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Abstract

Purpose – The construction industry (CI) faces massive IM challenges between project stakeholders, especially during the COVID-19 pandemic. That raises the need to manage information as a principal strategic goal of the firms. This paper aims to develop a BIM-based stakeholder information exchange (IE) workflow during the initiation phase in mega construction projects (MCPs).

Design /methodology/approach – A research methodology consisting of literature review, case studies, and survey questionnaire was designed to achieve the aim mentioned earlier. Based on the above, the research developed a BIM-based IE workflow to facilitate IM implementation in MCPs.

Findings – This paper has provided extensive insight into the types of exchange, difficulties, and ways to hand over information. From that, it was concluded that there is not only one possible solution, but also different manners of managing this information. However, it needs to be planned from the beginning of the process, agreed upon between different parties, tested, and verified for it to be successful. Furthermore, responsibilities should be clearly defined.

Research limitations/implications – The scope of this research is limited to the MCPs during the initiation phase.

Practical implications – Adopting the proposed IE workflow developed through this research will help implement BIM& IE synergy during the initiation phase in MCPs.

Originality/value – This paper contributes to understanding information flow during the project initiation phase and how to control it properly. The findings are of interest to stakeholders involved in the project's strategic view, where a global examination of all variables of the project is fundamental. Generally, the deliverables of this paper could be used by professionals involved in the BIM processes to enhance information control and the utilization of the produced information throughout the entire process.

Keywords: Building Information Modelling (BIM), Information management, Workflow, Mega Construction Projects (MCPs).

Paper type: Research paper.

1. Introduction

Throughout the building process, a high volume of information needs to be communicated, coordinated, and exchanged. Building Information Modelling (BIM) shows up as an efficient tool to facilitate the management and concentration of the building lifecycle information. Nevertheless, the information generated and required in each phase is different, and to be managed more effectively, it requires a better understanding of its workflow.

Information management (IM) is one of the most important construction processes because it affects the performance of the building throughout its life cycle. The best value for projects can be gained through effective communication and collaboration between the project participants during its life cycle. However, the traditional IM approach, commonly adopted in the construction industry, has proven to contain many flaws and difficulties. This is because it obstructs construction professionals' knowledge, experience, and skills in the project processes. The increasing demand for complex and innovative projects and the mega projects being developed necessitated adopting a new approach that encourages effective communication and collaboration between the project participants.

Information plays a significant role in managing construction projects. This information is generated at different lifecycle stages by various parties, providing additional values to various stakeholders. Also, as construction projects become more complex, a lot of information must be communicated, coordinated, and exchanged along the project life cycle (PLC). As such, without proper information management (IM) platforms, data spreads and gets lost along the project lifecycle, sometimes without reaching its targeted stakeholders. In that context, BIM is one of the popular tools utilized in the construction sector to exchange and manage information.

One of the primary standards developed about IM, PAS 1992-2:2013, where it defines IM as “tasks and procedures applied to inputting, processing and generation activities to ensure accuracy and integrity of information”. All stakeholders involved during a PLC require and produce information, which must be shared, communicated, and exchanged. Each involved party has to clearly understand what is required to perform their tasks and what needs to be achieved. One of the leading publications in the past years on digital IM focusing on buildings and civil engineering is the ISO 19650 international series standard. ISO 19650 utilizes BIM to guide and standardise IE on construction

projects. BIM appears as an efficient tool to assist in centralise and manage the information along PLC (Xu et al., 2014).

Although BIM helps centralize information and standardize IM, there are still some challenges related to interoperability, accuracy, and delivery format. For example, lack of BIM experience to require information is stated by Cavka et al. (2017). Issues on importing and using data from design and construction phases for operations were reported by Pishdad-Bozorgi et al. (2018). These examples brought attention to the need for more profound studies on IM using BIM. Hence, given these limitations in existing SM tools, knowledge, and practice, analysing information processes and exchanges between different stakeholders along PLC is essential.

1.1 Research objectives

This research aims to discuss the challenges of implementing IM and develop a BIM-based stakeholder information exchange (IE) workflow during the initiation phase to facilitate the implementation of smart stakeholder management in mega construction projects (MCPs).

The research objectives are:

RO1. Build a comprehensive background about the research topic and IM as well as challenges of implementing IM in MCPs;

RO2. Examine the perception of organizations towards the challenges of IM implementation in MCPs; and

RO3. Develop an IE workflow to facilitate the BIM&IM synergy during the initiation phase in MCPs.

