project Stage	Expected construction period	Materia l	Quantity	Delivery method & timings	Estimated Design & Construction Waste %	Design waste	Construction process wastage %	Supply route

Appendix E - Site Logistics Mobilisation Checklist

Phase 2; Phase 2 Integrated Project Set-Up: Site Setup/ Logistics Mobilisation Checklist template for historic building R&M Projects (Based on the principles of: CIOB, 2014; Griffith and Watson, 2004; PMI, 2008)

ACTIVITY DESCRIPTION	Required ✓	✗	Reference Docs.	Action by when	Action by whom
INITIAL SITE ORGANISATION					
Finalise site layout	✓			Complete	JK
Order site accommodation	✓			Complete	JK
Requisition furniture and stationery requirements		✗		Complete	JK
Obtain locations of existing services on / near site				Complete	JK
Arrange termination/diversion of existing services if required		✗		Complete	JK
Finalise hoarding layout and obtain licence				Complete	JK
Agree site signboard design with Client, obtain planning permission (if req'd) and requisition sign	✓			Complete	JK
Order site telephones, fax and B.T. lines				Complete	JK
Plan and order site computer equipment		✗		complete	JK
TEMPORARY WORKS, SERVICES and PLANT					
Obtain temporary electrical supply quotes and place orders				complete	JK
Obtain temporary water supply quotes and place orders				complete	JK
Order Hoist and obtain base details.				N/A	N/A
Finalise Temporary Works scheme.				complete	JK
Nominate Temporary Works Co-ordinator(s)				complete	JK
ADJACENT OWNERS and TENANTS MATTERS				complete	
Compile/agree Schedule of Pavement/Road Conditions using photographs and text or video as appropriate				complete	JK/BI
Compile/agree Schedule of Adjacent Properties Conditions using photographs and text or video as appropriate				complete	JK/BI
Contact adjacent Occupiers/Owners as appropriate				complete	JK
Obtain Party Wall Agreement and analyse requirements				complete	N/A
Check any Rights of Light/Rights of Way/ Tree Preservation Orders that may affect construction process				complete	JK

HEALTH and SAFETY MATTERS					
Prepare and agree construction phase health and safety management plan			H & S Operating Procedures	complete	JK
Complete items on H & S mobilisation checklist				complete	ALL
ENVIRONMENTAL MATTERS					
Complete items on Environmental Pre-Commencement Checklist				complete	JK
LOCAL AUTHORITY and POLICE MATTERS				complete	
Obtain planning consent and listed building consent and analyse for any matters affecting construction process				N/A	N/A
List emergency services/authorities contacts and telephone nos.				N/A	JK
Check requirement for archaeological work/attendance/monitoring				complete	JK
Agree temporary crossovers and street light/road sign/services relocation with local and statutory authorities. Obtain licence				complete	JK
Agree working proposals with Police and Highways Department				complete	JK
Arrange suspension of parking meters and pedestrian crossings				complete	JK
Confirm parking arrangements for staff and operations				complete	JK
SITE ESTABLISHMENT				complete	
Confirm scaffold schedule and erect. Obtain agreement as necessary from Local Authority and neighbours				complete	JK
Arrange delivery and erection of site accommodation, hoardings and gates				complete	DH/MF
Place requisition for early requirement of materials				complete	MF
Place requisition for initial requirement of plant and equipment				complete	MF

