BIM-based Sakeholder Information Exchange (IE) During the Planning Phase in Smart Construction Megaprojects (SCMPs)

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Abstract

Purpose – Information plays a significant role in managing construction projects. The architecture, engineering and construction (AEC) industry encounter a massive information exchange (IE) challenge. This study aims to develop a BIM-based stakeholder information exchange (IE) workflow scheme during the planning phase in smart construction megaprojects (SCMPs) that faces a massive IE challenge, especially during the COVID-19 pandemic. Design/methodology/approach – To accomplish the above stated goal, a research approach including a literature analysis, case studies, and survey questions was developed. Based on the aforementioned, the study created a BIM-based IE workflow to simplify the implementation of IM in SCMPs. Findings – This study has yielded an extensive insight into the types of information exchange, difficulties, and ways to its hand over. In the context of CMPs, The research conceptualised BIM&SM synergy and proposed IE Workflow strategy during the planning phase in MCPs. However, IE needs to be planned from the beginning of the process, agreed upon between different parties, tested, and verified. Research limitations – The scope of this research is limited to the SCMPs during the planning phase. Practical implications – This study contributes to the developing body of knowledge addressing the application of BIM& IE synergy during the planning phase in SCMPs. The outcomes of this research will be beneficial for clients, contractors, and project managers, when taking into account in future plans. Originality/value – This study provides contributes to understanding information flow during the project planning phase and how to control it properly. Generally, the deliverables of this study could be utilized by professionals engageded in BIM and SM practices on SCMPs to enlightens and enhance information exchange and the utilization of the produced information throughout the entire process.

Keywords: Building Information Modelling (BIM); Information management; Workflow; Smart Construction Megaprojects (SCMPs).

1 Introduction

Information plays a significant role in construction project management. It is generated at different project stages by various parties, providing additional value to various stakeholders (Ahmed, S., 2018). Also, as construction projects become more complex, much information must be communicated, coordinated, and exchanged along project life cycle (PLC) (Elgendi, A.F., et al., 2021). In that context, Building Information Modelling (BIM) is one of the popular, efficient tools utilized in the construction sector to facilitate the

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exchange and manage information (Elhendawi et al., 2019a). A high volume of information needs to be communicated, coordinated, and exchanged throughout the building process.

PAS 1992-2:2013, is considered one of the primary standards developed about IM. It defines IM as "tasks and procedures applied to inputting, processing and generation activities to ensure accuracy and integrity of information". In that context, ISO 19650 international series standard is one of the leading publications in the past years on digital IM, concentrating on buildings and civil engineering. In contrast, ISO 19650 employs BIM to guide and standardise IE on construction projects. Furthermore, BIM seems to be an efficient tool for centralising and managing the information via PLC (Xu et al., 2014).

Although, BIM helps centralize information and standardize IM, some challenges are still related to interoperability, accuracy, and delivery format (Elhendawi, A.I.N., 2018; Shaban, M.H. and Elhendawi, A., 2018.). For instance, Cavka et al. (2017) stated that the absence of BIM experience needs information. Besides, Pishdad-Bozorgi et al. (2018) illustrated the issues of importing and utilizing data from design and construction phases to operations phases. These instances brought attention to the need for more profound studies on IM using BIM. Accordingly, analysing information processes and exchanges between different stakeholders via PLC is essential given these limitations in existing SM tools, knowledge, and practice (Evans, M. et al., 2020b).

1.1 Research objectives

This study seeks to discuss the challenges of BIM&IM synergy and develop a BIM-based stakeholder information exchange (IE) workflow through planning phase to simplify smart SM performance in (SCMPs).

The study objectives are:

RO1. Establish a broad background concerning the research issue and IM, as well as the challenges of executing IM in SCMPs;

RO2. Investigate the organizations perception towards the challenges of IM implementation in SCMPs; and;

RO3. Develop an IE workflow to ease BIM&IM synergy during planning phase in SCMPs.

2 Literature Review

2.1 BIM Overview

BIM has been described in different ways, for example, 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 everyone throughout its life cycle can use." Furthermore, Abanda et al. 2015, described BIM as a "digital technology that", could enhance the efficiency of delivering construction projects and could yield a higher return on investment (Olatunji et al. 2017b; Evans et al., 2021b; 2021c). Likewise, BIM is described as "a group of applications and processes capable of generating and managing project information via the project development phases with multiple advantages to project stakeholders". (Olatunji et al. 2017b). It is progressively permeating the construction industry (CI) due to its potential ability to enhance project practices in design, procurement, prefabrication, construction, and post-construction (Cao et al., 2015; Evans et al., 2020a; 2020c; Elhendawi et al., 2019b).

