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Implementation Framework for BIM Adoption and Project Management in Public Organizations

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Abstract: The arrival of Building Information Modelling (BIM) platforms to the Architecture, Engineering and Construction (AEC) markets and companies has led to a significant increase in efficiency in this economy sector. However, many AEC companies try to implement BIM as a normal or incremental change or improvement in technology rather than as a technological paradigm shift that radically affects most organizational processes. This paper aims to present a basic BIM framework amenable to ensure a successful BIM adoption in Brazilian federal public organizations. Based on a literature review, we propose to split the factors into three groups: project development procedures, model development procedures and public governance policies. Some processes were studied in order to infer which of them is necessary for a successful BIM adoption. A BIM implementation is expected to be a success only if all groups of factors are well defined and the established goals for each of them are reached. We also describe results of two concept proofs related to actual cases of BIM implementation, with changes in product and governance management processes. Main results show that any BIM adoption should consider the close relation among model management, product management and governance management groups.

Key words: BIM adoption, collaborative design, BIM, public works.

1. Introduction

The current main paradigm for project process managing is the Building Information Modelling (BIM). It can be defined as a set of associated technologies, processes and policies to produce, communicate and analyse constructive models, enabling the stakeholders to collaboratively design, build and operate a facility [1, 2]. It has been successfully implemented around the world, becoming a common practice in many countries and internal markets, whether public or private.

However, while the adoption of BIM is commonly related to significant increases in efficiency, many public organizations are unaware that BIM is primarily a process change that depends on a well-defined action plan to be successfully implemented.

This work aims to develop a management framework for BIM adoption in Brazilian public organizations, which encompasses all main factors that could guarantee an optimized implementation process.

This paper is organized in five sections besides this introduction: Section 2, with a literature review on BIM adoption and all factors related to a successful BIM implementation; Section 3 with the management framework enunciation; Section 4 with the description of two concept proofs in two different public organizations in Brazil; and a conclusion with the main remarks about results.

2. Literature Review

2.1 BIM Adoption in Public Organizations

Many countries around the world have adopted BIM. The United States is believed to be one of the pioneering countries for BIM adoption, and several of USA public-sector organizations in different government levels have established BIM programs, set up BIM goals, begun implementation roadmaps and created BIM standards [3].

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Apart the USA, many European and Asian countries have been implementing BIM successfully. Noteworthy is the United Kingdom, which published its family of PAS 1192 standards—in revision and transformation processes to international standard ISO 19650 [4, 5]. Studies on BIM adoption in public environments can also be highlighted, for example, in Sweden, Finland, Norway and Singapore [6].

BIM has been implemented in Brazilian public organizations since 2010, when the first state action with public results took place with the development of an initial version of a BIM component library for state program "Minha Casa Minha Vida" [7, 8]. Several public and state organizations have been implementing BIM in their project processes; most adopted use cases have been quantification take-off, 4D planning and geometric modeling of civil engineering projects.

Experiences in contracting BIM projects have been developed in southern Brazilian states, with accurate BIM mandates with guidelines for projects to be contracted by the state government. The technical evaluation of the companies' proficiency and the level of development of their projects have been carried out with the analysis of industry foundation classes (IFC) models with automated routines of code checking [7].

In an operational point of view, Brazilian Army has improved real estate management quality by using the Unified System of Works Process (from the Portuguese expression "Sistema Unificado do Processo de Obras", whose acronym is OPUS), a technology information and communication system developed by its Directorate of Civil Works. OPUS is described as an integration of specialized Enterprise Resource Planning (ERP) software with construction building information models, created for supporting built environment lifecycle management including buildings and assets related to Architecture, Engineering and Construction (AEC) [8, 9].

2.2 Management Factors

One can try to figure out the factors that influence a good BIM adoption in public environments. In this work, these factors will be classified into three groups of actions, described below and illustrated in Fig. 1.

- Model management actions, referring to building information models utilization in process management and all related specifications, including the BIM adoption effort in organizations;
- Product management actions, referring to product adequacy to client technical specifications and its compliance with deadlines and costs; design and construction methodologies conducted by related teams are also included in this group;
- Public governance management actions, which submits any and all project effort to auditing rules and all necessary and legal internal and external governance and auditing rules.