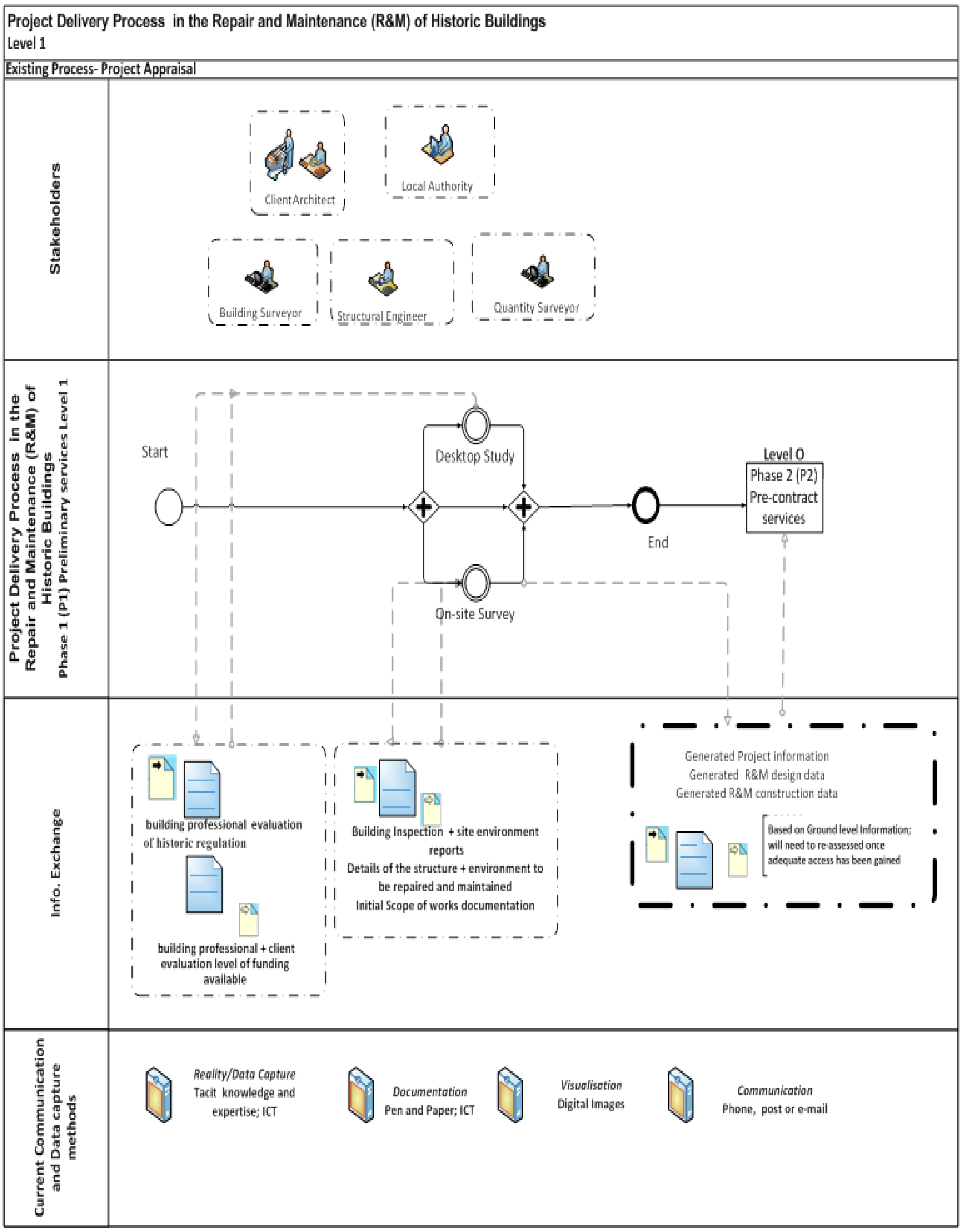
MANAGEMENT RECORDS and CONTROL DOCUMENTS					
Establish Risk Register				complete	MH
Prepare On-site operations Management Plan (OMP)				complete	JK
Start site diary, events file and labour records				complete	DH
Set up drawing registry and distribution system				complete	MH
Draw up outline construction programme, agree internally and issue externally				complete	BI/JK
Draw up outline procurement programme/schedule, agree internally and issue externally				complete	BI
Compile construction method statements				complete	Sub contractors
Draw up key subcontract programme, package list and contents schedule				complete	DB
Compile information required schedule, agree internally and issue externally				complete	MH
Obtain material samples and submit for approval				complete	MF
Compile material schedule and issue to Buying Department				complete	MF
Establish Digital Technology Equipment Log				complete	MF
Arrange Project Insurances, Warranties and Bonds				complete	DB
Set up meeting schedules and include in OMP				complete	JK
Set up internal project reviews and reporting structure and include in OMP				complete	JK
DESIGN MANAGEMENT AND CONTRACT DESIGN SUPPLEMENTS				complete	
Initial Meeting with Design Team, to establish or confirm: • Design brief and responsibilities • Information requirements Design output requirements				complete	MH

Appendix E - Phase 4; On-site operations QA Inspection checklist template for historic building R&M Projects

