15 BIM Coordination Oriented to Facility Management

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Abstract

BIM coordination is an iterative process that requires an accurate roadmap to adequately manage the exchange of information, overcome communication barriers, improve the decision-making environment and guarantee a successful and collaborative work throughout the project's lifecycle. Although the actual coordination practice satisfies the requirement of routing the whole systems in a proper way, it presents a lack of sequential, constructability, operation and maintenance issues. In order to contribute to the BIM coordination process knowledge, this paper introduces a coordination methodology that is based on the sequential approach and includes O&M (Operation and Maintenance) criteria. Regarding the previous idea, the project information should be organized in a coordination matrix that adds accessibility, functionality and installation requirements to each discipline. This proposal guarantees that the maintenance criteria and physical constraints are consistently meet, preserving a continuous flow and identifying wastes, delays, rework and cost overruns from the first stages of the buildings lifecycle. The suggested methodology aims to generate a more efficient coordination process which ensures that all efforts are headed in the right direction. As a result, the coordinated model will become the As-Built one.

Keywords

Building information modeling (BIM) • Coordination • Facility management

15.1 Introduction

Building Information Modeling (BIM) is the integration of technology, people and procedures with the intention of reaching a building's desired performance in terms of schedule, costs, systems disposal, sustainability, among others. The vehicle that allows this assimilation is a BIM model, defined by Azhar et al. [1] as "a 3D representation that carries all the information related to the building, including its physical and functional characteristics and project life-cycle information in a series of small objects".

A key aspect that BIM consolidation changed notably is coordination, defined as the disposal of all of the systems into the building's envelope, in a way that avoids common interferences which may result in rework and over costs. Coordination used to be a conflictive, strenuous, large and difficult chore, due among other aspects, to the lack of willingness of design consultants to reroute their systems and also to an inaccurate management of information. Although many procedures have changed with the inclusion of BIM, some authors argue that there is a general avoidance of maintenance requirements in the coordination efforts [2–4].

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To partially solve this problem, this article seeks for a strategical coordination methodology that besides integrating all systems on a harmonious way (by satisfying critical design criteria and constructability issues), also addresses maintenance concerns [2]. This means that all systems are located in a way that allows accessibility for subsequent operation and maintenance labors on the facility and improves the space management performance.

This article will chase the following sequence: first, a general overview of the state of the art of systems coordination is exposed in Sect. 15.2. In Sect. 15.3 we describe a proposal for integrating accessibility criteria faced to facility management during the coordination process. Finally, conclusions, limitations and further research are drawn.

15.2 The State of the Art of BIM Project Coordination and Facility Management

Systems coordination is mandatory between the design and construction phases of the project's life cycle. The main purpose of the coordination process is foresee on site the constructive interferences in order to reduce rework costs during the construction phase by using preliminary designs of all the systems [4]. According to a study conducted by Love et al. [5], these costs represent almost the 10% of the total construction cost. To achieve an outright coordination is fundamental an integrated design process. This means that all members of the project's team should be included from the preliminary and, while the project proceeds, they are able to make decisions that concern the effective delivery of the project delivery, in a collaborative way.

Before the adoption of the BIM collaborative procedures, the design coordination was driven by the physical overlapping of drawings (or layers), also called 2D coordination, requiring many coordination meetings to route the systems and determine which trade was making the change [4]. This was an iterative non-ending process, because all systems must satisfy several kind of constraints, and all the parties are unwilling to change their designs.

Another obstacle that design consultants, constructors, and facility managers face during the coordination process is managing the flow of information. The uninterrupted modification of the designs during coordination meetings may provoke out of date versions. Other possible obstacles include design complexity, avoidance of constructability and functionality matters, difficulties related to interference detection in depth (for example ducts), among others [4]. This occurs especially in MEP (Mechanical, Electrical and Plumbing systems) coordination.

Korman and Tatum [4] identified the importance of a methodology for the MEP coordination to avoid some of the issues stated below. In order to solve these problems, the authors improved the SCOP (Sequential Comparison Overlay Process) that is the current identification of physical interferences, by highlighting the integration of design criteria, construction experience and operation and maintenance knowledge. They also assemble some of the typical interferences between the architecture of a building and its systems, proposing a way to avoid them during the coordination process. Later, the information provided by this process, would contribute to the MEP coordination scheme using BIM.

The development of the BIM methodology supposed a significant evolution in the manner that project coordination was developed. By using BIM, all participants are able to access an updated 3D representation of the building including its systems, on a collaborative environment. In accordance with the paragraph above, Korman et al. [2] identified a huge potential of this tool and came up with an improved version of the SCOP process, calling it SCOPE (Sequential Comparison Overlay Process Evaluation Method). This improvement establishes that MEP coordination must follow a hierarchical order to shorten the rework and coordination meetings. The routing of systems should begin from the biggest and stiffest one (HVAC dry system) to the smallest and more flexible one (Control and telephone) [2].