2.3 Model Management

All tasks on this group refer to the growing influence and impact of BIM in project process, from its implementation in company to supervision of all day-to-day procedures. Building information model (BIModel) turns into the principal database of any architecture or engineering project:

- Employer Information Requirements (EIR), sometimes called "BIM mandate" or "BIM manual": document where the contractor declares what they are after when they ask for BIM [5].

Fig. 1 Management groups in BIM adoption.

- A BIM Execution Plan (BEP), with an identification of the objectives and the goals of the implementation process in answer to the EIR desired by the organization, as well of the definition of all supporting infrastructure needed. This phase can be split in two parts: one pre-contractual BEP before procurement, containing the project implementation plan, its schedule, all information modelling and collaboration goals, as well the main milestones of the project information design creation; and a post-contractual BEP, beyond pre-contractual BEP, it still encompasses all project management processes description and to all methods and procedures that will be followed, as well as all solutions to be employed in implementation, including software, hardware, cloud and network solutions [5, 10].
- A Project Execution Plan (PEP), with all necessary guidelines for good work of professionals. It encompasses all guidelines that make BIM workflow possible: modelling, file linking, work sharing, work sets, interoperability between programs and collaboration among professionals, information exchange. It also regulates all deliverables that would be produced (e.g. quantity take-offs, model templates, model views, annotations, sheets and model standards) [10, 11].
- The modelling process itself, which is always related to a cyclic design process with high BIM tool interoperability and broad collaboration among professionals. It encompasses all development process with intense BIModel creation under BEP and the PEP directives.

Generally, the three first steps described above are developed by consulting companies specialized in BIM implementation. It involves generally a knowledge transfer agreement contract, which may or may not cover the sale of software licenses, modelling software training or in-company support.

The modelling process of all disciplines and the related federated BIModel is always developed by the project team, along with product management and great participation and aid of the team of BIM champions.

2.4 Product Management

Product management is related to project development and all stages that form part of it. Under this group task, client's technical demands and needs must be considered for the development of the project. It also includes all the documents that regulate them, such as sustainability analyses, budgeting and scheduling rules, works supervision standards and its compliance with performance, operation and quality organizational standards.

Although there are different definitions and standards for which project phases exist, the phases generally follow a sequence. In England, for example, there are six design phases: brief, concept, definition, design, build and commission, handover and closeout, followed by maintenance and proper use [5].

On the other hand, Brazilian standards divide project effort in a design preparation phase, including feasibility studies, preliminary and specific data collection and location definition; and a technical design development phase, including draft development and construction design itself.

The modelling process of all disciplines and the related federated BIModel is always developed by the project team, along with product management and great participation and aid of the team of BIM champions.

2.5 Governance Management

In general, a public organization must always be accountable for its actions and expenditures, so BIM adoption processes must take it into account. In this group are included all efforts of the public organization for public hiring processes, personnel admission and accountability principles, guaranteeing compliance to public administration principles.

Unlike the other two groups, governance management activities are not sequential, but all of them interfere the entire project process. A summary of some important governance tasks that ensure a good project development and BIM deployment is given in the following:

- Demand of the organization direction for starting a new project;
- Requirements definition for project development, cost and schedule management;
- Provision of all conditions for project team to develop the project (budget prediction and authorization for bidding);
- Definition of bidding processes for services and public process to select professionals necessary to enable the satisfactory development of the product;
- Monitoring and supervision of project development and the construction model;
- Definition of bidding process for contract award;
- Bidding process itself and contract award;
- Construction contract inspection and follow-up;
- Commissioning;
- Handover and close.

With respect to BIM implementation in public environments, Porwal and Hewage [4] define a BIM partnering framework for public construction projects, in opposition to traditional methods of procurement where design and construction processes are separated.

A broad integration between product management and model management activities is suggested from Fig. 2. Unfortunately, in some countries, Brazil included, there is little legal support for non-design-bid-build (DBB) bidding and procurement process, so most BIM public projects, if not all of them, follow DBB pattern.