2. Literature review

2.1. *Building Information Modelling*

The National Institute of Building Sciences (NIBS, 2008) described building information modeling (BIM) as “the process of planning, designing, construction, operating, and maintaining optimized using a standard, machine-readable information model for each facility, new or old, that contains all appropriate information created or

gathered around that facility in a format that can be used by everyone throughout its life cycle."

Furthermore, BIM is described as a "digital technology" (Abanda et al. 2015), which could improve the efficiency of delivering construction projects and could yield a higher return on investment (Olatunji et al. 2017b; Evans et al., 2021b; 2021c). BIM is described by Olatunji et al. (2017b) as a set of applications and processes capable of generating and managing project information throughout the project development phases with numerous benefits to the project stakeholders. It is progressively permeating the construction industry due to its potential capabilities in improving project practices in design, procurement, prefabrication, construction, and postconstruction (Cao et al., 2015; Evans et al., 2020a; 2020c)

2.2. *Information management*

ISO 19650:1 defines information as the "representation of data in a formalised use proper for communication, interpretation or processing". It can be classified as structured (geometrical models, schedules, databases) or unstructured (documentation, sound recordings).

Another essential concept is the definition of information management (IM) that PAS 1992-2 describes as methods and processes utilised to guarantee the accuracy and integrity of information on activities that occur on the input, process, and output. Information is generated during all stages of the project, and it must be well managed. BIM is an innovative way to manage project information exchanged between project stakeholders', verifying the quality, and increasing trust in the accuracy of what is being shared (EFCA, 2019).

In general, IM is a process to ensure that specific information created for a pre-defined aim is handed over to the correct place at the correct time (UK BIM Framework, 2020). The PMI (2017) states that it is essential to understand who needs each information, who can access it, when needed, and where it can be found. Other significant concerns are the information format, access to it, and any barriers that may appear, such as cross-cultural differences.

2.3. *Stakeholders involved*

It is essential to define and evaluate the stakeholder and their expectations (PMI, 2017). The stakeholders chosen for this workflow were the traditional roles concerned in the

CI, but they should have experts with skills in BIM since they are engaged in the BIM process. The roles considered are mentioned, with a summary of their functions. 1) Appointing Party (Owner/Client): The owner is responsible for defining the aims for the project, such as function, schedule, and budget (AIA, 2007). In addition to being responsible for choosing the engaged team, the type of contract, delivery processes, and the definition of general specifications and requirements (Sacks et al., 2018; Mashali, 2020a; Mashali, 2020b); 2) Appointed Party (Contractor): Responsible for performing and coordinating the construction of the project. Also, the contractor manages the time and cost of the construction activities (AIA, 2007); 3) Subcontractor: Party hired by the contractor to fulfill specialized services (Sacks et al., 2018); 4) Design Team which comprises architects and engineers responsible for the project design, where most project information is described (Sacks et al., 2018); and 5) Quantity Surveyors (QS) who are responsible for quantity take-offs and cost estimation. Also, QS could be considered under the contractor's responsibility.

2.4. *Standards*

It is essential to determine the applicable standards and guides for the project. The aim is to define a coherent procedure for the collaboration of all parties, aligning the work with industry standards (BIFM, 2017). The applicable standards and guides applicable to the country of work for IM and AIR need to be verified. Also, the responsibility for verifying the standards compliance is presented in Table 1.

Table 1.: BIM Standards, adapted from (ISO 19650, 2018)

Standards	
Standard	**Application**
ISO 19650-1:2018	Information management using building information modelling - Part 1: Concepts and principles
ISO 19650-2:2018	Information management using building information modelling - Part 2: Delivery phase of the assets
PAS 1192-2	Specification for information management for the capital/delivery phase of construction projects using building information modelling
PAS 1192-3	Specification for information management for the operational phase of assets using building information modelling
PAS 1192-4	Collaborative production of information Part 4: Fulfilling employer’s information exchange requirements using COBie – Code of practice
PAS 1192-5	Specification for security-minded building information modelling, digital built environments and smart asset management

3. Research methodology

The study employed a mixed research design to develop and validate the proposed workflow. It involves conceptualizing the proposed workflow, case studies, and expert survey validations of the workflow.

3.1 Process and Considerations for the Workflow Development

Based on Sousa, et al. (2020) and Rail Baltica (2019), a schema is created to assist stakeholders in dealing with BIM and IM in all project phases, as displayed in Figure 1. It presents the structure of information levels that involves the field of study in this paper, going from a conceptual approach to its applications, starting from the BIM area. The improvement of these work deliverables includes discussing information requirements that can be included in the Employer's Information Requirements (EIR), Asset Information Requirements (AIR), and BIM execution plan (BEP) and the process map to exchange information in every phase.

