

# Comparative analysis of critical factors for BIM adoption in airport

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**Abstract.** Through the review and summary of the previous study, it is found that the construction industry has many inherent problems, and at the same time, with the impact of the coronavirus epidemic swept the world, the intrinsic problems within the construction industry are more prominent, so it is time for the construction industry to apply new technologies to solve the increasingly prominent problems, and BIM technology as an innovative technology that has been widely used in construction industry recent years, the benefits it brings to construction projects are still being explored, but It is found that BIM technology can be applied not only to construction projects, but also to infrastructure projects, so it is also applicable to airport projects, which belong to infrastructure construction. This research summarized a template of BIM roadmap for airport project facilities over the full life cycle, investigated the universal benefits and barriers among case reviews. Provides suggestion to BIM practitioners who confronts barriers for a better BIM implementation effect.

**Keywords:** BIM adoption strategy, airport, project management, infrastructure.

## 1. Introduction

Research indicates that the new digital technology has not embraced by construction industry, while construction industry with agricultural industry is still among the least digitalization level, although the long-term benefits are significant [1]. Due to the slow pace of adoption new technology in construction industry, the intrinsic problem exists in the construction process of project is the project cost and schedule overrun [1-2], which last for decades and still cannot be solved. What is more, the Coronavirus pandemic impacts has swept the globe, a decline in the economy and business interruption phenomenon happened in construction industry [3-4], the action required to response impacts caused by pandemic to ensure the continuity of safe and productive construction operations. Thus, with all challenges mentioned above, building information modeling (BIM) has been gaining immense adoption in the AECO industry, with the function of innovative business process that uses digital data to manage the entire lifecycle of a building, from design and construction to operation phases, enables all parties involved (e.g. architects, engineers, contractors) to access and share the same information, utilizing technology that allows for seamless communication and collaboration without limitation of space and time. Also, with the building information management function of using digital prototypes to manage and control the asset lifecycle process, including centralized and visual communication, exploration of options, sustainability, efficient design, integration of disciplines,

site control, as-built documentation, etc. It helps to develop an asset lifecycle process and model from conception to retirement [5].

## **2. Literature Review& Research Motivation**

Infrastructure is defined as “the basic physical and organizational structures and means that are necessary for the operation of a society or enterprise” [6], The infrastructure project can be broken into five domains: transportation, energy, utility, recreational facilities and environmental [7]. The infrastructure project has the characteristic of complex, politically sensitive and economically uncertain [8]. The concept of smart infrastructure comes out, its use of real-time information and the integration of urban form are examples of how this concept is applied. Additionally, smart infrastructure includes cost-effective, efficient, adequate, and equitable multi-modal transport networks that promote sustainability for the movement of people, goods, and services over a long period of time [9]. To realize the smart infrastructure functions, BIM adoption for data management and exchange remains the same, which can provide the data from BIM model handover process for the purpose of smart infrastructure model, despite infrastructure projects having distinct characteristics that require different modeling methodologies [10]. In a study, the use of BIM in 13 different projects was analyzed, which included infrastructure projects as well as building projects. The results showed that BIM led to a 38.5% improvement in quality, a 38.5% decrease in conflicts, a 61.5% increase in design clarity, a 23.1% reduction in modifications, and 30.8% more accurate cost estimates [11]. The feasibility of BIM adoption in infrastructure project is obvious that improves the productivity and time saving in design phase, meanwhile, BIM adoption to infrastructure projects is an important prerequisite for the realization of smart infrastructure.