3. Methodology

The research methodology adopted in this work is the Design Science Research. Design is concerned with how things ought to be, with devising artifacts to attain goals. The discussion of design when the alternatives are not given has yielded at least three additional topics for instruction in the science of design: adaptation of standard logic to the search for alternatives (the search is for sufficient, not necessary, actions for attaining goals); the exploitation of parallel, or near-parallel, factorizations of differences (means-ends analysis is an example of a broadly applicable problem-solving technique that exploits this factorization); and the allocation of resources for search to alternative, partly explored action sequences (is to think of the design process as involving, first, the generation of alternatives and, then, the testing of these alternatives against a whole array of requirements and constraints) [12].

This article aims to present a basic BIM framework that can ensure successful adoption of BIM in public organizations. For this, two real case studies will be followed, managed by the Brazilian armed forces. Three main factors will be analyzed: project development procedures, model development procedures and public governance policies. The scientific approach used is the deductive method. In it the artifact design is selected and its development closely monitored. At the conclusion of this will be made evaluations of the artifact.

4. Framework Map Process

Once all management groups have been described, one must organize them in order to reflect an acceptable sequence for the framework. In its representation in Fig. 3, it is assumed that the public institution has not yet implemented BIM or that an unsuccessful implementation has been initiated.

First action was the decision of the authority responsible for construction of the work, followed by site location definition according to feasibility studies of the project.

In this way, all efforts to acquire the necessary resources—hardware, software, new network solutions, CDE, contract auxiliary services—topographic and geotechnical surveys, demolition teams, and hire professional and technical personnel must be initiated. All processes must be conducted according to well-defined bidding documents that have undergone prior legal analysis.

Only from this moment, after all contract awards, model and product management have their main actions. Any unplanned service may put design and project development in risk.