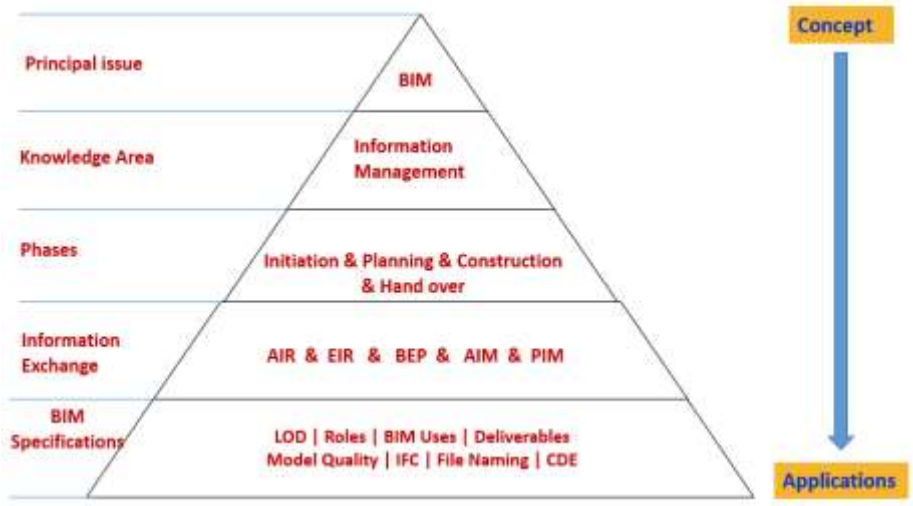

Figure 1: Information's Structure

4. The Proposed Workflow

This proposed workflow is an integrated process that focuses on IE during the initiation phase. This principle aims to improve the decision-makers' abilities to provide a sound and solid strategic management basis for IE development. It is inspired from (Penn State, 2019; Sousa, et al., 2020; Rail Baltica, 2019).

A workflow is created to assist the knowledge of IM in the initiation phase. It enables having a strategic opinion on the significant collaboration of all concerned parties in the BIM process. According to the planned project phases, the workflow is arranged vertically as follows: Initiation.

Moreover, it is arranged horizontally into processes and information exchange. In the "Processes" part, all activities, relationships, and stakeholders concerned are included. The "Information exchange" lane comprises the whole documents, files, and models exchanged in the process. Furthermore, they include how this information is relevant to the activities.

An arrow with a solid line is utilized for the workflow relations to display the sequence of activities flow. Concerning the files exchanges, a dashed line with an arrow is utilised. But the events, activities, and gateways, the symbols are displayed in the legend. A color scheme is utilized to characterize and smooth the perception of the stakeholder engagement in each activity (Figure 2). The developed workflow is presented in the subsequent subsection.

The workflow starts from this stage, where the owner defines information requirements and defines EIR, AIR, and BEP. In this phase, the design team, quantity surveyors, contractor, and facility manager have communicated the specifications and considerations required in the EIR, AIR, and BEP, as shown in Figure 2.

Moreover, some aspects to consider are the model's WBS, the measurement rules followed, modelling requirements, what classification system will be applied to correlate model and bill of quantities, and necessary parameters for 4D and 5D, etc. Accordingly, the contractor presents and develops the BEP, which must be shared with the concerned team.

Figure 2 shows the developed process map. It is possible to understand well the information flows via the whole process during the Initiation phase. It demonstrates that stakeholders interact, exchanging information and associated tasks. Moreover, this workflow can be properly utilized by organisations associated with BIM projects to gain strategic insight into handling information, anticipate potential problems, and planning how to handle information effectively. Also, for modifying the workflow or use on various projects, the firms require that the aims of BIM adoption, stakeholders, responsibilities, and outputs be defined.