Khanzode et al. [6] exposed a case study applying BIM coordination tools, reaching similar conclusions to the SCOPE approach. Starting with the building's envelope (architecture and structure) to its core (MEP disciplines), each system was disposed considering the physical constraints defined by the envelope and the already coordinated ones [7]. They also found out that BIM coordination follows a sequential process, instead of a Parallel one, as was commonly assumed by the literature.

Lee and Kim [7] applied both sequential and parallel coordination techniques to a pharmaceutical building with the purpose of making a comparison between productivity and flow of information. They concluded that the sequential coordination is three times faster than the parallel one because it allows the adjustment making, based on already coordinated models, so irrelevant information is ignored. On the other hand, parallel coordination tends to be a chain of circular changes, because everyone is working at the same time without enough information related to other disciplines.

In relation to FM (Facility Management), the ISO 41011:2017 [8], establish that is "an organizational function which integrates people, place and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business". On the BIM environment, FM is considered the seventh dimension and its main target is the collection of the buildings life-cycle information for operational and maintenance mediation. Some authors believe that the mixture of relevant data, design and construction criteria may help to reduce operational costs. Kassem et al. [9], by referencing the BIM Task Group, assures that these amounts are near three times the building construction cost during the O&M phase.

Some uses of BIM in FM applications are maintenance work, space planning and management, inventory management and inspections, move and real estate portfolio management [1]. The increasing development of BIM in FM applications has encourage some Governments to conceive regulations related to building's data acquisition for Operation and Maintenance purposes, such as the United Kingdom law PAS 1192-3 [10]. However, BIM relation to FM is still a trending research topic, and there are several reports related to BIM software interoperability with FM platforms [11], information requirements for corrective maintenance or even BIM and 3D point cloud integration to track MEP components maintenance [12].

In this line, the international standard COBie (Construction Operations Building Information Exchange), arose with the idea of gathering the created data in design and construction phases of a facility, to support the operation and maintenance phases [11]. COBie is a list of assets and spaces that uses a codification system (OmniClass) to register information as the project moves forward. This tool results imperative for collecting operational documents that may bring some benefits such as reducing the detection time of abnormal conditions or even avoiding destructive testing [11].

With the aim to contribute to the body of knowledge of FM with BIM, this study exposes a proposal of a coordination methodology based on the sequential procedure, which includes FM requirements to warrant adequate spaces for all of the components of a certain room. This proposal assures the accessibility for further maintenance works. Having this in mind, the iterative process will have a double function: routing each system by satisfying physical, design and other constraints and generating an accurate model for the whole asset lifecycle [13].

15.3 The Relationships in the Buildings Lifecycle

The general BIM coordination process starts with the collection of 3D models that reflect pre-designs of all of the systems that conform a facility (all of them share an unmovable origin point in order to assure both vertical and horizontal alignment). Later on, all the files are exported to an IFC (Industry Foundation Classes) format that allows their introduction to any coordination platform. Once the files are added, the intra-discipline tests are created, with the aim of making the interference checkups, 3D model corrections and generate rules that exclude admissible interferences by following a defined coordination procedure.

Our proposal of a coordination methodology took shape with an already existing resource: a coordination matrix based on the Singapore BIM guide [14]. This five by five matrix, incorporates the main disciplines that conform a facility in the following order: Architecture (Arch), Structure (Str), Mechanical (M), Plumbing (P) and Electrical (E). This disposition is based on Lee et al.'s proposal [7], ordered by the following hierarchical criteria: coordinating from outside to inside, from large to small and from hard to soft. The main diagonal of the matrix represents the restraint of all the duplicate tests or the ones that verify interferences between each system and itself. In other words, it diagnosis clashes due to double objects, which the native software did not catch previously, or even clashes between categories associated to the same discipline (e.g. nonstructural walls and ceilings).

The tests that are over the main diagonal are a transposed version of the ones that are located under it. Giving priority to the rows, coordination starts with the building's covering, continuing with its skeleton and finishing with its inner systems. Along each iteration, one discipline is coordinated each time. In the following iterations, the other trades are modeled around it, and so on [15]. The goal is that the coordination process moves along each row and under the main diagonal, following the introduced ranking. Other aspect to take into account, especially with MEP components, is the space allocation, which is adhered to certain predefined zones for routing each system [14]. In summary, the Singapore's BIM Essential Guide for Collaborative Virtual Design and Construction coordination methodology is based in prioritizing intra and inter discipline checks.

