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# Investigating the Synergy of Integrated Project Delivery and Building Information Modeling in the Conservation of the Architectural Heritage

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**ABSTRACT**

*Architectural heritage conservation projects are one of the most risky and complex projects in the construction industry. Many studies have reported frequent performance failures in terms of time, cost and quality. To implement a quality management in the conservation projects and enhance their performance; we propose the adoption of two emerging and innovative approaches: Integrated Project Delivery (IPD) and Building Information Modeling (BIM). Through an analysis of literature review (journals, white papers, norms and standards) on the subject, a comprehensive qualitative study in theoretical term has been carried out to define the potential advantages of the synergy between the BIM and IPD to face conservation issues and constraints through project lifecycle. Finally, we draw some general conclusions, summarize the implications for practice and set out recommendations for further research.*

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## 1. Introduction

Architectural heritage building is a complex system that embraces interlinked tangible and intangible values (Attenni et al., 2017). A worldwide awareness calls for the conservation of cultural heritage to preserve, enhance and integrate it harmoniously into the contemporary living environment; and ensure the development of cultural tourism (ICOMOS, 1999). Conservation project is a complex and sensitive approach required various skills and knowledge; In addition to the risky and uncertain nature of these projects, their fragmented and hierarchical delivering has affected project effectiveness; notably cost

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overruns and delays which are significantly higher in heritage conservation projects than in overall public works contracts (Guccio & Rizzo, 2010).

In this context; complex conservation projects require the adoption of emerging and innovative approaches, it needs more sophisticated project management models with flexible contracts to take care of the contingencies (Debopam & Satyanarayana, 2017); to enhance communication, collaboration and remove obstacles during project lifecycle. Recently, emerging digital technologies are dealing with digital document and interconnected Cultural Heritage information on a variety of delivery platforms, devices and environments; they are changing architectural heritage conservation in increasingly profound ways: functionalities, relationship and roles, to implement a quality approach and eliminate weaknesses in current project delivery systems.

In latest years, the BIM field has become a topic of great interest within the developed technology and methods notably 3D laser scanning and photogrammetry which generating 3D cultural heritage models (Logothetis et al., 2015; Dore & Murphy, 2012; Cheng et al., 2015). The power of BIM is their ability to integrate different skills, information throughout the entire project lifecycle (conceptualization and programming, survey, conservation, exploitation, maintenance). The BIM has a limited use by heritage professionals around the world (Historic England, 2017; Arayici et al., 2017); moreover a few academic researches explore the BIM added value in the management of heritage conservation project considering its whole aspects and process.

To turn into BIM in the construction industry is obviously a process of change not only in execution processes but also in functional capabilities and contractual agreements, it aims to provide better project delivery solutions (Migilinskasa et al., 2013; Hamdi & Leite 2014); nevertheless the fragment of traditional approaches and the fights for individual benefits goes against the collaborative atmosphere for BIM implementation.

Thus, integrated project delivery emerged as an innovative approach and relational alternative delivery methods based on collaborative decision making, shared values and common goals. It can effectively reduce inefficiencies and wastes that are embedded in the current design and practices of the construction industry (AIA, 2007; Kent & Becerik-Gerber, 2010; Azhara et al., 2014).

AIA (2007) indicates that the full potential benefits of both IPD and BIM are emphasized when they are used together; although it is possible to achieve IPD without BIM (Kent & Becerik-Gerber, 2010), many studies stated that BIM is essential to efficiently achieve the collaboration required for IPD.

Despite the complexity of architectural heritage conservation projects and the frequent failures of its management within traditional delivery methods, there is a total lack of research concerning the adoption of IPD in the conservation sector. In this research we intend to highlight theoretically the potential benefits of the synergy between the BIM and IPD to face conservation issues and constraints.