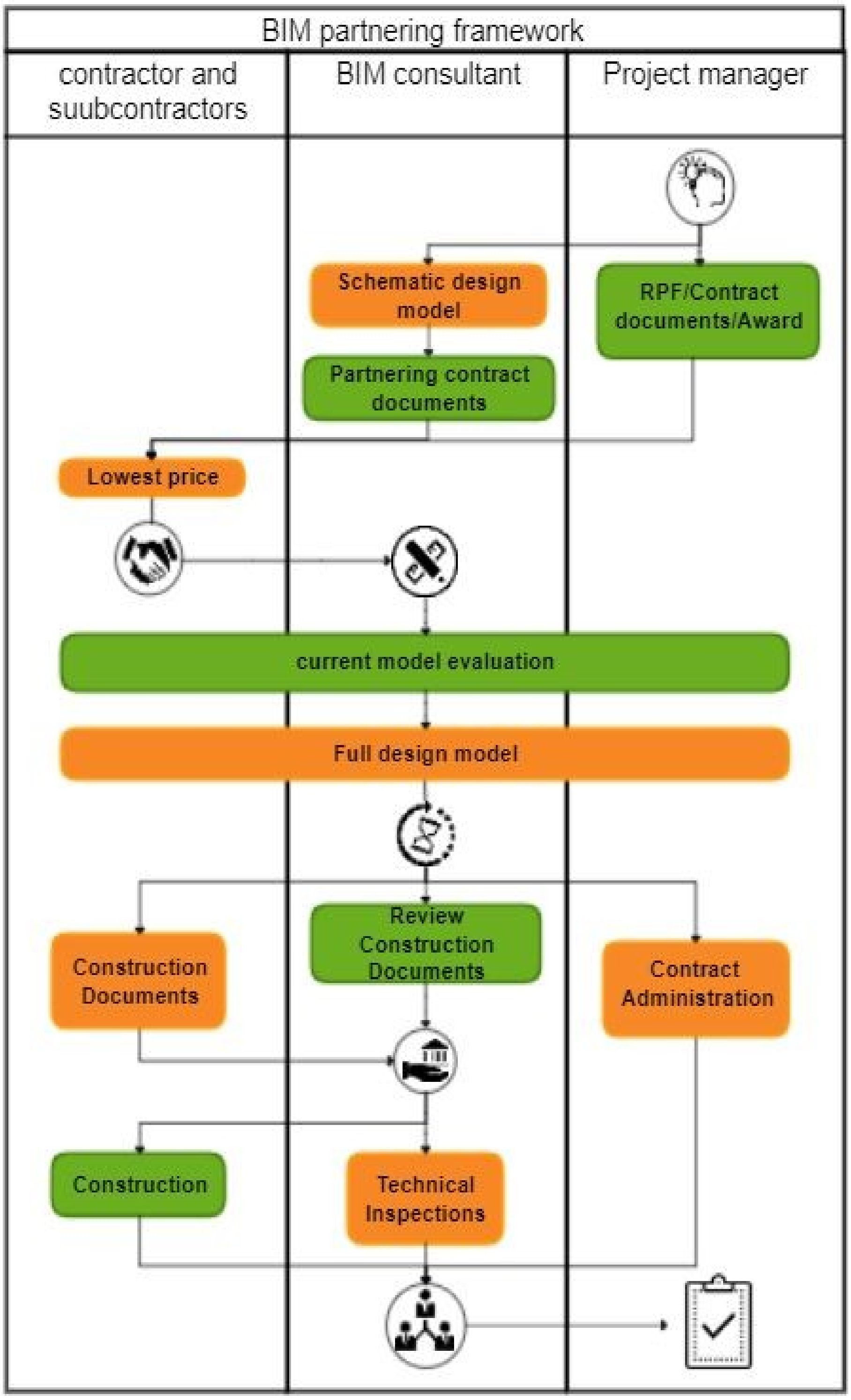

Fig. 2 Partnering framework for public construction projects.
Source: adapted from Ref. [4].

