ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

Innovations and Requirements of Strategy for Digital Maintenance Management in Construction Project

1st Mohamed Ali Abd Al-Abaas Noaman[2st] and Sawsan Rasheed Mohammed [2]

***Abstract*- The strategy for digital maintenance in construction projects is considered as the main transformational power which is causing unprecedented changes in the architecture, construction, and maintenance sector to redefine innovation and requirements to success strategy for digital maintenance in construction projects, through systematic review and evaluation relevant to published studies. The initial findings include four interlocking main themes highlighted that requirement for digital maintenance strategy within controlling cost to the budget, Maintenance management, documentation by centralization of database and maintenance priority, also three main innovations within cloud computing (CC), integrated BIM and IPD, and the requirements and innovation's themes further produced a total of 38 subthemes. This study contributes to the body of knowledge by expanding the requirements and innovations across the building life cycle, especially in the maintenance phase, and to present the requirements and innovations to succeed in the strategy for digital maintenance in construction projects. the first portion depends on the literature the second portion has resulted from a pilot survey about requirements and innovations the study was performed by surveying 15 project managers, questionnaires were submitted to project managers in a different occupation, qualifications, and experiences, and the main objectives of this paper are to study the correlation between requirements and innovations to success digital maintenance management and evaluating relationships between the seven success factors related to digital maintenance management in construction projects in Iraq and to give a global picture about strategy for digital maintenance.**

Keyword- Building Information Modelling (BIM), Systematic Review (SR), integrated project delivery (IPD), Cloud Computing (CC),

Introduction

With increasing the numbers of published researches, it is very difficult to identify relevant studies inefficiently, especially when the research topic is complex, therefore conducting a literature search to identify relevant researches from databases and search engines that required rigorous search techniques systematic literature review (SLR) is a type of literature review that used to define strategies to reduce bias in identification and analysis of data from the articles and published researches.

BIM has been speed growing in maintenance works of the buildings and it offers many advantages and new opportunities to enhance effectiveness and efficiency, but integrated BIM and Cloud computing is leading to higher levels of collaboration and cooperation and supplying an effective communication platform for all parties.

Materials and methodology

This portion begins with a brief literature review of published researches in BIM and cloud computing in search engines and picked databases to identify topics that not consideration and research gaps, A systematic review is developed to identify, screen, and access significant studies, also to collect and analyses data that are included in a review that is based on specific techniques and formulated research questions.

2.1 Formulating research question

When conducting a Systemic Literature Review (SLR), the first step is formulating an answerable and clear research question to clarify the objectives and the study inclusion and exclusion criteria to answer the following review question: what is innovation strategy for digital maintenance management in a construction project? And what's the requirement to success maintenance digital strategy?

2.2 Create Systemic protocol

A research protocol must be developed before execution of any systematic literature review to identify inclusion criteria and exclusion criteria, inclusion criteria were used to a systematic review (1) are available amongst journals/ databases, (2) be written in English to avoid confusion and complication (3)is unique have no duplication (4) regard to period, a duration of 18 years (between 2002 and 2020) because The concept of digital talk about using it Dr. Michael Grieves, at the Florida Institute of Technology, that introduced the digital at a Society of Manufacturing Engineers conference (5)relevant articles included keywords that mention previously exclusion criteria were used to systemic review (1) review articles (2) conference paper (3) articles that were not in English language (4) workshop reports (5) published date not available (6) conference review

2.3 Identify keywords and create search strings

When reading articles can be extracted from them many keywords which covered our subject keywords e.g., BIM, cloud computing, maintenance strategy for building, digital technology, innovation strategy for maintenance building, information management in operation and maintenance. After that using search strings to achieve a more specific search[1]. The keywords will be used with search strings (AND/OR/NOT) as follows in Fig.1 illustrate search strings for (SLR) and summarizes the key information that must be extracted from the studies and articles included in a SLR