Airports as an essential asset of the transportation infrastructure, during the construction period, it can be challenging due to several critical issues, including securing funding, minimizing environmental impact, acquiring land, addressing noise pollution, coordinating complex construction, and complying with environmental regulations. The study was observed that it is very important to consider economic, social, environmental, and normal conditions as determine the success factors of the airport project [12]. Thus, how to successfully use BIM to facilitate in decision making of those success factors during airport project construction process is the critical problem need to be solved. Since the study found that under different society and cultural environment, AECO practitioners hold various perspective about BIM adoption, some organizations may adopt BIM for collaboration and efficiency, others may adopt it for technical improvement, and some companies tend to be more cautious while implementing new technology, while other companies prioritize change management and empowering subordinates [13]. Previous studies have shown that there are still some gaps, such as the lack of a common data format for infrastructure, the requirement of developing a virtual data integration engine, the integration of business processes with BIM processes and framework for information governance and defining 'data usefulness' in infrastructure [14].

Under aforementioned research, a question raised up: What are the barriers specified to BIM adoption in airport project? This research will focus on several airport BIM adoption cases in the following content, after a comparative analysis of cases, barriers of BIM adoption in airport project construction process will be emerged. The following contents are organized as follows. Section 3 presents the general benefits and barriers according to cases review; followed by Section 4 – discussion & suggestion. The conclusion is given in Section 5.

## **3. Case Documents Reviews**

The purpose of this part is to compare the adoption situation of BIM in various location and types of airports project, to find out the general benefits and barriers of BIM adoption in real-world airport project, then providing a theoretical basis for discussion and suggestion.

### 3.1. Overview of case study

*3.1.1. Naples Capodichino International Airports, IV Bridge.* The Naples Capodichino International Airports, IV Bridge project is an expansion project that has adopted BIM (Building Information Modeling) technology. The focus of BIM adoption for this airport is multi-disciplinary modeling, which includes architectural and structural modeling as well as the structural analytical model of reticular structures and clash detection.

The research has demonstrated that Building Information Modelling (BIM) offers a range of benefits. BIM improves design efficiency by enhancing the integration of different model components as drawing elements, thereby requiring fewer modifications. BIM also enables the creation of an organic view of the project, incorporating geometric and dimensional attributes, parametric constraints, and other data, useful for management and analysis. BIM optimizes operating flows, productivity, and saves time and cost by eliminating errors, duplications, and interferences. It also avoids downtime and wasted costs by identifying problems such as clash detection and avoidance. BIM is a software platform for integrated design, planning and collaboration that enables seamless information flow between stakeholders. The digital BIM model is constantly updated throughout the project with a visual representation of the building and other asset-related information. In conclusion, BIM coordinates complex sociotechnical processes and aligns different factors and information across projects, networks, and markets, making it more than just a technological innovation [15].

*3.1.2. Istanbul Grand Airport.* Istanbul Grand Airport is a new construction project, the BIM adoption mainly focus on drafted a BIM execution plan prescribed a roadmap for project BIM implementation process, multi-disciplinary modeling (Architectural, Structural, MEP and BHSs), Clash Detection, constructed cloud based data management tools used to manage BIM workflows, integrated with mobile computing to support onsite quality assurance-quality check activities [16], 4D Schedule Simulation for improving project management of construction sequencing, 5D quantity estimation used BOQ Control on subcontractors.

The research found that integrating BIM with Lean concepts can result in cost reduction, waste elimination, and on-time project delivery. BIM implementation can also accelerate efficiencies in design and construction, leading to the fulfillment of schedule goals. BIM adoption enables intelligent design interrogation, resulting in quicker and more cost-effective design processes. Improved coordination of documentation and communication for IGA project management and supply chain is possible, including real-time progress monitoring and quality control communication. BIM can also lead to more effective change control, fewer process repetitions, timely resolution of foreseeable clashes, and better-quality constructed products [17].

*3.1.3. Kuwait International Airport.* Kuwait International Airport is a new Construction project, the main BIM adoption include: BIM execution plan prescribes the detail, workflows, and method of Project BIM implementation process, multidisciplinary modeling (Architectural, Structural, MEP) and top-down design drawings from specified sheet models, common data environment (CDE) with different project stages and responsibilities of data transfers between stakeholders, clash detection, quality assurance and quality check with data visualization & analysis extracted from model, CFD simulation analysis for various architectural characteristics of project, 4D schedule simulation, based BOQ Control on design and procurement process of 5D Cost estimation, BCF-based cross platform software collaboration, facilities management attributes associated with BIM objects.