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2.2 Information Management

Information is described according to ISO 19650:1 as "a formalized use of data suitable for transmission, interpretation or processing." It may be divided into two categories: organized (such as geometric models, timetables, and databases) and unstructured (documentation, sound recordings). Information management (IM), which is defined by PAS 1992-2 as the procedures and processes used to ensure the correctness and integrity of information about activities that occur on the input, process, and output, is another crucial idea. Every stage of the project generates information, which needs to be effectively managed. BIM is a cutting-edge method of managing project information transferred between project stakeholders, ensuring the standard and raising confidence in the veracity of what is given (EFCA, 2019). Generally, IM is a procedure to guarantee and make sure that particular information developed for a predefined goal is delivered to the right location at the right time (UK BIM Framework, 2020). According to the PMI (2017), it is crucial to comprehend who needs each piece of information, who can access it, when it is required, and where it can be located. The structure of the information, how it may be accessed, and any potential obstacles, such cultural differences, are all major issues.

2.3 Stakeholder involved

Defining and evaluating the stakeholder and their expectations is essential (PMI, 2017). The stakeholders selected for this workflow have traditional roles involved in the CI, while they should own experts with BIM skills since they are engaged in BIM process. The roles considered and a summary of their functions are mentioned as following: 1) Appointing Party (Owner/Client): The owner is responsible for determining project purpose, like function, schedule, and budget (AIA, 2007). Moreover, to be responsible for selecting the engaged crew, type of contract, delivery processes, and definition of general specifications and conditions (Sacks et al., 2018; Mashali, 2020a; Mashali, 2020b); 2) Appointed Party (Contractor): Responsible for performing and coordinating project construction. Besides, he manages construction activities' time and cost (AIA, 2007); 3) Subcontractor: Party hired by the contractor to execute specialized technical services (Sacks et al., 2018); 4) Design Team, which comprises architects and engineers responsible for project design, where most project information are characterized (Sacks et al., 2018); and 5) Quantity Surveyors (QS) who are responsible for quantity take-offs and cost estimation. Furthermore, QS could be considered under the contractor's responsibility.

2.4 Standards

It is substantial to decide the applicable standards and guides for the project. The aim is to define a solid procedure for the collaboration of all parties, aligning the work with industry standards (BIFM, 2017). Standards and guides applicable to country of work for IM and AIR need to be verified. The responsibility for verifying standards' compliance is illustrated in Table 1.

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

BIM 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

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	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 and Data Collection

The proposed workflow was developed and validated by the study using a mixed research approach. It encompasses conceptualizing the proposed workflow, case studies, and expert survey validations of the workflow.

3.1 Method of data collection

As shown in Figure 1, a schema is made to help stakeholders cope with BIM and IM in all project phases based on Sousa, et al. (2020), Mashali, et al., (2021) and Rail Baltica (2019). From a conceptual standpoint to its applications, starting with the BIM sector, it offers the structure of information levels that pertains to the subject matter of this work. The discussion of information needs that may be included in the Employer's Information Requirements (EIR), Asset Information Requirements (AIR), BIM Execution Plan (BEP), and Process Map to Exchange Information in Every Phase is part of the enhancement of these work deliverables.

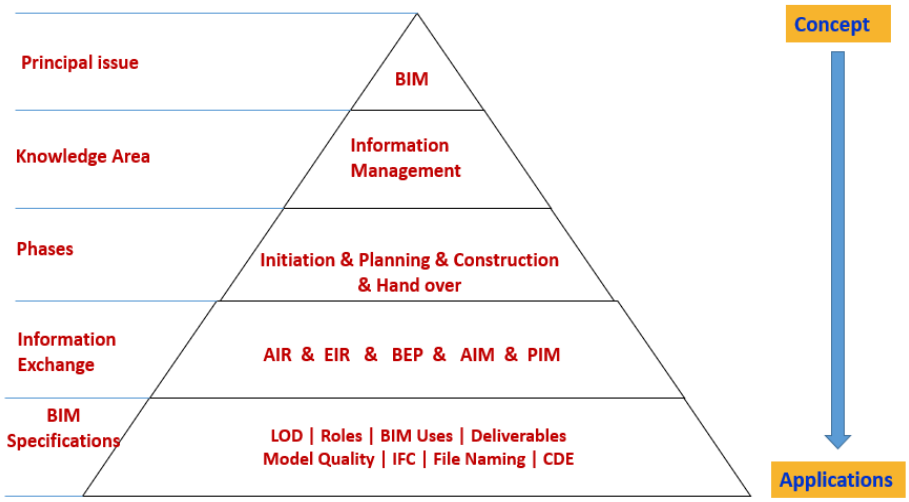

Figure 1. Information's Structure (Mashali, et al., 2021; 2022)