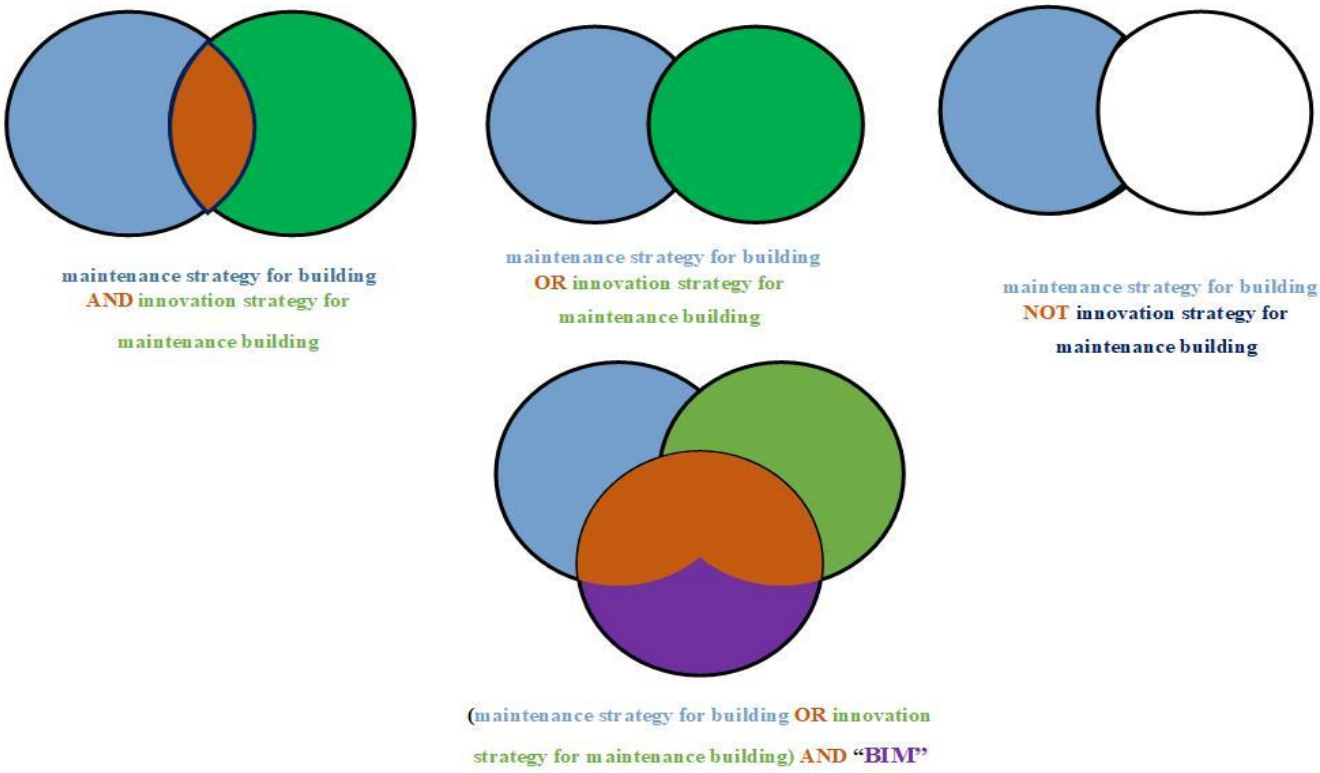

FIG I: ILLUSTRATE SEARCH STRINGS FOR SLR

2.4 Search in databases

major research databases and search engines which include (scopas, science direct, google scholar) in all fields (title, abstract, keywords, full text, etc.), in this portion results of our (SLR) are shown in table I. and Fig. II. the summarized our (SLR), be found 628 different publications, depending on the searching possibilities of these databases.