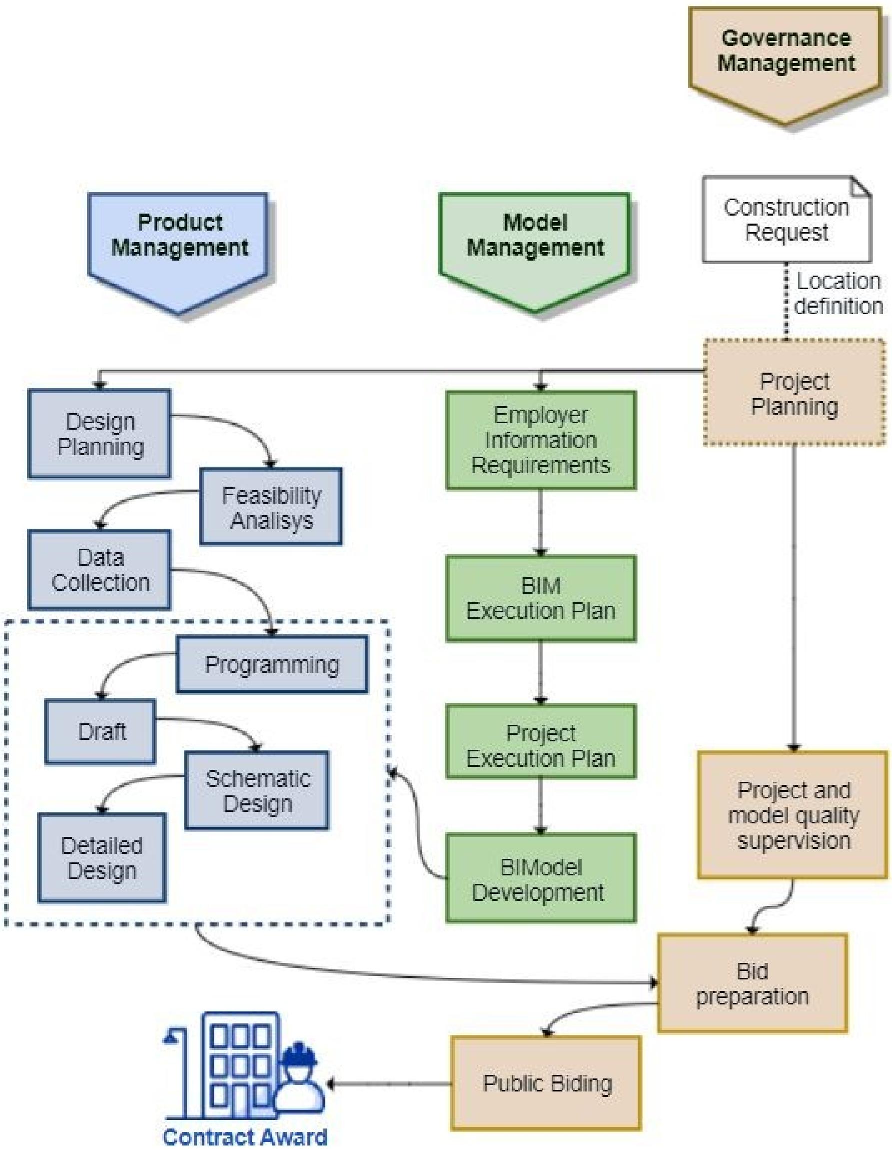

Fig. 3 Framework proposition, with all three management groups.

Model management efforts, represented in green boxes in Fig. 3, are initially defined by the client in the EIR. They are then best developed in the BEP, which describes all implementation efforts and procedures of all work processes, and in the PEP, which encompasses all information regarding to day-to-day work conducted by the professionals since the very beginning of design development.

Product management phases, represented in blue boxes in Fig. 3, however, are directly linked to project development, beginning with its planning, following the feasibility analysis, data collection and design programming.

At all stages of model and product management, there must be supervision of engineers, architects, and managers who are able to oversee the developed products—designs, models and their deliverables—as well as to manage all contracts related to project.

A careful preparation of all tender documentations, where all bid conditions are given, is mandatory for a good public bidding. Any lack of data could make the bidders request for further information, and then, cause delays in tender documentation openings.

At the end of tender preparation, bidding process should be launched, usually on an on-line platform for government acquisitions. Tender process continues until contract award.

5. Concept Proofs

Two concept proofs are presented, each one in a distinct public organization responsible for military work projects. Both projects have a profile of defense and public safety, which began to be developed within the framework of two recent BIM deployments.

Each experiment refers to public works projects focused on strategic and control areas that are currently being developed. Organizations are expected to tender both constructions by DBB contracting process.

5.1 Concept Proof 1 (CP1)

The first experiment is a project that will be built in an area of about 20,000 m^2 with a constructed area on a plot of about 28,000 m^2, from a demand of Organization A, currently considered one of the references in BIM adoption in Brazilian public service. Due to project order of magnitude, a specific BIM adoption became necessary.

Since project beginning, there was a rigid delivery schedule that was accompanied by the project management team and the client, with strict delivery deadlines. Thus, construction is formed by a building with five floors, being them underground, ground and three floors.

Programming studies and draft development were then developed over several meeting cycles, considering all necessary terrain and geotechnical surveys, predicted area for each office based on their organizational requirements and all expected mechanical and electrical equipment needed for the involved complex operation.

Since project initiation, a room was separated for the team, which worked collaboratively on a shared network even with development of the initial drafts in Autodesk AutoCAD.

BIM implementation in project office started to be conceived from this moment to optimize collaborative work within the project process, obtaining all necessary means—personnel and technologies—to guarantee its success, by bidding processes and professional selection processes, always with legal approval of a federal attorney:

- Personnel: personnel selection processes were initiated, in which civil engineers, electricians and mechanics as well as architects were hired. A good knowledge in BIM software was mandatory, though most of them had only some prior knowledge;
- Hardware: fixed workstations were acquired in three different biddings, with necessary configuration for collaborative work and the building information model's development;
- Software: through a specific bidding process, new software licenses were acquired to enable model development by all professionals;
- Computer networks: there was no assembly of a new network with support to the high flow of information, dedicated to the project; new computers were connected to the existing administrative network;
- BIM consultancy: through a bidding process, a BIM consultancy was also contracted, whose mission was the technology transfer as a progressive process of BIM implementation, involving development of a BEP, component library development and all necessary software training and support for adequate design development.