15.4 The Inclusion of FM During the Project's Life Cycle

Several authors consider that the traditional approach of project conception and delivery, is focused merely on design and construction phases, avoiding operation and maintenance issues on important stages of a project [2–4]. As claimed by Korman and Tatum [4], due to a lack of communication between designers, constructors and operation personnel, is difficult to integrate O&M (Operation and Maintenance) knowledge on the coordination process [3], bringing difficulties such as rework, out of date information and a hindered decision making mechanism.

On the other hand, the Integrated Project Delivery (IPD) approach considers the enrollment of all the parties that are related to the project's life cycle (including the Facility Manager), since the early stages of the activity. Thus, each part is offering its experience and knowledge to warrant a single cause: adding value to the project and satisfying the client's requirements. Korman and Tatum [4] identified that each part provides different criteria: design consultants know to perform coordination and are the ones that must follow the routing rules; constructors are the ones that evaluate constructability issues and operation/maintenance managers are in charge of foreseeing how the building is going to be used.

With respect to the previously exposed ideas, the coordination matrix for an integrated focus is complete since the early stages of the project's lifecycle. Therefore, it should be an establishment of the information needed to ensure an organized operation process (minimum distances required for O&M) from the predesign phase. Moreover, in the traditional approach, the coordination matrix does not exceed two dimensions, because the architecture gives its general guidelines to all the parties and hardly integrates all of the incoming info. This lack of information management is one of the reasons why decisions are taken without conceiving the forthcoming facility's use.

The Singapore's BIM Essential Guide for Collaborative Virtual Design and Construction suggests a quality coordination review to develop beforehand the delivery of the coordinated model. This covers General, Code compliance, Constructability and Maintainability checking. In this case, Maintainability checking allows a coordination oriented thought that leads with potential accessibility difficulties and other functional types of interferences for operation and maintenance purposes. This quality review is the previous step before turning the design coordinated model into the construction one.

15.5 The FM Coordination Matrix

The FM coordination matrix, combines the pre-established guidelines in a coordination methodology that includes facility management criteria on each discipline along the iteration process. This tool improves the traditional coordination process (which already covers codes and design standards) by adding O&M knowledge, with the purpose of reaching an As-Built coordinated model.

In line with the previous approach, the suggested matrix is divided into two main regions: the first one makes reference to the traditional BIM coordination matrix (focuses mainly on the disciplines) and the second refers to the incorporation of FM. Region one is composed by zones one to three, which include duplicates control and intra and inter-discipline interferences. On the other hand, the second region covers zones four to six, which incorporate accessibility and functionality additional reviews per discipline—zones four and five—and the priorities definition among FM criteria—zone six (see Fig. 15.1).

The proposed FM coordination matrix in addition of incorporating maintenance related reviews has also other uses, related to interferences concentration (color scale) and responsible identification (see Fig. 15.2).

The "Color Scale Use" allows the identification of trends related to the combinations of systems or cells that require greater effort in terms of iterations and routing criteria, in order to guarantee the operational efficiency of the facility. This identification can contribute to a later establishment of guidelines to resolve clashes in form of an interference control sheet. Moreover, the "Responsible Use" enables an identification of the disciplines who are in charge of redirecting or accommodating, so that the system that carries the priority can satisfy the proposed design, space restrictions, connectivity and other constraints.

The following Table 15.1 describes the relationship between the previously defined zones, the identified uses and FM incorporations. This ordering of information will certainly ease the decision making environment during the coordination process, allowing an immediate recognition of those responsible and detecting the systems that require a deeper analysis. It should be noted that the information that feeds the matrix with each iteration, must be exported from the native software with the intention of speeding up the coordination process.