The adoption of BIM provides several benefits, including the achievement of collaborative work among stakeholders regardless of time and space limitations. BIM models with a high level of detail can fulfill top-down design requirements, and promote the efficiency of intelligent design supervision, with traceable changes. BIM can also lead to more effective change control, fewer process repetitions, timely resolution of foreseeable clashes, and better-quality constructed products. Additionally, BIM can reduce storage costs and improve material turnover through model-based quantity takeoff for

procurement planning and storage management. Lastly, BIM can help achieve the goal of whole life cycle information transfer with a project unique coding system, ultimately leading to a completed asset information model for O&M phase utilization. [18].

**3.1.4. Ezhou Huahu Airport, Ezhou Hub Engineering.** Ezhou Huahu Airport is a new construction project, the mainly BIM adoption is mainly focused on BIM execution plan and BIM technical standard for project implementation process, multidisciplinary modeling (Architectural, Structural, MEP) and top-down design drawings from detail design models. clash detection, quality assurance-quality check, BIM model based on light weight platform and detail drawings for visualization and delivery between various stakeholders, BIM Integrated with VR for safety education purpose, construction quality management based on BIM model attributes, 5D cost estimation: BOQ from BIM model integrated with comprehensive unit price method for measurement and payment, dual handover of physical entity and record model data of airport.

The adoption of BIM technology in this case brings several benefits, including increased on-site work efficiency, avoidance of rework, ensuring construction schedule and quality, improved quality inspection and evaluation, better information expression in architectural design drawings, and improved efficiency in cost estimation and measurement audit, leading to a decreased demand for quantity surveyor staff. BIM technology offers a more efficient and accurate alternative to traditional quality management modes and offline paper documentation, ensuring authenticity and accuracy of inspection and evaluation results [19].

### 3.2. BIM Adoption Summary

The selected airport case studies contain varying levels of BIM application. However, the lack of quantitative post-evaluation data makes it difficult to conclude that deeper BIM adoption leads to higher project benefits. Decision-makers should develop a project-specific BIM implementation strategy based on the project's construction scale, budget, and deliverables requirements during the planning stage. This will enable them to determine an appropriate BIM application roadmap for the project.

According to the four airports project case reviews of BIM adoption and reference to Building Information Modeling for Airports [20] by McCuen et al. and BIM project execution planning guide [21] by Messner et al., this research summarizes a general scope of BIM adoption over a facility life cycle for airports project, shown in Fig. 1.