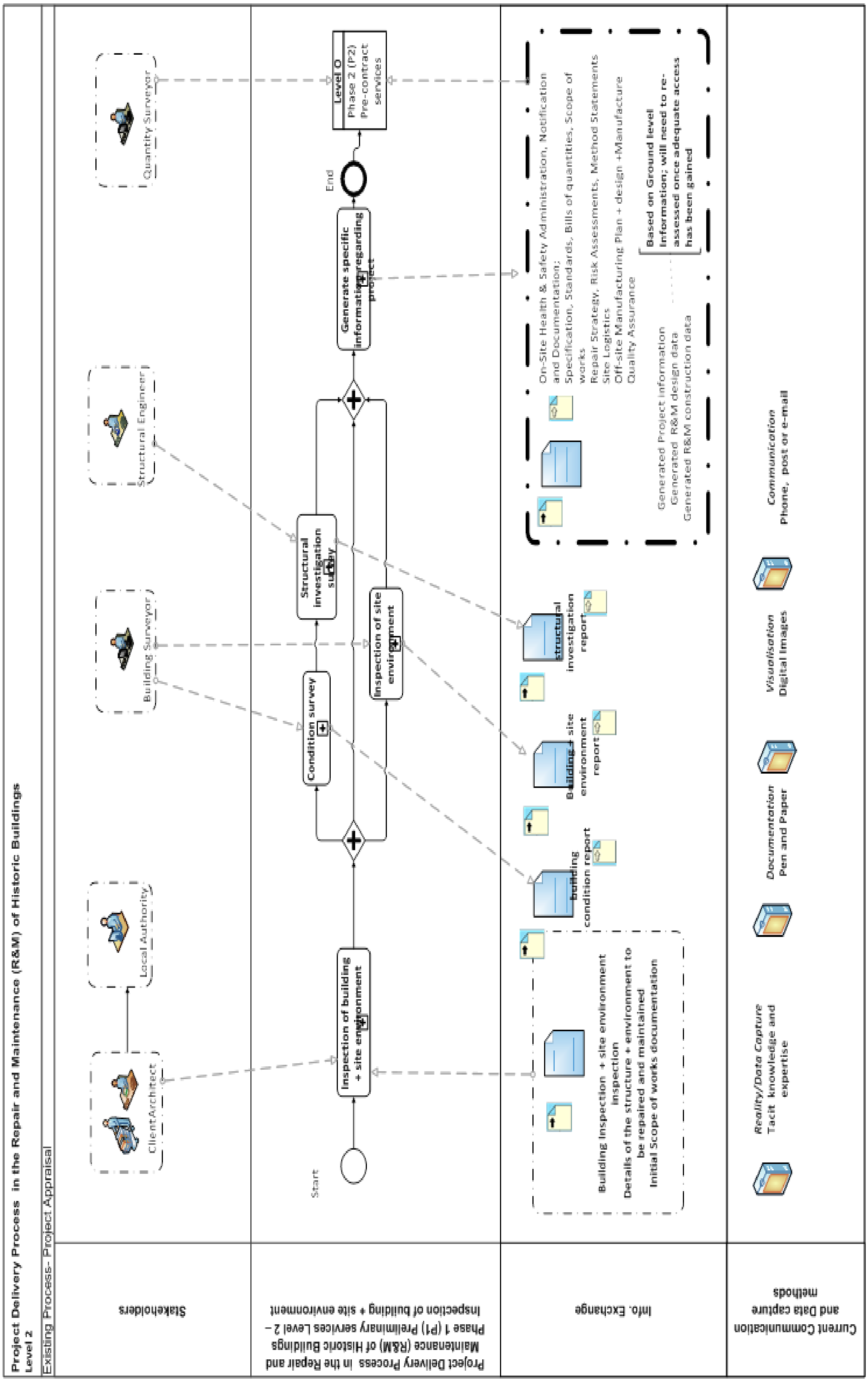
Full Stone Replacement Inspection checklist			
Project Details			
Project Name			
Area/Building		Date	
inspection: (Print name)			