4. Proposed Workflow

This proposed workflow is an integrated process concentrating on IE during the planning phase. This principle seeks to enhance the decision-makers' abilities to deliver a sound and solid strategic management basis for IE development. It is inspired from (Mashali, et al., 2022; Penn State, 2019; Sousa, et al., 2020; Rail Baltica, 2019). To help with the understanding of IM during the planning stage, a workflow is created. It makes it possible to form a strategic view of the crucial collaboration of all parties involved in the BIM process. The process is set up vertically as follows, in accordance with the planned project phases: Planning. Additionally, it is horizontally organized into processes and information sharing. All relevant actions, connections, and stakeholders are included in the "Processes" section. The complete set of papers, data, and models exchanged during the

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procedure are included in the "Information exchange" lane. They also explain how this information relates to the activities.

For the workflow relations, a solid arrow is used to show the flow of the various activities. The file exchanges are indicated by a dashed line and an arrow. However, the tale shows the events, actions, and gates as well as the symbols. To describe and improve the impression of the stakeholder participation in each activity, a color scheme is used (Figure 2). The next subsection presents the created workflow.

The owner determines the information needs at this stage, which also includes the definitions of EIR, AIR, and BEP. The requirements and factors needed for the EIR, AIR, and BEP have been communicated by design team, quantity surveyors, contractor, and facility manager throughout this phase, as illustrated in Figure 2. Besides, there are a few aspects to think about, such as the model's WBS, the measurement guidelines used, the modeling needs, the categorization scheme to link the model to the bill of materials, and the parameters required for 4D and 5D, etc. As a result, the contractor produces and provides the BEP, which must be shared with the relevant team.

The created process map is displayed in Figure 2. During the planning stage, it is possible to grasp the information flows across the entire process. It depicts how different parties communicate and share duties and information. Additionally, organizations involved in BIM projects may successfully use this process to acquire strategic insight into managing information, foresee possible issues, and plan how to manage information efficiently. Additionally, the organizations demand that the objectives of BIM adoption, stakeholders, duties, and outcomes be stated before changing the workflow or using it on other projects.

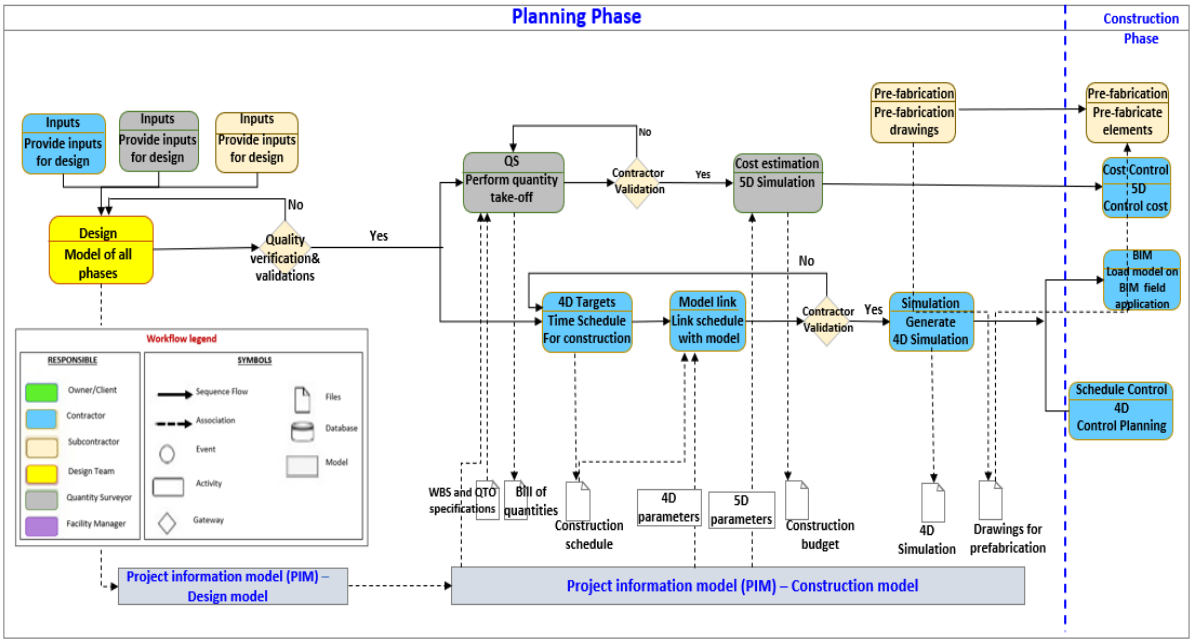

Figure 2. Proposed process map (Workflow)