The rest of paper is structured as follows: Section 2 introduces some necessary concepts and definitions related to the architectural heritage conservation projects and highlights related works. Section 3 presents and reviews related works to Building Information Modeling. Section 4 presents the relationship between Building Information Modeling and heritage conservation project. Section 5 presents integrated project delivery and reviews some related works. Section 6 presents the link between IPD and BIM and depicts the benefits of the synergy between them. Section 7 is the core of the paper, it discusses and analyses the benefits of an integrated approach for managing heritage conservation projects based on the junction of IPD and BIM processes. Section 8 concludes the paper and gives prospects to be continued in the future.

Architectural heritage conservation is a dynamic intervention aims to bring out the hidden architectural qualities of heritage; to restore its state of conservation and ensure its sustainability; it takes place in complex contexts involving intricate interactions of multi-disciplinary fields; including architects, engineers, historians, archeologists, chemists, environmentalists, geologist, surveyors, craftsmen, building economist , structural, mechanical and electrical engineers , town planner and other specialists , the involving of the building owner or his representative with all this expertise which demands a high degree of experience, communication and knowledge of building materials and construction improve decision making (Harun, 2011). Unfortunately, literature showed that heritage conservation is fragmented (Azizi et al., 2015 ; Avrami et al., 2000; Smith, 2005; Ismail & Azlan, 2010; Perovic et al., 2016); and a different organizational cultures and philosophies ranging from

archaeologists/ architect (Kamal, 2008); the developer/ the preserver (Azizi et al., 2015).
Several authors mentioned that heritage conservation projects are one of the most risky, complexes and uncertain within the construction industry, they are often confronted by a number of issues which make management of these projects extremely challenging (Azizi et al., 2015). Each conservation project is view as a unique and non-duplicate, involves indeterminate scope, a large number of variation in quantity of work and change orders make during project execution because of unavailability of information about the original structure; and pre-existing and unforeseen site and/or building conditions identified late only once the work is started (Daoud, 1997; Mckim et al., 2000; Mitropoulos & Howell 2002; Zolkafli, 2012; Perovic et al., 2016; Roy & Kalidindi, 2017; Naaranoja & Uden, 2007). As a result cost overruns, delays, level of contingency allocation are significantly higher in heritage conservation projects (Guccio & Rizzo, 2010; Reyers & Mansfield, 2001).
Conservation legislation for historic buildings is not specific and inflexible. Numerous researchers highlighted that conservation work suffers because of unskilled personnel and limited technical knowledge due to the lack of documents and guidelines that defines the purpose of these projects and reflects upon the processes or a methodological recipe for managing it. (Azizi, 2015; Azizia et al., 2016; Barbosa et al., 2016; Worthing & Dann, 2000).

## 1. Building Information Modeling

The Building Information Modeling is defined as a set of interrelating policies, processes and technologies that generate a systematic approach for managing the critical information within a digital model, it enables all project participants to collaborate more accurately and efficiently than traditional processes forming a reliable basis for decisions throughout the life cycle of a building (Succar,2009; Azhar et al., 2012; NBIMS,2007). The first theoretical approache of BIM is mainly the 3D modeling using a computer tool; the term "Building Information Model" was used by Eastman for the first time in 1975. Later, the concept of 4D-modelling (3D + time factor) appeared in research discussion of Rischmoller et al, (2000) and the vision for the 3D to nD project was defined by Lee et al. in 2002 to integrate prototyping platform for the construction and engineering industries. However BIM was adopted in pilot project even mid-2000.

Recently, many cases studies have been adopted in research to define the potential advantages of BIM in construction projects covered operational, managerial, organizational, and strategic factors. Several reviews are highlighting the multiple potential benefits of using BIM environments for different type of projects, actually the term BIM has given rise to other terms like: Existing Buildings Information Modeling (EBIM); Historic/ Heritage Building Information Modeling (HBIM); City Information Modeling (CYM); Urban Information Modeling (UIM); and Green BIM. In spite of this evolution, BIM benefits are not really covered; the BIM implementation is still in its formative stage, and should continue to struggle to achieve lifecycle BIM uses (Shou et al., 2015).
BIM implementation has concerned different delivery environments, it acted as a catalyst for change, and as a result, it has received significant consideration in manuals, publications, standards and contracts. Today, the construction industry investigates the synergy between new approaches and BIM to bring other additional benefits of the technology and supporting its implementation; such as Lean (Sacks et al, 2010; Eastman et al. 2010); Agile method (Tomek & Kalinichuk, 2015), integrated project delivery (AIA California council, 2007).