TABLE I SUMMARIZED RESULTS OF OUR SLR, IN THREE DATABASES

YEAR OF PUBLICATION	DATABASES (SEARCH CONDUCTED FROM 2002TO2021			TOTAL
	SCOPAS	SCIENCE DIRECT	GOOGLE SCHOLAR	
2002-2010	22	55	56	
2010-2015	66	64	77	
2015-2021	78	88	122	
TOTAL	166	207	255	628

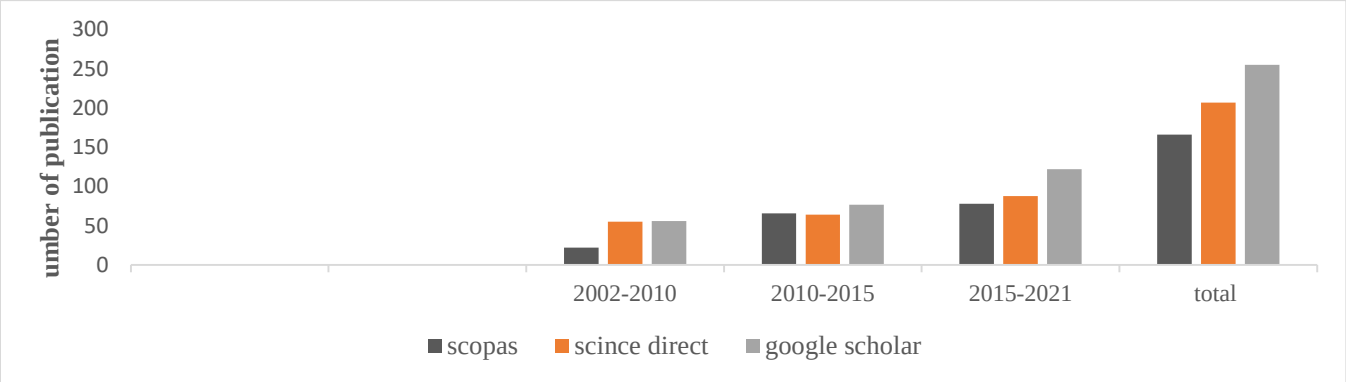

FIG II: NUMBER OF JOURNAL PUBLICATIONS IN (SCOPAS, SCIENCE DIRECT, GOOGLE SCHOLAR)

2.5 Data abstraction and analysis

In this section summarizes the results found in (SLR). The following flow diagram as shown in Fig. III shows results obtained at every stage, the initial number of 628 records, after the removal of 22 duplicated records. , 459 records were excluded depending on exclusion criteria, Finally, 39 full-text articles were included through screening introduction, conclusion, and abstract that be used for the qualitative analysis to identify themes and subthemes related to the innovation strategy for digital maintenance management, information management in operation and maintenance buildings and BIM-cloud computing for maintenance building stages