5: Validation of Proposed Workflow:

The acquired data analysis from a real-world case study is fully described in this part, along with the conclusions and expert's validations of the workflow.

5.1 Case study analysis

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The workflow SM system was validated through case studies using actual Qatari infrastructure projects. Relevant data from workflow components were collated for infrastructure projects. In order to complete the evaluation procedure, pertinent BIM models and SM-related data for the project were also obtained. The case study was chosen based on megaprojects that the researcher managed and had a combined worth of several billion US dollars. Since Qatar's ongoing initiatives provide good materials for our investigation. It's crucial to demonstrate that the secrecy issue is taken into account by excluding any information about the project, its specifics, or the organization's name. Additionally, the names of the interviewed personnel were withheld due to organizational considerations and based on ethical principles outlined by Goodpaster (1991), such as the unique social interactions within an organization, respecting stakeholders' right to anonymity, and the organization's right to remain anonymous when discussing the project or its name. The case study's conclusions are based on the organization's experience and on interviews with staff members, consultants, contractors, and suppliers who work with it and have extensive international experience working in SCMPs. The workflow was established and put into place after consultation with the owner, contractor, and consultant.

5.2 Validation survey and experts' demographics

The proposed workflow's propriety, efficacy, credibility, usability, and utility to facilitate and enhance the application of SM practices in CI were all evaluated using the questionnaire forms. On a 5-point Likert scale (1 being strongly disagreed with, 3 being neutral, and 5 being strongly agreed with), the experts were asked to score their degree of agreement on these validation questions (Q). They need to have appropriate BIM and SM knowledge and expertise for the CI. These standards were used to identify the targeted experts, who were then issued the survey forms. A total of 18 valid re plies came from the respondents. The experience information of the invited specialists is shown in Table 2. In contrast to other research, The sample size for the validation survey is sufficient for further analysis compared with past studies, which used 6, 7, and 5 respondents (Ameyaw, 2014; Darko, 2018; and Osei-Kyei, 2018), respectively (Olawumi, 2020).

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 analyses the degree to which the invited experts agreed upon the eight validity assertions. Eight queries about the suggested workflow were created. Furthermore, six of the validity questions (Q) have mean values of more than 4, and the final two - Q3=3.95, Q6=3.98 - are rated as "extremely significant" by the classification system (Li et al., 2013). As a result, the experts' perception analysis suggests that the four validation components of the suggested workflow - internal, external, construct, and content validity - are sufficient.

Q1 and Q8 are the questions that pertain to external validity; otherwise, Q6 and Q7 are questions about internal validity, Q2, VQ3, and VQ4 are questions about construct validity, and Q5 is a question about content validity. As a result, the suggested workflow's four validation features received high mean ratings, which showed that

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they were credible, reliable, repeatable, thorough, appropriate, inclusive, and suited for developing IE&SM practices in the SCMPs 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 planning 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 SCMPs.	4.06	√

5.3 Observations on Proposed Workflow Application

The following observations and advice can be made to the workflow to help it develop further:

- The proposals included adding BIM uses related to the procurements.
- The procedures of the model ownership with subcontractors.
- Applying it to a different procurement such as IPD
- Assigning responsibilities to the contractor rather than the client's BIM Manager is preferable.

5.4 Evaluation's Feedback

The proposed workflow process can be viewed as a road map for enhancing SCMP operations, keeping them on course, and possibly eradicating the negative perception of SCMPs in favor of a positive one. The verified workflow gave project teams a realistic conceptual solution that was built on BIM to handle their SCMP difficulties. An execution plan for BIM (BEP) is created collaboratively. The protocols outlined in the BIM execution plan that was delivered at the project's beginning were not fully followed. Instead of, they were viewed as recommendations to help practitioners in their job. Here, the participants brought out how practitioners' primary complaints about the execution plan ignore the need for diverse disciplines to coordinate with one another in a fast-track project. Additionally, the participants agreed and adopted the collective idea of

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advancing models and performing interference detection at certain times when the relevant elements had been accurately modeled.