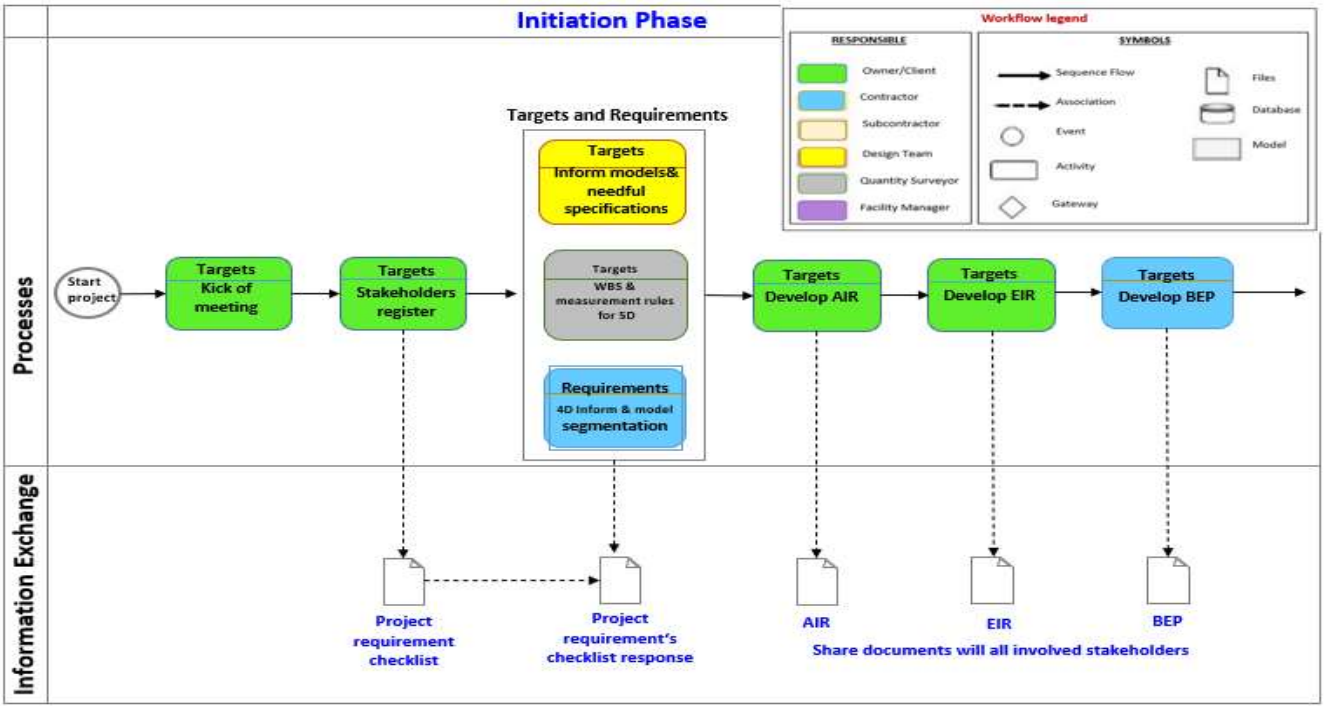

Figure 2: The Proposed Workflow

5. Validation of Workflow

This section provides full details of the collected data analysis from a real-life case study and discusses the findings and expert validations of the workflow.

5.1 Case study analysis

Case studies validation of the developed workflow SM system was carried out in real-life infrastructure projects in Qatar.

Relevant data from workflow components were collated for infrastructure projects. Also, relevant BIM models and SM-related data for the project were gotten to undertake the assessment process.

The case study is selected based on mega projects value multiple US$ billion, where the researcher was a project manager. Since the current projects in Qatar bear good sources for this study. It is important to confirm that the confidentiality factor is considered by not mentioning the project's information and details or the organization's name. Also, the names of interviewed personnel's due to some organizational consideration and

based on ethical factors declared by Goodpaster (1991) such as; the special social interactions within an organization, keeping stakeholders right in not mentioning their names and, the organization right in not mentioning the project's information or organization's name.

The case study findings are obtained from this organization's experience and interviews conducted with its staff, consultants, contractors, and suppliers dealing with this organization and having broad experience worldwide in working in the MCPs. Based on the coordination with the owner, contractor, and consultant, the workflow was defined and implemented.

5. 2 Validation survey and experts' demographics

The questionnaire forms were designed to validate the proposed workflow to validate the propriety, effectiveness, credibility, ease of use, efficiency, the usefulness of it to aid and improve the implementation of SM practices in CI.

The experts were asked to rate their agreement level on these validation questions (Q) based on a 5-point Likert scale (1= strongly disagree; 3= Neutral; and 5= strongly agree). They must have sufficient experience and knowledge in BIM and SM issues in the CI. Based on these criteria, the targeted experts were identified and sent the survey forms. Overall, a valid 18 responses were received from the respondents. Table 2. displays the experience information of the invited experts. The sample size for the validation survey is satisfactory for further analysis compared with past studies, which utilized 6, 7, and 5 respondents (Ameyaw, 2014; Darko, 2018; and Osei-Kyei, 2018), respectively (Olawumi, 2020).