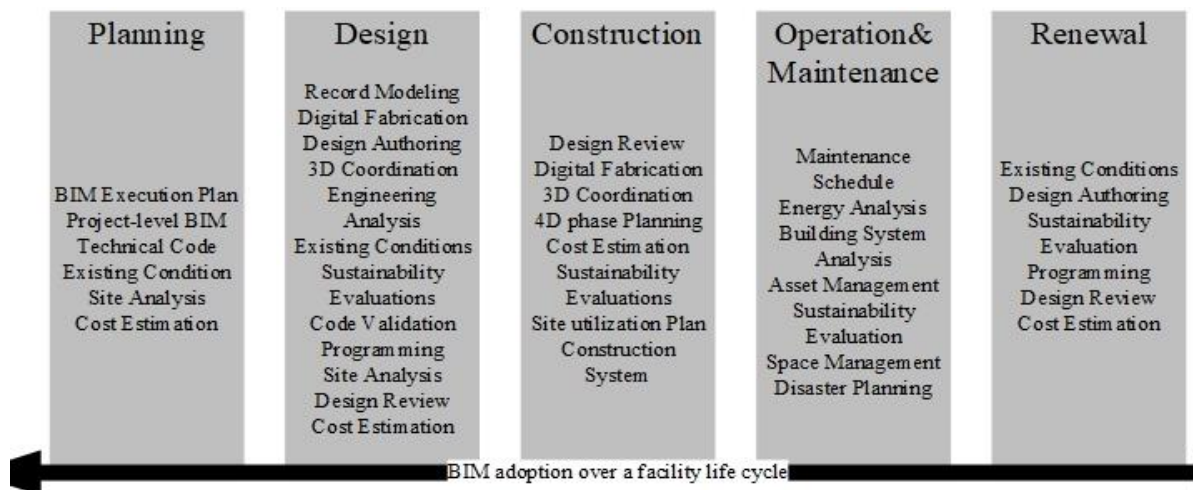


Figure 1. BIM Adoption over a facility life cycle.

### *3.3. General benefits of BIM adoption in airports project*

Through case documents reviews of airports, it is found that BIM adoption can contribute to the following general benefits for airport projects in the design and build process from the following perspective to fulfill project management objectives.

*3.3.1. Efficient Design Management.* BIM models allow project stakeholders to view and interact with designs in a 3D environment, helping to identify potential conflicts and issues early on. BIM model element modification requires less work than 2D drawings, improving design accuracy and compliance with codes and standards. BIM-based collaborative project design, integrated with cloud-based platforms, can quickly and accurately detect errors and collisions between multi-disciplinary design models, enabling timely feedback and comments from other designers. Compared to traditional 2D design processes, the cloud-based platform BIM design process has faster response and modification speed, greatly improving design efficiency and quality for projects with tight schedules.

*3.3.2. Ensuring Constructed Product Quality.* Clash detection and walk-through animations within models to identify and resolve design conflicts before construction, reducing the risk of errors and omissions caused by miscommunication. Model-based simulation can help identify and mitigate potential risks and improve construction efficiency. BIM objects can generate accurate quantities and schedules for planning and executing construction work. As-built BIM models can create a digital asset of the completed building, containing specified data for maintenance and operation, which can be used to verify and validate system performance before handover to the owner.

*3.3.3. Fulfill Construction Schedule Goals.* BIM with detailed construction schedules incorporating spatial and temporal relationships can improve planning and coordination for construction crews, particularly in complex airport construction projects with tight schedules. 4D BIM models can be used to analyze and optimize resource usage, integrated with professional scheduling software to reduce waste, and improve efficiency. The model can also be used to simulate and analyze different scenarios, identify and mitigate potential risks that could affect the schedule. Integration of BIM with IoT and other digital technologies can create an ecosystem for real-time tracking of on-site progress and addressing deviations from the schedule plan.

*3.3.4. Project Capital Savings.* BIM models provide detailed information about building components and systems, including material quantities and types, enabling early cost information to be provided to the owner during the design phase. Accurate 3D visualizations of the building and better visualization of project and construction elements can reduce the need for costly change orders during construction. BIM models with 4D time-based simulations can help identify bottlenecks or delays that may impact costs. Based on 5D cost-based simulations, contractors, owners, and other stakeholders can accurately estimate project costs, track budgets throughout the construction process, and efficiently manage change orders.

### *3.4. Barriers to BIM adoption in the airport project*

*3.4.1. Unwillingness of practitioners to change traditional working practices.* According to Salvatore's et al. research[15], the significant barriers and obstacles to using BIM is the resistance from the unwillingness of practitioners in AEC industry to change traditional working practices, it also corroborated by McCuen's et al. [20] research data, only 27.8% of respondents were truly aware of the benefits of BIM adoption, the main reason are as follows: Implementing BIM often requires a significant upfront investment in new software and training, which can be a barrier for some practitioners like small scale subcontractors. Some practitioners may not fully understand the benefits of BIM or how to use it effectively, leading to resistance to adoption. Adopting BIM often requires a significant change in working practices, which can be difficult for some practitioners who are used to

traditional methods. Some practitioners may be skeptical of the value of BIM or may have had negative experiences with the technology in the past, leading to resistance to adoption.