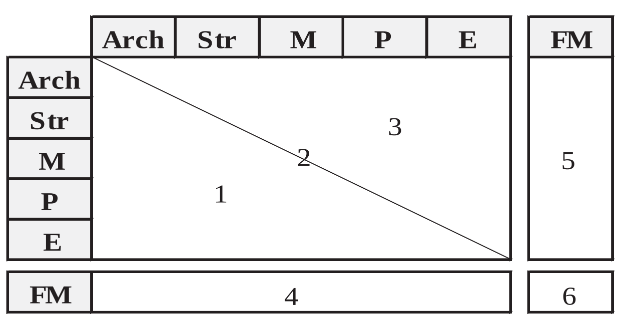

Fig. 15.1 FM coordination matrix proposal

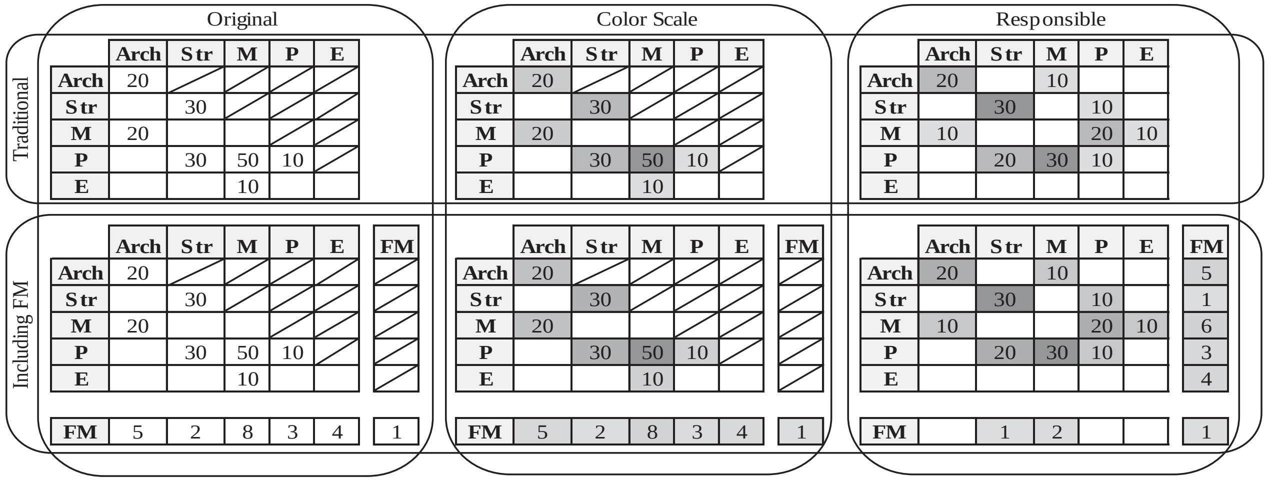

Fig. 15.2 Traditional and FM coordination matrix contrast

Table 15.1 The matrix relationship with the proposed uses

	Zone	Original	Color scale	Responsible
1	Inter-discipline interferences	Number of interferences among disciplines	Conflict zone (darkest cell)	Number of interferences solved by the trade of the rows
2	Intra-discipline interferences	Duplicate check	Critical intra-discipline system (darkest cell)	Auto corrections
3	Transposed version of 1	N/A	N/A	Number of interferences solved by the trade of the columns
4	FM criteria	FM requirements	Critical FM requirements (darkest cell)	Criteria conceded by the facility manager
5	Transposed versión of 5	N/A	N/A	FM criteria that has been solved by the trade of the rows
6	Intra-FM interferences	FM requirements	Critical FM requirements (darkest cell)	Remaining FM criteria

15.6 Results

The proposal of an FM coordination matrix is the result of the experience that has been gathered from the categorization, revision and control of the different emerging interferences, during the coordination process of some real estate projects. This iteration tracking made it possible to test the sequential coordination approach and identify its advantages in comparison with the parallel coordination methodology. One of those benefits was the gained productivity that results from the sequential approach.

After a thorough review of the literature, it was identified that the operational phase was lagging during the coordination process and this would be surely translated into over costs at the operational phase. The introduction of FM from coordination into the construction oriented model, in addition to ensuring the accessibility of the maintenance and operation personnel, allows an additional use that the Pennsylvania's BIM Project Execution Guide defines as space management and tracking [16].

15.7 Conclusions and Further Research

The research has contributed to understand the importance of including facility management in the coordination procedure. FM is introduced not as another discipline of the coordination matrix, but as a complement of each system coordination requirements. Those are related to accessibility, functionality, installation and other issues that are part of the operation and maintenance benchmark.

In this proposal, FM is not related with the code requirements or design parameters of each system because they are previously defined from the design phase. On the other hand, it reinforces the relationship between all disciplines and their systems in terms of clearance space, insulation and other attributes that mitigate operational concerns.

According to Kelly [13] "buildings are currently driven by short-term construction savings rather than operational savings". By applying an Integrated Project Delivery approach and the FM coordination matrix, both Facility Manager's experience and knowledge are included from the early stages of the buildings life cycle. This may certainly reinforce the decision making process, reducing reworks that materialize in cost overruns.

By integrating FM in the coordination procedure, there is an assurance that all the stakeholder's efforts are aligned into a unique direction: the buildings integrity during its lifecycle. Similarly, the implementation of the FM coordination matrix assures that the coordination exercise follows two main objectives: routing all the systems by satisfying design, operational and other constraints and also obtaining a model to count with before construction.

At the moment, there is a lack of knowledge related to the IFC export in terms of central and 3D separated files. This limitation is related to the management of certain properties from the native software, which may be required in the coordination procedure.

To turn into reality the introduced coordination methodology, further work regarding coordination by using a rule generator software (Solibri, Navisworks, among others) needs to be done. With the inclusion of COBie and some of the interferences and attributes identified by Korman and Tatum [3], we hope to produce an automated rule generator for clash detection. This tool will reflect the FM requirements that are part of the 4th zone of the matrix, by sending warnings when there are physical or operational interferences, till the elements involved satisfy the required restrictions.

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