## 2. Building Information Modeling in heritage conservation project

The BIM technology generates a new evolution of integrated and efficient information management for the conservation process due to its attitude to store semantic inter-related information, on favoring the dissemination of the intangible values of the building during its life cycle (Garagnani & Manferdini, 2013; Brumana et al., 2017; Angelini et al., 2017). The latest years, Numerous studies proposed a methodology for linking together Heritage-BIM and different digital technologies and simulation notably laser scanning and photogrammetry, for the presentation, analysis and document the complicated structures remotely, efficiently and precisely contrary with preceding survey techniques (Logothetis et al., 2015; Dore & Murphy, 2012; Cheng et al., 2015, Gigrliarelli et al., 2017). Zhao (2017) considered laser scanning as hot topics related to BIM research. It can be used to capture dense 3D measurements of a facility's as-built condition and the resulting point cloud can be manually processed to create an as-built BIM; Historic England (2017) defined Historic BIM as "a multi-disciplinary process that requires the input and collaboration of professionals with very different skillsets". Having access to an as-built heritage building facilitates interpretation of the nature of building, monitor its changes and document each investigation and intervention activity in the proposed model, it ensuring the availability, accessibility, consistency, coordination and coherence of all the knowledge related to a historical/archaeological artifact; which supporting the make interventions decisions. In (Simeone et al., 2014, Cheng et al., 2015) authors argued that the identification of emergency situations, the scheduling of intervention activities and the planning of routine management and maintenance artifact increase the productivity, profitability and accuracy of a project.

The application of BIM in conservation has given rise to other terms: Historic Building Information Modeling, Heritage Building Information Modeling, HBIM, BIM for heritage and BIM for historic buildings, they have been used almost interchangeably (Historic England, 2017).

The initial development of BIM in conservation project can be referred to the existing BIM experience from the building industry. The benefits of BIM for managing heritage conservation projects are not currently covered; a few published prototypes with limited use reports the significantly different requirements of BIM in these project (Angelini et al., 2017; Simeone et al., 2014; Arayici et al., 2017; Historic England, 2017).

## 3. Integrated Project Delivery

As the construction industry has become more complex, specialized, and uncertain, traditional project delivery methods become inefficient and litigious (Azhara et al., 2014; El adaway et al., 2017). Integrated project delivery emerges as a solution of the critical need of alternative relational contracts for reducing current inefficiencies and wastes of the construction industry and makes it more predictable, accurate and responsible outcomes (Matthews et al., 2003; Kent & Becerik-Gerber, 2010; Azhara et al., 2014).

Numerous published articles, reports, and white papers discuss the differences between traditional project delivery and IPD to help owners choosing appropriately for their projects. The traditional systems are hierarchical and fragmented, based classically on transactional bilateral agreement; focus on sub-optimization of project participants, a limited cooperation and innovation. In contrast, IPD is a relational multiparty agreement between a minimum of the owner, designer or engineer, and builder; it defines the connection point between subsystems and negotiates their interfaces; IPD is a convergence of opportunities brought about by technology and business process innovation, it requires a cultural and organizational change within new roles and competencies for achieving project purposes in a collaborative environment over the individual interest of each one, in an effort to mitigate risk (Autodesk, 2008; Taylor et al., 2012; Neve et al., 2017; El-adaway et al., 2017).