*3.4.2. Fragmentation of BIM adoption.* Zhan [22] found that in the Ezhou Huahu Airport project, most of the BIM consulting service providers were only involved in part of the implementation stage or part of the industry of BIM implementation process, and they were not good at the detailed problems encountered in the full-life cycle of BIM implementation and the adoption difficulties. This leads to most BIM adoption staying in a single discipline (such as mechanical and electrical integration, large-scale curtain system design), or a certain stage (design stage reverse modeling, construction stage simulation demonstration), and before Ezhou Huahu Airport, there are very few cases of BIM adoption in multidisciplinary for the full life cycle in China. However, the ultimate purpose of BIM adoption for mega-project like airports is to form an Asset Information Model for O&M decisions, capital investment and life cycle costing, planning, and budgeting, and linking these data to existing enterprise information systems in the operation and maintenance phase [23], realizing the digital twin among the physical and digital world.

*3.4.3. BIM data exchange difficulties in the construction process.* For both cases of Ezhou airport and Kuwait airport, the information requirement is full lifecycle information transfer, culminating in an asset Information model in the O&M phase. Considering the airport project modelling process, an intricate structure of models including multi-disciplinary and variant versions with high LOD requirements, data exchange and data management between the multi-disciplinary models with various design authoring software are difficult to transfer data during such a BIM implementation process. To fulfill the quality management goals of project, the design and construction process needs to extract BIM data for analysis and guidance of model quality controls. Xu et al. [24] found that as airport projects scale expand larger, the span of the data managed therein grows exponentially more difficult. At the same time, as the project developed, it is a common phenomenon of data loss, data errors, due to a problem of how to manage those big data from BIM models.

#### **4. Discussion and Suggestions**

Since this research summarizes and analyzes airport BIM adoption cases in multiple countries and regions, considering that there are differences convention rules in project delivery methods among countries, regions and industries, and the previous research has already summarized and concluded the pros and cons of BIM adoption in various delivery methods [25,26], this factor not considered as the focus of this research.

##### *4.1. Establishment of BIM Binding document system*

For each project BIM implementation demands, to establish a complete binding document system, the decision maker of BIM process should determine BIM implementation binding documents for the specified countries and industries, for example, in US, NBIMS-US is being used, these documents are the broadest restrictions and constraints of BIM implementation, all project BIM documents should under development in those binding documents initiative. Most of the cases in this research also took binding documents into consideration, but most of the projects did not complete a full set of binding documentation system, so for an airport BIM project, the suggestion for establishing a basic binding document system consists of the following: BIM project charter, BIM project agreement or contract, BIM execution plan (BEP) and BIM project closeout report.

With the BIM projects charter, the owner and BIM consultant will reach a consensus of the whole BIM adoption process, since it establishes the overall objectives and scope of the BIM effort, as well as the project team's commitment to using BIM. The project agreements and contracts lay out the binding agreement between the stakeholders involved in the project that BIM will be used and its deliverables, these document outlines the legality of the BIM implementation process. Through the above two documents, on the one hand, the owner has a deeper understanding of the BIM adoption

process, within the project requirements make a consensus with BIM consultants for BIM implementation goals, at the same time, due to the owner's deeper knowledge, with the help of the agreement and contract, the owner can strongly push the process of BIM implementation, thus solving the unwillingness of some suppliers for BIM implementation, so as to ensure the depth of BIM adoption.

The BIM Project Execution Planning Guide - Version 2.2 states that the BEP is a crucial document that provides stakeholders with the necessary BIM implementation information for a project. It includes project goals, organization roles, BIM workflows, data and model transfer protocols, requirements for BIM and facility data, collaboration procedures, key timelines, and quality control measures for BIM models. The BEP helps all stakeholders understand the project's scope and requirements, improving collaboration and model data exchange accuracy. Additionally, the BEP should be updated as the project progresses.