Based on the analysis of the expert demographics (Table 2.), the experts are from diverse groups of key professional stakeholders engaged in the CI and own adequate years of experience in this issue. Additionally, more than two-thirds of the experts are either in a top-level managerial position or in middle-level roles, which presents that the invited experts own the Fundamental experience in the CI. The demographics analysis of the invited experts additionally provides credence and reliability to the data collected for this validation practice.

Table 2.: Experts' demographics concerning the validation process

Description	Frequency	Percentage (%)	Description	Frequency	Years of experience
Principal position			**Positions**		
Project director	1	5.55	Top-level managers	10	≥ 15
Project Managers	3	16.67	Middle-level staff	5	10 - 15
BIM Managers	3	16.67	First-level staff	3	5 - 10
BIM Coordinator	2	35	**Total**	**18**	
Control Managers	2	11.11			
Quantity Surveyors	3	16.67			
Architects	1	5.55			
Civil Engineers	2	11.11			
Academics	1	5.55			
Total	18	100			

Table 3. shows the analysis of the level of agreement of the invited experts to the eight validity statements. The eight questions relating to the proposed workflow developed. Otherwise, six of the validity questions (Q) have a mean value of more than 4.00, and the remaining two – Q3=3.95, Q6= 3.98, which is classified as “very important” according to (Li et al., 2013). Hence, the experts’ perception analysis implies that the proposed workflow's four validation aspects – internal, external, construct, and content validity – are adequate.

The questions relating to external validity are Q1 and Q8; otherwise, Q6 and Q7 relating to the internal validity, and Q2, VQ3, and VQ4 refer to the construct validity, While Q5 relates to content validity. Therefore, the high mean scores attained by the four validation aspects of the proposed workflow demonstrated credible, reliable, replicable, comprehensive, proper, inclusive, and suitable for advancing IE&SM practices in the MCPs in CI.

Table 3.: Validation survey outcomes

Code	Validation statements/questions	Mean	IE Workflow
Q1	The required documents in the workflow component and its process map are sufficient and proper.	4.09	√
Q2	The identified attributes are adequate and appropriate.	4.21	√
Q3	The information required from workflow component is sufficient to assess a SM performance at initiation phase are adequate and appropriate.	3.95	√
Q4	The proposed workflow is inclusive, complete, and in a rational and consistent structure.	4.03	√
Q5	The appropriate use of the workflow would lead to a successful implementation of SM in CI.	4.21	√
Q6	The proposed workflow Is easy to understand and easy to apply.	3.98	√
Q7	The workflow adequately handles the purposes and objectives of the thesis.	4.01	√
Q8	The workflow is proper and sufficient to implement the smart SM in CI, especially in MCPs.	4.06	√

5.3 The Observations on the Proposed Workflow Application

Some observations and ideas could be added to the workflow for further developments as follow.

- The suggestions included adding BIM uses related to the procurements.
- The procedures of ownership of the model with the subcontractors.
- Implementing it in another procurement such as IPD
- It is better to assign responsibility attributed to the contractor rather than to the client's BIM Manager.

5.4 Evaluation’s Feedback

The proposed workflow is a roadmap aiming to improve the operations of MCPs, keeping them on the right track, and potentially replacing the negative image of MCPs with positive impressions. The validated workflow provided a practical conceptual solution, based on BIM, to address project teams' challenges on MCPs. The preparation of a BIM execution plan (BEP) is deemed collaborative work. Regarding the BIM execution plan provided at the project start. The processes detailed in the BIM execution plan were not strictly utilized. Instead, they were seen more as guidelines to guide practitioners in their actual work. Here, the participants mentioned that

practitioners' principal criticisms about the execution plan do not consider the requirement in a fast-track project for different disciplines to coordinate with each other. Moreover, the participants adopted the collective idea of advancing the models and performing interference detection at planned moments when the appropriate elements had been appropriately modelled.