6 Discussions

Figure 2.0 shows the proposed process map during planning phase. It is possible to comprehend how information moves through the entire process to complete all project phases. It depicts how different parties communicate and share duties and information. Additionally, organizations involved in BIM projects may successfully use this process to acquire strategic insight into managing information, foresee possible issues, and plan how to manage information efficiently. Additionally, the organizations demand that the objectives of BIM adoption, stakeholders, duties, and outcomes be stated before changing the workflow or using it on other projects.

This phase focuses on applying BIM models to construction planning, and it is involved construction scheduling and cost estimation, as displayed in Figure 2.0. The required information considered is the WBS, considered units specifications, and rules of measurement. Accordingly, the generated information is the bill of quantities in a previously agreed format that is exact and beneficial. Hence, the primary responsibility for the tasks of the quantities and cost activities is the quantity surveyor. Furthermore, the 5D model integration needs the software choice and model rules to be agreed on previously to reduce information losses, allow quick feedback, cost analysis and simulations. Consequently, the output is the construction budget. The deliverables produced are utilized to plan the construction phase.

The researcher advises institutions to identify concerned stakeholders during the project planning phase to establish the project requirements that satisfy the customer and acquire consent to advance for the second stage smoothly and help develop a more dependable phase. Plans will be created for obtaining agency licensing and permissions in conjunction with stakeholder identification. Because it offers the core managerial components needed to properly implement the next phases, this phase is highly strategic. Therefore, to plan and implement this phase effectively, a robust and capable management system is needed. Following is a definition of the primary sub-elements of planning stage:

- Pre-qualification Questionnaires
- Request for Information (RFI's)
- Permitting Manual
- Permits & Approval Procedure
- Permits Log
- Permit Tracking Sheet
- Any required Memorandum of Understanding (MOU)
- Environmental Risk Assessment
- Environmental Permitting time Schedule

7 Conclusion

In order to connect the different information exchanges between BIM processes and stakeholders, this study explored a novel method for integrating BIM into the established workflows for construction management. The effects of BIM on information sharing amongst project stakeholders were gradually examined in this article. In the end, we concluded that adopting BIM may result in additional information sources, richer, more reliable information, improved information transmission efficiency, and a decreased risk of incorrect information

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interpretation. Even so, we believe that this article might provide project managers with some guidance on improving management and determining whether or not to embrace BIM.

The purpose of this study is to improve the workflow for information management and exchange using BIM. Furthermore, the workflow applied on which was created especially for SCMPs. Through the project planning phase, information needs and procedures were also established. The produced and required information for the stage, and the relevant stakeholder must be handled in accordance with its intended use, scope, and objective. Additionally, this study stated that early stakeholder participation might improve the usefulness of the information during planning phases. The owner, contractor, and facility manager are the primary stakeholders who help determine the IE processes after the requirements are clarified. As well as supporting the adoption and use of the model in BIM processes, identifying information parameters and technical requirements for construction and operations.

The study also made clear need of flawless information transmission, particularly across different stakeholders, when considering the interoperability of the used systems. The study takes part in how project initiators see information flow and how it might be managed. Therefore, those participating in the project's strategic perspective will be interested in the results. The findings of this study are helpful to practitioners as well as to others who are interested in IM. Weak of IM enforcement may have unintended consequences that the owner may not be satisfied with. The study's findings advance the objectives of IM strategies and support their use. The research's findings improve IM in SCMPs and provide stakeholders with a road map. The study's findings generally advance and further the objectives of IM and CI.

8 Limitations and assumptions of research

The following is a summary of the research's limitations:

- The research findings are restricted to Qatari construction projects.
- The scope of this study is limited to SCMPs.

However, the study is still acceptable and may be used to assess the SM in SCMPs.

9 Recommendations

In order to increase the adoption of smart and SM practices in the CI, the following recommendations are provided for the concerned stakeholders based on the findings of the current study. They include the following:

- The workflow's implementation in construction projects in different contexts and potential future enhancements might be the subject of future research investigations.
- Future studies may look into ways to integrate the data produced by the BIM process with FM systems, taking into account the potential of open formats.
- To facilitate the implementation of smart SM practices by construction enterprises, government authority and professional bodies should collaborate to offer financial incentives.

Therefore, this study recommends that key players in CI develop proactive and upbeat attitudes about IM. They are also counseled to employ effective IM strategies early on in their projects to boost productivity and, eventually, project success.

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