Neve et al. (2017) perceived IPD as a Virtual Enterprise Paradigm on incorporating the five elements of integrating an IPD project identified through the researches of Kim & Dossick (2011) and Fischer et al. (2017), i.e. contract, culture, organization, lean construction and BIM, which interrelate and enhance one another's effectiveness. IPD is not a 'one-size-fit-all' approach, different IPD integration levels are demonstrated, certain characteristics of a particular project or delivery model such as legislative restrictions, policy limitations or cultural barriers may affect the level of integration that can be achieved (AIA 2007; Yee et al., 2017; NASFA et al., 2010; Sive & Hays, 2009; Burcin Becerik et al., 2010).

Many researchers highlighted the advantages of IPD method through different case studies, analyzed for lessons learned and shortcomings of the current IPD practices and adoption; Although there is a large unexploited potential of IPD integration and its adoption is still limited and in its beginning (Yee et al., 2017; Shou et al., 2015; Azhar, 2014), more evidence needs to be searched to prove the fully adopt IPD as a project delivery method (Yee et al., 2017; Kent & Becerik-Gerber, 2010).

## 4. Building Information Modeling and Integrated Project Delivery

Much of BIM and IPD researches are indicating the several links and the benefits of their synergy. BIM is mentioned in almost all of the documents that discuss IPD; they point that integrated projects can greatly benefit from BIM implantation. However, IPD is suggested by researchers as the best project management method to leverage BIM functionalities.

### 6.1 The IPD joined to BIM

As mentioned above, the organizational changes required by BIM to implement it effectively are restricted by current contractual arrangements. The IPD seems to be a delivery method that could most effectively facilitate the adoption of BIM in construction project. The IPD team reaches a clear understanding regarding BIM and leverages the tool's capabilities; the IPD contracts is one of the most effective ways to deal with BIM technical and legal risks (AIA, 2007; Kent & Becerik-Gerber, 2010; Azhar, 2011). While BIM is used the most on IPD projects to a high level of sophistication, BIM or advanced information technology applications are not a prerequisite for IPD, nevertheless BIM is one of the key factors to accomplish effectively the integration required in one database to achieve better decision-making during the IPD project lifecycle (Kent & Becerik-Gerber, 2010; Xie & Liu, 2017); moreover, it can present an important role to leverage the potential advantages of Lean principals (Sacks et al., 2010; & Eastman et al., 2010), and adds major value for IPD public owners in the exploitation phase (NASFA et al., 2010).

### 6.2 The potential advantages of the synergy BIM/IPD

The successfully implementation of BIM / IPD system is a mechanism for involving all key participants for optimal results (AIA, 2007; Ilozor & Kelly, 2012), the instruction of participants over their roles and responsibilities takes an important place to successfully implement these two innovative approaches (Shendkar & Patil, 2017); it could significantly increase a collaborative supply chain management (Khalfan et al., 2015); enhancing proper communication, collaboration among stakeholder, reduces the confusion between them, supporting decision making process; therefore assuring cost and time optimization (Ilozor & Kelly, 2012; Shendkar & Patil, 2017); reduce the risk of design errors and omissions (Xie & Liu, 2017). Even though, many researches identify the need to verify this synergy through quantitative studies and in the different type of project.

## 5. Discussion and analyses

Project complexity is one of the key characteristics that should be considered in the selection of the appropriate project delivery strategy by an organization; the complexity of conservation projects which are pluridisciplinary, uncertain and risky may achieving the benefits of deep collaboration generated by the BIM environment and IPD contract. This section discusses and investigates the benefits of using BIM in conjunction with IPD to provide solutions to the problems faced by the project team on managing the conservation of architectural heritage.