Item	**Measurement of standard (examples)**	**✓/ X or**
Health and safety		
All relevant Job documents are available:	Safe Work Method Statements (SWMS), Risk Analysis, Material Safety Data Sheet for each product	
Personnel aware of the contents of the SWMS and are complying with its requirements for risk control	All employees: adhering to SWMS and have the appropriate PPE as specified by SWMS	
Electrical equipment and leads are free of damage **All machinery & equipment is in a safe and clean condition** **All guards are in place – where applicable**	Electrical equipment has been tested and tag date is within service period	
Working area has been isolated from public traffic: barricades/tape, etc	Clean at all times	
Emergency access/egress is clear and free from obstructions	Complies at all times	
Adequate first aid kits with appropriate contents are available	Complies at all times	
Work Package		
Measure area required for stone indent and check against stone replacement dimensions	±1 mm	
Remove damaged area to receive stone indent carefully	Compare with	
Cut out defective stones to full depth	±5 mm	
Prepare selected area to receive stone indent	Free from residual debris	
Build stone replacement using appropriate mortar as per spec.	Matching arrises between indent and existing stone; ±0.5 mm	
	Face true with existing stone	
	All joints and beds: ±1 mm	
	Point in mortar, leaving no voids, with correct finish	
	All staining is removed from surface area	
	Aftercare of mortar is completed	

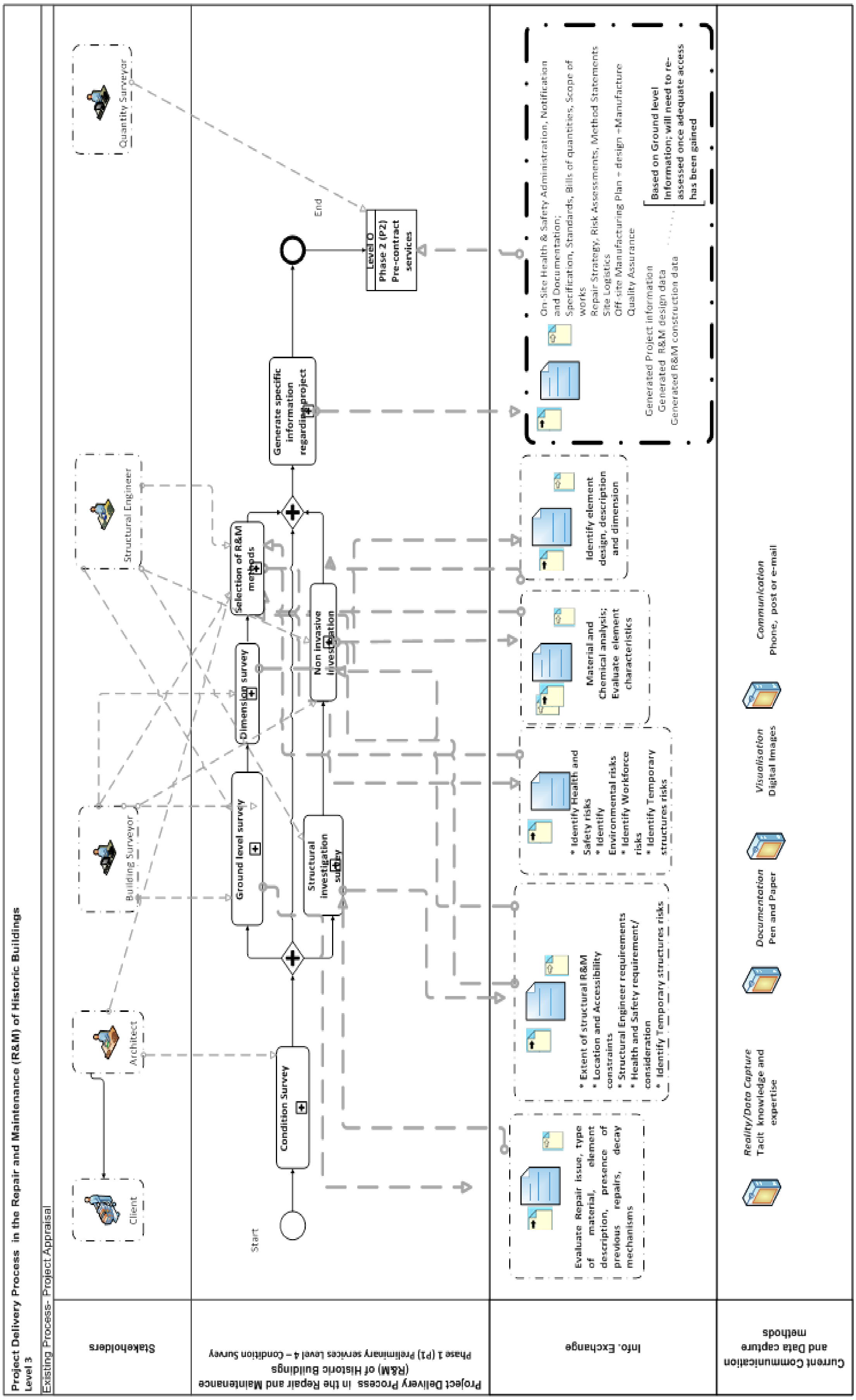
Appendix F- Phase 1: Process Map Levels 1-3