6. Discussions

During the project initiation phase, an organization's executive team usually involves small resources to develop the initial project information. The researcher recommends that institutions identify stakeholders during the first phase. The goal/ purpose of this stage is to define the project needs that achieve the client's satisfaction and obtain approval to proceed for the second stage smoothly and help build a more reliable phase. Initially, all the stakeholders will be identified; the Engineer is responsible for identifying all project relevant stakeholders who have an influence and/or interest in the project. After identification, they will be incorporated into the stakeholder register. After listing the entire project stakeholders in the stakeholder register, their need has to be identified concerning the project work and requirement. Different types of stakeholders should be treated with their requirements and expectations. The contractor shall comply with all SM requirements and as directed by the Engineer. Public outreach and awareness plan shall be made at the initial stages of the project; the awareness plan shall include the following as a minimum:

- Adhering to the Stakeholder Communications Guidelines on what communication channel(s) to use for each category;
- Adhering to the Stakeholder Communications Guidelines and templates on stakeholder engagement to include, but not exclusive to;
- Adhering to the Stakeholder Communications Guidelines on messaging surrounding the project.

As combine with stakeholder identification, public complaints, and requests management plan, plan for licensing and approvals from agencies, and as-built approval management plan will also be made at the initial stage of the project. This phase is more strategic as it provides the fundamental management elements to implement the following phases successfully. Thus, a strong and capable management system is required to plan and implement this phase significantly.

The main sub-elements of the Initiation stage are defined as follows:

- Stakeholder register
- Interface matrix
- Organizational information requirements OIR.
- Asset information requirements (AIR).
- Employer's information requirements EIR.
- Proposed list of Stakeholders, Permit requirements, and associated RACI.
- Stakeholders' coordination methodology
- Stakeholders Log & Communication Protocol.
- Stakeholders Action Plan Flow Chart.
- Permit Application Process
- BIM execution plan.
- Modelling guidelines.
- Work process & BIM responsibilities.
- Hardware & software platform.
- Defining project scope & priorities.
- Defining objective.

7. Limitations and assumptions of research

The limitations related to this research are briefly outlined as follows:

- The research was carried out in the State of QATAR. So, the findings are limited to the Qatari construction projects.
- The construction industry in Qatar is different from other countries where public projects have the priority to develop the infrastructure of the country prior to the world cup competition.
- The scope of this research is limited to the MCPs.
- The impact of low awareness and knowledge of SM not considered.

However, the study is still reasonable and fortunately, it is suitable to evaluate the SM in MCPs.

8. Conclusion

This paper discussed a new approach for implementing BIM into the traditional construction management workflows in order to integrate the various information exchanges between BIM processes and stakeholders.

This paper gradually analyzed the impacts of BIM on information exchange between project stakeholders. In the end, we concluded that the adoption of BIM may produce new information source, create richer, more clear and accurate information, improve the efficiency of information transmission and reduce the possibility of wrong interpretation of information. Even though, we think that this paper can give project managers some advice to realize better management and to decide if they should adopt BIM.

This study was established to develop the information exchange and management workflow using BIM. Additionally, the workflow used on which was specially designed for MCPs. Also, information requirements and workflow were setting up via the project initiation phase. The information created and needed for the phase and concerned stakeholder must be managed according to its actual usage, scope, and aim.

Moreover, this study declared that the initial stakeholder's engagement could enhance the information usability on project stages. Following the requirements are defined, the key stakeholder," owner, contractor, and facility manager," assists in setting IE procedures.

Also, determining information parameters and technical specifications for construction and operations support adopting and applying the model in BIM practices.

Also, the study clarified the significance of perfect information exchange, mainly among various stakeholders, considering the interoperability of the applied systems.

The study participates in the perception of information flow in project and how can control it during the initiation phase. So, the outcomes will be of interest to stakeholders involved in a strategic view of the project.

The outcomes of this research are beneficial not only to practitioners, but also to others who are concerned about IM. The weak enforcement of IM may create some unforeseen

outcomes which could not achieve the owner's satisfaction. The study outcomes contribute to and develop the goals of IM approaches and reinforce its implementation. The research conclusions give a roadmap to stakeholders and enhance IM in MCPs. Generally, the study's outcomes contribute to and develop the goals of IM and construction industry.

9. Recommendations

Based on the current study outcomes, the following recommendations and practical strategies are described for the involved stakeholders for improving the adoption of smart and SM practices in the CI. These comprise the following:

a. Future research studies can focus on further improvements on the workflow and its deployment in construction projects in other contexts.
b. Future research could investigate solutions for integrating the information generated in the BIM process with FM systems, considering open formats possibilities.
c. Government authority, and professional bodies, should provide synergy toward delivering financial incentives to construction firms to support their adoption of smart SM practices.

Therefore, this research recommends that construction key stakeholders adopt dynamic and positive attitudes to IM. Also, they are advised to be proactive in adopting efficient IM approaches in their projects to improve and ultimately project success.

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