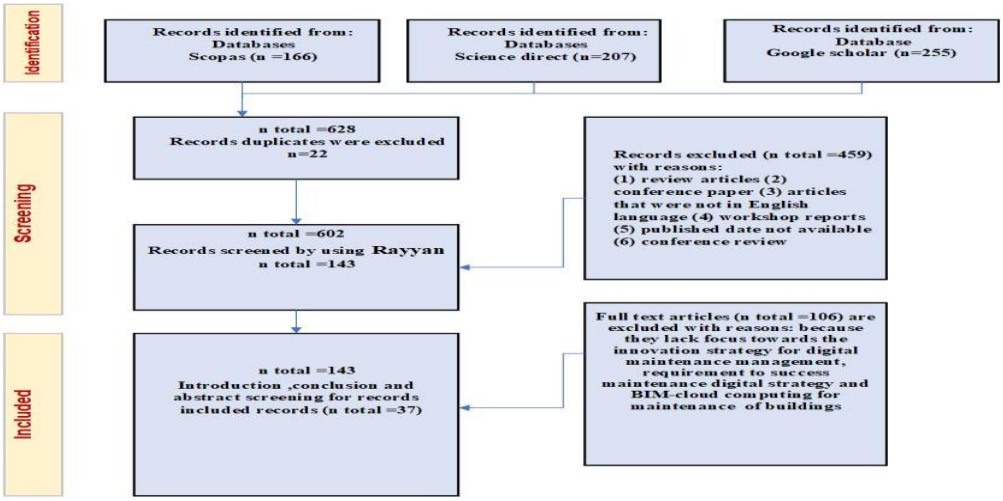

FIG III: SYSTEMATIC REVIEW FLOW DIAGRAM

Data analysis and interpretation

The results obtained from the thematic analysis are illustrated in figure IIII. The review derived four main requirements and three innovations associated with success and digital maintenance management in construction projects. The four interlocking main themes are controlling cost to budget (5 subthemes), maintenance priority(3 subthemes), Maintenance management (6 subthemes), documentation by centralization of database (8subthemes), and three main innovations are the innovation of cloud computing for digital maintenance (5 subthemes), innovation of building information model for digital maintenance (6 subthemes) and innovation of integrated project delivery (IPD) for digital maintenance (6 subthemes). The tendency of previous researchers to use a qualitative approach might be due to their need to depth understanding of the main requirement and innovations associated with success and digital maintenance management. The following subsections will discuss in greater detail the main themes and subthemes that support the success of digital maintenance management in construction projects.