BIM project closeout reports summarize the results of the BIM effort, facilitate handover of the project to the owner, providing accurate and up-to-date information about the building's systems and components, ensuring that all relevant information is transferred and provides recommendations for future BIM projects.

#### *4.2. Collaboration platform with specified project requirements*

Based on the research by Keskin et al. [27], BIM is an effective solution for improving collaboration throughout the construction supply chain by providing a central repository of project data that can be easily accessed and reused by all parties involved. The critical functions performed by collaboration platform based on BIM data in the research are document management on cloud, design management, construction coordination, progress monitoring and asset information management. Not only the reuse and transfer of BIM data within the collaboration platform, but also utilization of project data to its full potential via multi-dimensional data processing capabilities of BIM, which enhanced collaboration by convergence on project information, outcomes towards successful project delivery. With barriers of model data transfer in airport project, BIM binding document system facilitates stakeholders to understand and transfer model data in a consensus way, which solved most of the issues caused by miscommunication between different parties, while there is another essential issue that technology infrastructure requirements should be defined in the planning phase and its function should fulfil project BIM implementation goals. In the case reviews, although collaboration software or platform utilized during the process, the effect of collaboration varies regarding the region-specific and project-specific factors, but the critical factors that affect the result determined by technology vendors' software development capability and understanding the owner's centrality within a complex ecosystem of airport project. Therefore, the owner should set procurement technical requirements for collaboration platform vendors, especially be aware of past product development experience, development team capabilities and for advance understanding of the vendors towards information requirements for the airport project.

#### *4.3. Pilot projects and post-project evaluation*

Since airport are large infrastructure projects always with tremendous investment, so when considering how to use BIM technology in airport projects, decision makers can consider conducting small pilot projects first, according to research by McCuen et al., with the pilot projects, owners, especially the owner who not familiar with BIM technology, can better understand the value of BIM adoption, which is beneficial for strengthening owners to promote the full implementation of BIM in the whole process of an airport project. At the same time, the pilot project facilitates the various stakeholders involved in the implementation of BIM to understand the risk behavior of the whole process of BIM implementation, so that ultimately in accordance with the complete airport BIM implementation plan can maximize the benefits of BIM adoption. Post-project evaluation for pilot project is meaningful for the subsequent BIM implementation of the airport project, there are several maturity evaluation benchmarks to evaluate the BIM adoption of pilot project [25], such as BIM

scorecard with Vico software, BPM from University of Indiana, BimSCORE and CMM by NBIMS V3. These benchmarks should be utilized by decision makers with specific BIM implementation goals. The evaluations can be conducted through surveys, interviews, data analysis and case studies and can provide valuable insights into the effectiveness of the BIM project and identify areas for improvement in future projects. Since the adoption of BIM technology in large infrastructure projects in most countries and regions is still in the early exploration stage, this research focuses on the design and construction stage of airports and does not deeply explore the delivery process from the completion stage to the O&M stage, the issues and obstacles encountered in the implementation of BIM in the O&M stage. As the maturity of BIM adoption in airport projects gradually higher, the sample size of the research will gradually increase, and the data of airport operation phase based on BIM model will be accumulated for a long time, which will help this research to propose the strategy of BIM application in the whole life cycle of airport projects through more quantitative evaluation methods.

## 5. Conclusion

This research found that BIM technology has feasibility when applied to airport projects, which are an essential asset of infrastructure. After the comparative analysis of the case reviews has identified the universal benefits and barriers of BIM technology applied to airport projects and a roadmap of BIM adoption to the whole life cycle of airport projects is summarized. The benefits include efficient design management, ensuring construction quality, meeting construction schedule goals, and cost savings. The main obstacles are the resistance of practitioners to change, varying levels of BIM maturity among stakeholders, and the lack of a common data format for data exchange. The study proposes three suggestions to overcome these barriers, including compiling BIM binding documents, establishing a digital collaboration platform, and using a pilot project. This research is suitable for airport owners and related participants to customize the stratagem for planning of airport project application of BIM technology to meet the project requirements.

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