Project Appraisal Phase Level 1



Project Appraisal Phase Level 2



Project Appraisal Phase Level 3

Appendix G- Publications

G1: McGibbon, S., Abdel-Wahab, M., & Liang, Y. (2018). Digital surveying for historic buildings repair and maintenance: two demonstration projects from Scotland's built heritage. In *HERITAGE 2018. Proceedings of the 6th International Conference on Heritage and Sustainable Development Conference. vol. 1, Green Lines Institute, HERITAGE 2018 6th International Conference on Heritage and Sustainable Development, Granada, Spain, 12/06/18.*

http://heritage.greenlines-institute.org/sites/_conference_heritage/public/2018/books/H2018_BOOK%20OF%20ABSTRACTS.pdf

Digital surveying for historic buildings repair and maintenance: case studies from Scotland's built heritage

ABSTRACT:

Scotland's built heritage (pre-1919 residential and non-residential building stock) is exhibiting varying levels of disrepair caused by continual neglect and poor practice, in particular for stonemasonry works. The nature of historic buildings Repair and Maintenance (R&M) is increasingly complex and necessitates a multidisciplinary approach, yet current surveying practices tend to be ad-hoc and unstructured. This paper thus presents a demonstration of the application of Digital Surveying in the form of an e-Condition report whilst incorporating digital technologies, such as laser scanning and thermography- where appropriate.

Digital surveying (e-Condition report) provides a structured approach for capturing the real condition of historic buildings thereby informing timely and cost-effective repairs. We report on the application of digital surveying (e-condition reporting) on selected projects in Scotland; ranging from private housing to hotel to a school located across the central Strathclyde region, highlighting how it can facilitate multi-disciplinary collaboration for buildings' R&M and providing value for money to the client. We argue that our structured approach for digital surveying of historic buildings' is scalable whereby data analytics could be employed for informing timely repairs of historic buildings. Failure to provide timely repairs for buildings would endanger the historic value of Scotland's built heritage.

G2: McGibbon, S., Abdel-Wahab, M., & Sun, M. (2018). Towards a digitised process-wheel for historic building repair and maintenance projects in Scotland. *Journal of Cultural Heritage Management and Sustainable Development. DOI: 10.1108/JCHMSD-08-2017-0053*
https://www.emerald.com/insight/content/doi/10.1108/JCHMSD-08-2017-0053/full/html?skipTracking=true

Towards a digitised process-wheel for historic building repair and maintenance projects in Scotland.

Abstract

Purpose - With the increasing demand for high-quality economical and sustainable historic building repair and maintenance (R&M) allied with the perennial problem of skills shortages (project management (PM) and on-site practice) investment in new technologies becomes paramount for modernising training and practice. Yet, the historic

R&M industry, in particular small- and medium-sized enterprises have yet to benefit from digital technologies (such as laser scanning, virtual reality and cloud computing) which have the potential to enhance performance and productivity. The paper aims to discuss these issues.

Design/methodology/approach - A qualitative participatory action research approach was adopted. One demonstration project (Project A) exhibiting critical disrepair, showcasing the piloting of a five phased digitised "process-wheel" intended to provide a common framework for facilitating collaboration of project stakeholders thereby aiding successful project delivery is reported. Five semi-structured interviews were conducted with industry employers to facilitate the process-wheel concept development.

Findings - Implementing only Phase 1 of the digitised "process-wheel" (e-Condition surveying incorporating laser scanning) resulted in an estimated 25-30 per cent cost and time savings, when compared to conventional methods. The accrued benefits are twofold: provide a structured standardised data capturing approach that is shared in a common project repository amongst relevant stakeholders; inform the application of digital technologies to attain efficiencies across various phases of the process-wheel.