### 7.1 The conceptualization and the programming phase:

Starting from the beginning of the project, the early involved key participants through a Multi-Party Contract Agreement may define and synchronize earlier participant roles and responsibilities, jointly developed and validated projects objectives and obtain more inputs. The subcontractors and heritage consultants can be brought into the IPD agreement by flow-through provisions in their respective agreements with the contractor and the conservator architect, or can be included in the IPD agreement by "joining agreement" amendments. In this phase, Laser scanners can be used to create an as-built BIM; a primary investigation for the building is established to determine its values, problems, define goals and choose the appropriate type of intervention depending on its condition. If the building is severely damaged, an emergency protection system is considered in the modeling building/site. Preventive measures have to be designed before the initiation of restoration works in order to prevent further damages and enhance safety conditions during the process of examination and have to be applied by the contractor earlier by implementing lean tools.

The schedule and budget will be estimated based on organization's business case and may be linked to the BIM Model to enable rapid assessment of intervention decisions. The IPD contract must respect the specific conservation funding and guidelines, identify the appropriate organizational and business models, consider interests and seek involvement of selected third parties, such as building official(s), local heritage field organizations, associations of the protection of cultural heritage, and other stakeholders. It may identify key communication methodologies, materials, tools and technologies; such laser scanning and photogrammetry; plan the implementation of BIM and facing interoperability issues (protocols and standards, BIM management plan, etc.). Key provisions, regarding compensation, obligation and risk allocation which are due to uncertainties and unforeseen conditions, should be clearly defined and should encourage trust, open communication and collaboration.

**7.2 The survey phase:**

Professionals from different expertise and interests involve earlier at the appropriate time in this phase which is the key point of the conservation project to establish a detailed survey with great sensitivity, a global and detailed approach to the building starts to identify its problems, so as to preserve and valorize the rare qualities of the buildings materials, architecture and craftsmanship. The contract may contain specifics sections about responsibilities, material and technologies used in the building examination. The 3D model generated by the 3D laser scanner involves a hybrid approach to visualization of heterogeneous datasets; due to its structural, physical, historical and cultural complexity including tangible and intangible values; through a reverse engineering and analysis of existing conditions; each investigation are documented in the as-built BIM, where a massive quantity and stores semantic inter-related information are represented as well as external documents, it integrates of geometric and non-geometric datasets (historic information, photographs and drawings, legacy data, geospatial geophysics and remotely sensed data, etc.)

**7.3 The design phase:**

During the design phase, an interdisciplinary collaboration/integration between the fields, arts, and technologies of conservation generates and evaluates various design alternatives at an early stage using integration platforms; the BIM model allows to test scenarios for analysis of virtual proposed interventions and determine what the team will accomplish, simplify the task of understanding designs to help client deal with this complex product and a conservation code regulations will be incorporated into the design process. Intervention decisions are made at an early stages where informed decisions have the greatest effect focusing on "best for project" basis, In IPD the team develop a commitment to the overall project, not just to their individual component, based on open, direct, and honest communication, ideas are judged on their merits, not on the author's role or status; which reduce the differences between engineers/architects, archaeologists/architects, developers/ preservers; and augmented opportunities for innovation and improvement; however, detailed decision process and ultimate authority of the participants varies significantly depend on needs of specific projects and participants; clients or end-users are engaged in simultaneous reviews of different scenarios, due to the digital representation they can more easily identify conflicts between their requirements and the proposed systems will provide. The selected alternative may has both minimum effects on heritage values and is most efficient; this is arguably more important in the case of significant historic assets, where any change in the historic fabric must be carefully considered and justified, the broad experience of the diverse team benefits target value design.

A BIM database that integrates all existing construction interface-related information of subsystems (interface events, interface descriptions, and interface conditions) defined by the collaborative work, and makes verification and validation of the design more efficient with an automated clash-checking to solve interface problems, thereby eliminating unnecessary mistakes and delay at site. Visualization of building model is tied to cost and schedule models, they are better informed due to collaborative approach, to perform based clash detection in addition to the traditional static clash detection, and commitments to them are more firm to allow visualization of deviations from planned sequences and earned values.