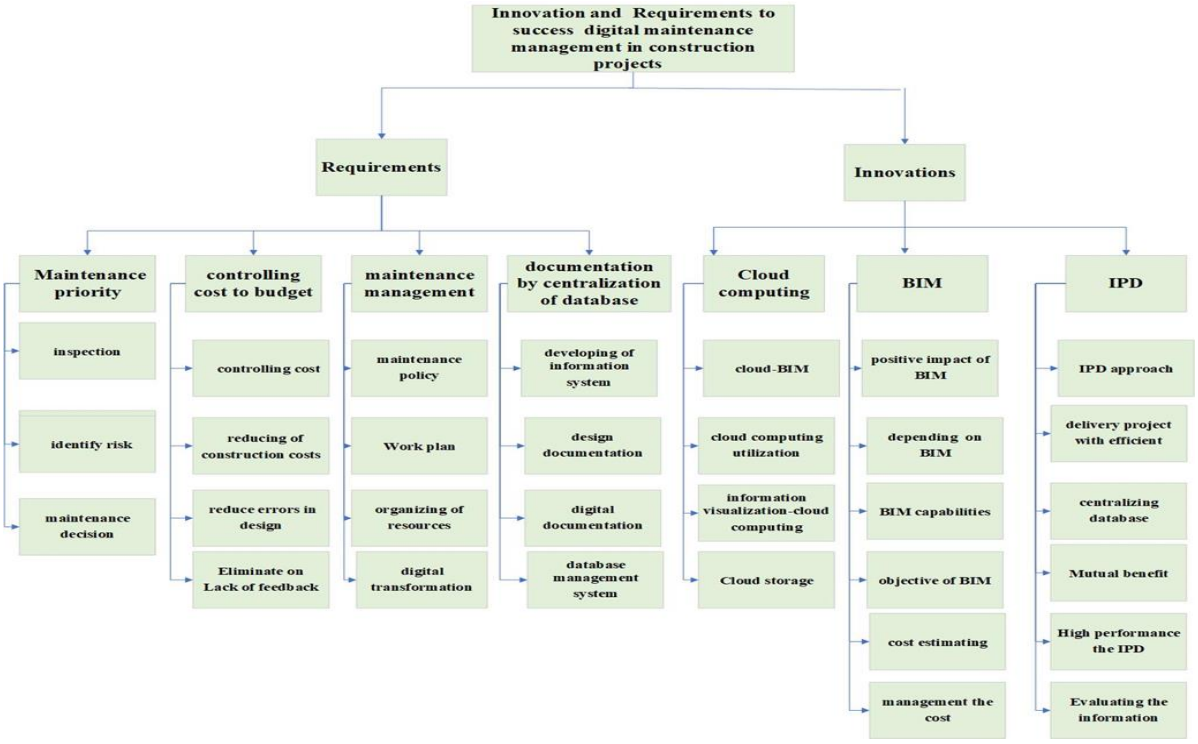

FIG IV: REQUIREMENTS AND INNOVATION FOR DIGITAL MAINTENANCE

3.1 Controlling cost to the budget

- controlling cost to budget: can be made have an important impacting on the cost of maintenance, a proper estimating cost of maintenance is contributing to perform the activities of maintenance within available a budget, especially in the public sector because of using public funding, therefore have to be developed framework to help stakeholders in collect and record the required information to controlling cost to the budget
- Until recently, the architects, contractors, and clients were toward for reducing of construction costs, no attention to the reduction of maintenance costs of buildings because of the methods to calculate operating and maintenance costs are unique and not very accurate therefore need to record, analyzing and classifying cost maintenance and comparing against
- In the design phase, errors in design are common especially in architectural and civil designs that would affect the construction and operational maintenance of the project, which will be affected the cost of the construction or maintenance phase, also lack exchange of information and feedback from design to maintenance teams and communication, therefore all parties have to knowledge in coming up with various strategies to get the cost-effective facility in the construction and maintenance stages.

3.2 Maintenance priority

- Maintenance decision depends on right priorities, when comparing between costs of maintenance and available budgeting without consideration for the pertinence and consequences of the actions, caused inefficiency and ineffectiveness in maintenance performance and influence on maintenance negatively, therefore needed to know how maintenance should be prioritized within limited resources which allocated to obtain right priorities
- Identify risk, the risk is considered one of the frequently used factors in deciding the priority of maintenance, Risk is related to accident and safety which is considered is one of the main purposes of effective maintenance, risk is usually defined as likelihood and consequences likelihood refers to the possibility of the risk occurring while consequences refer to the required expenditure in terms of material and labor cost other criteria such as the effects on users and effects on the condition of building are using in maintenance prioritization for building
- Effective maintenance is based on inspection for anomalies to gain productivity through condition surveys for gathering information on the state of a building. This information helps to inform strategic decisions on a program of replacement or repair, to identify the priority of maintenance to components of building

3.3 Maintenance management

- Maintenance management is including the organizing of the resources to deal with maintenance problems to get maximum benefits, through examining the management functions in the building and highlighting the innovation processes that are required in the organization to obtain effective and efficient management of maintenance
- Digital transformation, it is important to understand that it is a not only technological shift at any level, but it is involving in all levels from the top management to the bottom levels through creating bases of knowledge, therefore the facility managers can reach this goal by using digital transformation to enhance their designing new solutions, capabilities of molding innovative ideas, and fully implementing needs and expectations of the user
- Work plan depends on the ability of the maintenance manager to manage the cumulative work plan, that including the scope of work, and identify all requirements to complete the work
- Maintenance policy includes formal organization plan chart, method of approval of work, material requisition techniques, and Information filling and retrieving techniques-manual-electronics

3.4 Documentation by centralization of database

- Design documentation is a group of documents which using in construction or maintenance work and containing instructions on maintenance and other relevant documents, specifications, expert opinions, and survey reports, and other documents
- database management system is a product framework that is used to access the information contained in a database. The goal of a database management system is to provide a suitable and effective method of storing, defining, and recovering the data in the database. It has incorporated control of the database to prevent unapproved or fraudulent users from getting the data and guaranteeing the protection of the data
- Developing of information system for projects is depend on documentation made from a series of documents designed during the project life cycle. Any project usually should end with a set of documents used as a starting point in decision-making for continuing the project, to ensure the success of the project[2]
- Digital documentation is utilized to address the condition of the building environment the advantage of BIM integration with digital twins is permitting centralized access to the digital documentation for partners, probably using the trend of the pattern of online and mobile communications platforms for improved correspondence and data exchange.