After consultancy contract award, diagnostic meetings between the consultant and office representatives were then held for the development of a BEP. The target was set so that, at the end of the project, the management procedures and all project professionals would evolve from the "pre-BIM" stage to stage 2, when BIM collaboration procedures are totally based on BIModels [1].

BEP contained general guidelines for template and file development, file naming, component material creation, as well as shared parameters creation. Components were then developed at the same time the design was being developed, according to the professionals—engineers and architects—needs.

The first implementation activities had as first case uses to be developed the design authoring, 3D coordination, cost estimation and phase planning, 4 out of the 25 BIM uses described by Nascimento et al. [12], so that the technical requirements, budget development and schedule planning were directly linked from beginning of the design.

It was from the preliminary phase that the concepts of construction information modeling developed a greater synergy with project management, where a maximum of 14 professionals were involved in model and design development.

Based on BEP, a common data environment (CDE) was created within existing organization network, where all professionals developed their model designs, obeying a previous norm of file and model naming. Because of the organizational security requirements, the use of cloud-based CDE, as well as any cloud communication platforms, has been strictly banned.

Geometric coordinates were shared from the design beginning, either through work sets or through model links to a federated model. For each main discipline in the first-level partition around federated model, a discipline model was created; second-level subdivisions were then linked to each discipline model, as shown in the scheme of Fig. 4.

IFC was interoperability standard for communication between suite software and interference detections. However, in cases where software offered few interoperability resources or did not have versions that could be IFC-compatible, DXF file format was then used: DXF drawings were created from design models and then they were read by the applications. BEP predicted these interoperability guidelines.

The collaboration and interoperability procedures made clash detection much easier and more efficient. Compatibilization routines were realized in a daily basis, and clashes were solved as soon as they were discovered. Team communication was done personally in the team room in short reunions all the time or through a message platform where all design decisions and interference resolutions were recorded.

In general, design development expanded from design programming (still with CAD files) to schematic and detailed design completely developed using BIM software. Once design had a minimum maturity, 4D planning and cost estimation, based on Brazilian cost databases, evolved quantity take-offs and specific budgets provided by qualified suppliers.

4D planning was carried out initially in MS Project, following a defined process. As quantity take-offs were extracted from all discipline models, predecessors and successors were defined for all tasks for project Gantt chart, for future work progress visualization using Autodesk Navisworks.

Budget development was based on take-offs extracted from discipline models and calculation reports extracted from engineering software. There was no direct interface of BIM authoring tools and the budget development software adopted by the organization. Although budget process was constantly error-prone, an experienced planner revised project budget and schedule all the time.

Currently, detailed design is near to completion. Client seeks from federal agencies the money needed to bid and contract the project.

5.2 Concept Proof 2

The second experiment describes BIM implementation in organization B, conducted differently from the first experiment.

In 2016, BIM usage became mandatory for all professionals. Before that, only some professionals have had an interest in applying BIM in their workflow, with initial training in geometrical modelling and information management. These pioneer professionals, called internally “BIM team”, have already used some BIM processes in their workflow in the development of three simple proofs of concepts.