All these approaches provide an opportunity to perform precisely and efficiently the environmental performance analyses and sustainability-enhancement measures on delivering modeling protocols contributing guideline and specification to support the LCM across time and reduce life cycle cost of operating heritage building; in addition, the team work provides an opportunity to share knowledge, embrace learning for the repair and maintenance of historic architecture and traditional techniques and augment cultural consciousness.

**7.4 The construction phase:**

During construction phase, construction administration will be primarily a quality control and cost monitoring function, unlike traditional project where issues are addressed and solutions achieved to actual real-life problems; because of the higher intensity of preceding phases where an efficient information management has provided between the involved participants and conflicts have been resolved virtually; it enables a better understanding of design intent so RFIs are fewer required during the intervention stage. The BIM model maybe used to augment, manage and enhance the RFI process, less office construction administration effort is required because submittals have already been integrated into the model; enable more strategic use of prefabricated materials and systems to speed construction, less waste and injuries because work is being performed in a controlled environment and more material is factory generated, in addition, modeling the site environment after a collaborative reviews between parties before starting work helps plan logistics, assure good access and egress, and gain control of public protection risks.

Communication between professionals and craftsmen and general laborers enhance understanding of scope of work; nevertheless, the fact that scope definition is often uncertain, inaccurate and new information surfaced during the process of restoration works may affect the original restoration decisions necessitates the continuum of emergency measures even during the application process. In IPD project Work can be organized in small batches to reduce variability and increase the reliability of planning and scheduling of work; BIM advantages presented on an adjusted model based on “as built” conditions, automated quantity take off which is linked to the BIM model improves flow by reducing variability and ensures that the quantities are always accurate when changing the design at a later stage; the online access helps to bring the most up-to-date design information to the work face.

In traditional approach, each party minimizes their own risk, and most of risks are usually transferred to the contractor in most cases; IPD contracts combine the risks of all team members. Contractual provisions in the IPD agreement regarding liability waivers motivated to seek solutions to the increased risks and uncertainties problems in conservation operation rather than assigning blame; increase communication and creativity; reduce litigation costs and limit unnecessary contingencies; in addition the division of project contingency into many smaller allocations impairs effective contingency management.

### 7.5 The exploitation phase:

After the intervention is completed, the BIM model can be used to compare actual to planned performance; it will be the basis for the monitoring, management and routine maintenance of the building. The IPD team brings more facility management expertise into the process; a complete building information model will be integrated into the building operating system and provided to the owner for their long term use, the BIMFM system allows facility staffs effectively to identify, track, coordinate, and access facility maintenance work in the 3D environment and used for asset management. However the interoperability provides a potential for interfacing with other enterprise systems such as CMMS, CAFM.

The 3D virtual heritage model opens a wide spectrum of further applications (sharing for education, research, entertainment, tourism purposes, etc.); in addition offers a way to transmit knowledge about heritage places to future generations.

## 8. Conclusion

This paper has presented a broad overview of the potential advantages of the implementation of integrated project delivery as a delivery method and the implementation of building information modeling in heritage conservation projects. The successfully implementation of BIM / IPD system can deliver efficiency conservation projects and enhance its performance. It is a mechanism for involving all key participants for optimal results where integrate different skills, information and various stages throughout the entire lifecycle of the conservation project (conceptualization and programming, survey, conservation, exploitation, maintenance) to involves the sharing of data-rich 3D models among stakeholder, reduces the confusion between them, enhancing proper communication, collaboration, and supporting decision making process, minimizing risks, and uncertainties, therefore assuring cost and time optimization on eliminating wastes. It is expected that this paper could contribute some benefits to the owners to choose the appropriately method and process to achieving a conservation project of heritage building. Further research is required to discuss the feasibility and the practicability of related concepts to successfully implement BIM / IPD in architectural heritage conservation projects; notably, how certain characteristics of such particular project may affect the level of integration that can be achieved, and what adds to a standard BIM and IPD contract in this context. It recommended to proven the theory by implementing it on some projects. Moreover; it is necessary to identify the potential synergy BIM /IPD in each type of conservation project separately.

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