3.5 Innovation of cloud computing for digital maintenance

- Cloud computing utilization to visualization the data and control by users that located at different sites, through giving admittance to the software and its functions as a web-based service and users can get to these services available in the web cloud anyplace, and at any time[3]
- Information visualization-cloud computing is essential for information distribution and communication, Therefore project management systems just provide comprehensive information to facilitate project management, without providing different visualization tools to help with information communication and distribution information visualization-cloud computing can present significant information in multiple modes such as text and graphical formats, by accessing the database [4].
- Cloud storage is giving feedback to the user through working interface pictures, not being expected to download the model to amend and upload it. And collaborative work between all the participants in the design phase and construction phase, with BIM, can exponentially increase the efficiency of information communication but Cloud storage is intended to give the moment collaboration [5].
- Cloud-BIM has centered on the building design and construction phases, Cloud-BIM could be utilized to give an efficient means of quick and real-time identifying facility maintenance requirements, access to original building maintenance records, for example, building management may intend to move an eternal wall to establish a new space usage in a building. Rather than checking the actual building, they may review the piping systems located in the planned location via their BIM reference. Additionally, certain pipe specifications, manufacturer, and other important information could be retrieved to the building management to better evaluate the strength and deficiency of the plan without information loss in a model, these implementations are still rare particularly in existing buildings, because of updating of BIM information and handling of data uncertain [6]

3.6 Innovation of building information model for digital maintenance

- management of the cost, BIM is considered an efficient tool in architectural, engineering, and construction to increase the productivity on construction projects, through controlling the cost [7].
- Dependency on BIM is managing all the project stages and documents through planning, design, and costing in a situation dynamic one entity, to gain the proper employment of available information [8].
- The cost estimating process starts with exporting the data from 3D models to BIM-based for preparing quantity takeoff, then the bills of quantities are generated and exported to a database. Automated quantification will automatically consider any changes in design and shorten the quantity takeoff processing time[9].
- depend on the positive impact of the building information model in phases of design and construction the facility managers are looking for a way to benefit from this positive impact to improve the operational and maintenance phases, through the design and construction phase can be using this information for maintaining and operating throughout the life of the project cycle [10].
- the objective of the building information model is to gain complete information about the component and system of a building which the information would be are consistent, formal, non-redundant, and non-ambiguous rather than the traditional approach that the facility managers are received a series of project documents and exchange the information between phases that caused main issues and inconsistent of information [11].
- BIM capabilities like visualization of projects and auto alerts can enhance and provide different approaches from current traditional practices which used in processes of facilities management. visualization is promoting the participants to effectively collaborate, and detect the defects in the early stage, therefore using visualization of the project is not only important for architecture but also to imagine how the facility will operate and maintain (Olatunji and Sher 2009).

3.7 Innovation of integrated project delivery (IPD) for digital maintenance

- To deliver a project with efficiency, the final goal is having information in an external database that is existence for all project participants with accuracy, clarity, and utility all participants [12]
- IPD approach, includes five phases in the life cycle of a project which describe as criteria of design, detailed of design, implementation of the documents, construction, and finally close out phase the first phase is criteria design, all the stakeholders from the preceding phase remain present till define the goals and building components, and others the second phase detailed design, all parties remain presented in this phase, the details and specifications are developed depending on the previous phases the third phase implementation the documents, the documents and materials are generated, like specifications and designs the fourth phase the construction phase, the project execution begins applying the specifications and designs which defined in the preceding phases, Finally, the fifth phase is called the closeout phase the finalization of the project, where generate outcomes such as occupancy, warranty, and completion of documents [13].
- Today's buildings are complex and needed for the information to maintain and operate, the information will also assist to track facility components and systems carefully, and responding quickly to the user requests and each facility component or system has a cost associated with the installation, replacement or repair, therefor needed centralizing a database and not be a desert island for meeting both current and future requirements.[14].