Originality/value - This paper has provided original and valuable information on the benefits of modernising R&M practice, highlighting the importance of continued investment in innovative processes and new technologies for historic building R&M to enhance existing practice and in form current training provision. Future work will focus on further piloting and validation of the process-wheel in its entirety on selected demonstration projects with a view of supporting the industry to digitise its workflows and going fully digital to realise optimum process efficiencies.

Keywords - SME, Stonemasonry, Repair and maintenance, Historic buildings, Digital workflow
Paper type - Research paper

Acknowledgements - The authors are grateful for McLaren Stone Ltd, for their continued support and collaboration on this project. The authors would also like to thank the interviewees from the following organisations: Heath Architects and Stone Consultants, Hutton Stone Ltd, Stoneworks Ltd, Frew Conservation, and CBC Ltd Finally, the authors would like to thank Hobs Studio Glasgow for contributing to this project via delivering the laser scanning application and 3D modelling applications. This project was partially funded through the Scottish Innovation Voucher scheme (which is co-funded by the Scottish Government and the European Development Fund).

G3: McGibbon, S. and Abdel-Wahab, M., (2016) Stonemasonry skills development: two case studies of historic buildings in Scotland. *Structural Survey, 34(3), pp.218-241*
https://www.emerald.com/insight/content/doi/10.1108/SS-03-2015-0016/full/html

Stonemasonry skills development: two case studies of historic buildings in Scotland

Abstract

Purpose – Scotland's built heritage (pre-1919 building stock) is exhibiting varying levels of disrepair, in particular for stonemasonry works, despite the government's on-going efforts for promoting higher standards of repair and maintenance (R&M) of historic

buildings. The purpose of this paper is to examine the problems associated with the R&M of historic buildings.

Design/methodology/approach – Two case studies (Projects A and B) exhibiting critical disrepair are reported. Site surveying was carried-out on both projects, to identify site features and R&M problems along with proposed solutions drawing on the lead author's extensive industry experience as a stonemasonry consultant. Three semi-structured interviews were conducted with professionals involved in each project to elicit views on the challenges faced. Additionally, three industry experts were interviewed to provide a wider perspective of the R&M challenges facing historic buildings.

Findings – Neglect and poor practice resulted in both projects becoming more challenging and expensive than they needed to be, which was attributed to generic and advanced skills 6deficiencies of the workforce. There is an urgent need for a multi-disciplinary approach to the development of a method statement for R&M, drawing on the expertise of professionals and contractors, particularly when specifying repairs to structural elements.

Originality/value – This paper has provided original and valuable information on R&M problems, highlighting the importance of continued investment in skills development for historic building R&M to enhance existing current training provision and practice. There is a need for further similar project-based data to inform skills development strategies for the R&M of historic buildings as well as enhancing existing qualification frameworks.

Keywords - Repair and maintenance, Historic building, Skills development, Stonemasonry
Paper type - Research paper

G4: McGibbon, S. and Abdel-Wahab, M., (2016) Emerging Digitisation Trends in Stonemasonry Practice. *Information Sciences*, *1*, pp.177-183.

https://myresearchspace.uws.ac.uk/ws/portalfiles/portal/397440/13th_ICDCS_Paisley_2016_VOL_I.pdf

Emerging Digitisation Trends in Stonemasonry Practice

Abstract

Stone forms a major component of Scotland's pre-1919 building stock. Current governmental policy and conservation guidelines stipulate that high quality repair and maintenance should be carried-out without compromising the building's historical features whilst minimising the impact on the natural environment and providing value for money.

Addressing these challenges requires investment in new technologies and calls for innovative practice. Therefore, this paper examines digitisation trends in the heritage sector, which includes: Terrestrial Laser Scanning (TLS), Infra-Red Thermography (IRT), and Historic Building Information Modelling (HBIM). Such trends have the potential to revolutionise stonemasonry practice of historic buildings by providing accurate site surveying and diagnosis of the building condition for informing the development of appropriate method statements for repairs. Moreover, these technologies can provide Quality Assurance to ensure that the repairs have been carried-out to the required standards. Raising awareness of the current digitisation trends is essential for

shaping and informing curriculum development in Further Education (FE) colleges. Demonstration projects thus become paramount for showcasing the application of digital technologies in a live project environment along with its accrued benefits.