- Mutual benefit all of the team members participate to complete the project and sharing in benefits and risks, through making all the participants as one team toward one objective [15]
- The high performance of the IPD has proven its capability to rise performance, which includes schedule, quality, project changes, and communication among stakeholders through identified responsibilities from the beginning which creates a transparent and honest environment and solves the problems [16].
- Evaluating the information provided by operations and maintenance staff for its applicability to (Cobie), it is significant to assist the information created through the construction phase to provide information by designers and constructors, to allow the facility managers to capture all a data about the general characteristics of the facility at end of construction phase [17].
- All requirements and innovation themes and subthemes to success digital maintenance strategy are shown in Fig. IV.

3.8 Relationships between requirements and innovations for digital maintenance

- Many authors note that the strategy for digital maintenance management is based on requirements and innovations to success. This survey aims to give a picture about the strategy for digital maintenance in construction projects in Iraq the sample was selected to cover the different occupations of project managers. From 25 questionnaires distributed to project managers, 15 had completed the questionnaire most questionnaire responders are maintenance managers, also visited some enterprises which maintenance management level is good. the diversity of the project managers from different qualifications and occupations considered by the survey.

- To ensure the relationships between the seven factors related to success the strategy for digital maintenance management, the correlation studies are performed to give a general picture, Analysis of correlation between requirements and innovations to success digital maintenance management and evaluating relationships between the seven success factors related to digital maintenance management depend on views of project managers, the correlation test results obtained are presented in Table II

TABLE II. CORRELATION BETWEEN REQUIREMENTS AND INNOVATIONS FACTORS

Factors	F1	F2	F3	F4	F5	F6	F7
F1	1						
F2	0.679	1					
F3	0.105	0.448	1				
F4	0.25	0.159	0.023	1			
F5	0.041	0.101	0.055	0.494	1		
F6	0.055	0.240	0.055	0.041	0.599	1	
F7	0.013	0.014	0.138	0.579	0.101	0.041	1

Notes: F1: Maintenance priority, F2: Innovation of building information model, F3: Controlling cost to the budget, F4: Maintenance management, F5: Innovation of cloud computing, F6: Documentation by centralization of a database, F7: Innovation of integrated project delivery.

- According to the results shown in the TABLEII., we conclude the following points: there is a strong correlation between F2&F1which means maintenance priority depend on using BIM tools, F3&F2 moderate correlation, F4&F3 weak level of maintenance management effective is highly associated with controlling cost to budget because proper management of maintenance defiantly controlling on cost, F5&F4 strong correlation, maintenance management effective within cloud computing, through storing and retrieving all necessary data to the utility by all parties, F6&F5 strong correlation all parties can benefit from the project documents by sharing data in any time and anywhere and reduce loss the documents and F7&F4 strong correlation, through implementation IPD result ineffective maintenance management

CONCLUSION

The purpose of this study is to redefine innovation and requirements to succeed in digital maintenance strategy in construction projects' lifecycle. We conducted with the RQ of "what is innovation strategy for digital maintenance management in a construction project? And what's the requirement to success maintenance digital strategy?". The findings highlight that four main requirement and three innovations associated with success and digital maintenance management in construction projects The four interlocking main themes are controlling cost to budget (5 subthemes), maintenance priority(3 subthemes), maintenance management (6 subthemes),documentation by centralization of database (8subthemes) and three main innovations are innovation of cloud computing for digital maintenance (5 subthemes) ,innovation of building information model for digital maintenance (6 subthemes) and innovation of integrated project delivery (IPD) for digital maintenance (6 subthemes) depend on this survey, we can conclude that the main success to digital maintenance strategy that determine the maintenance strategy in projects in Iraq are maintenance priority depend on using BIM tools, maintenance management effective within cloud computing ,through storing and retrieving all necessary data to utility by all parties and implementation IPD result ineffective maintenance management to success the strategy of digital maintenance management, in this survey to give more accurate results in order to obtain an optimized model of digital maintenance management to be implemented in once privet or general sector

REFERENCES

[1] D. Denyer and D. Tranfield, "Producing a systematic review.," 2009.

[2] D. Oprea and G. Mesnita, "The Information Systems Documentation-Another Problem for Project Management," in *MANAGING INFORMATION IN THE DIGITAL ECONOMY: ISSUES & SOLUTIONS-PROCEEDING OF THE 6TH IBIMA CONFERENCE, Khalid S. Soliman, ed*, 2014, pp. 332–338.

[3] T.-H. Chuang, B.-C. Lee, and I.-C. Wu, "Applying cloud computing technology to BIM visualization and manipulation," in *28th International Symposium on Automation and Robotics in Construction*, 2011, vol. 201, no. 1, pp. 144–149.

[4] J. Peddie, "Ray-Tracing Programs and Plug-ins," in *Ray Tracing: A Tool for All*, Springer, 2019, pp. 181–330.

[5] L. Ding and X. Xu, "Application of cloud storage on BIM life-cycle management," *Int. J. Adv. Robot. Syst.*, vol. 11, no. 8, p. 129, 2014.

[6] X. Xu, T. Mumford, and P. X. W. Zou, "Life-cycle building information modeling (BIM) engaged framework for improving building energy performance," *Energy Build.*, vol. 231, p. 110496, 2021.

[7] S. Abrishami, J. Goulding, F. P. Rahimian, and A. Ganah, "Integration of BIM and generative design to exploit AEC conceptual design innovation," *Inf. Technol. Constr.*, vol. 19, pp. 350–359, 2014.

[8] A. Redmond, A. Hore, M. Alshawi, and R. West, "Exploring how information exchanges can be enhanced through Cloud BIM," *Autom. Constr.*, vol. 24, pp. 175–183, 2012.

[9] V. Popov, V. Juocevicius, D. Migilinskas, L. Ustinovichius, and S. Mikalauskas, "The use of a virtual building design and construction model for developing an effective project concept in 5D environment," *Autom. Constr.*, vol. 19, no. 3, pp. 357–367, 2010.

[10] D. K. Smith and M. Tardif, *Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*. John Wiley & Sons, 2009.

[11] F. H. van Nederveen *et al.*, "An immunohistochemical procedure to detect patients with paraganglioma and phaeochromocytoma with germline SDHB, SDHC, or SDHD gene mutations: a retrospective and prospective analysis," *Lancet Oncol.*, vol. 10, no. 8, pp. 764–771, 2009.

[12] M. Oraee, M. R. Hosseini, E. Papadonikolaki, R. Palliyaguru, and M. Arashpour, "Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review," *Int. J. Proj. Manag.*, vol. 35, no. 7, pp. 1288–1301, 2017.

[13] J. W. F. Wamelink, J. S. J. Koolwijk, and A. J. van Doorn, "Integrated project delivery: The designer as integrator," 2012.

[14] D. A. Jordani, "BIM and FM: The portal to lifecycle facility management," *J. Build. Inf. Model.*, vol. 13, p. 16, 2010.

[15] S. Rowlinson, "Building information modelling, integrated project delivery and all that," *Constr. Innov.*, 2017.

[16] M. El Asmar, A. S. Hanna, and W.-Y. Loh, "Quantifying performance for the integrated project delivery system as compared to established delivery systems," *J. Constr. Eng. Manag.*, vol. 139, no. 11, p. 4013012, 2013.

[17] E. W. East, "Construction operations building information exchange (COBie)," ENGINEER RESEARCH AND DEVELOPMENT CENTER CHAMPAIGN IL CONSTRUCTION …, 2007.