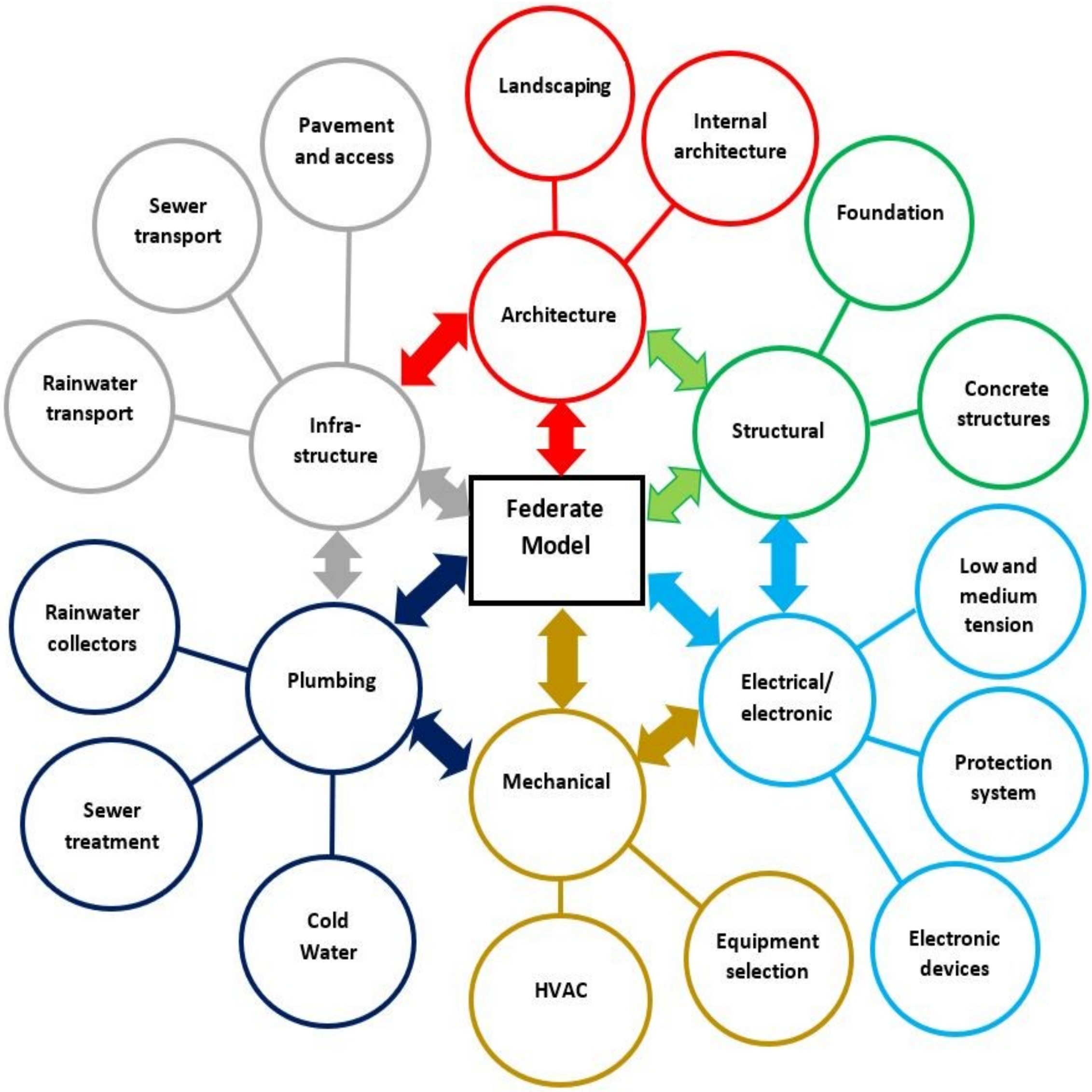

Fig. 4 Coordination scheme for CP1.

It was then necessary to contract an outsourced consultancy through a specific bidding and procurement process, in order to gain knowledge on BIM processes.

Implementation had as main aim technology the transfer of technology from outsourced consultants to BIM team. At the end of 24 months and three proofs of concept, which involves design, construction and operation of a building, the team would be responsible for disseminating knowledge obtained to all other design teams and professionals in other sections.

The consultants also had another aim: meet all information requirements for a new CDE that would provide interoperability between BIM models, data and related databases. It would play a similar role in construction and operational management that OPUS already plays in Brazilian Army.

Hardware in organization B—workstations in general—is at least three years aged. The last software acquisition was four years ago, when 2015 Autodesk Building Design Suite was installed in all computers.

Professionals working at organization B are generally high skilled, partially because of specific scope of all projects which are developed there. They have been working in organization at least for 10 years.

To meet organization demands, a broader BEP was developed by the consultants, encompassing several use cases related to design, construction and operation. BIM implementation would then last two years from contract award but would also include future tasks for the next eight years.

First concept proof conducted by organization B is currently in progress—an operational update of a 1,000 m^2 and four floors design, aiming to improve operational project in order to allow the installation of other specific electronic equipment. At that time, it became necessary to update terrain and geotechnical survey of the construction area; based on new organization needs, new architectural and operational requirements were developed.

Until beginning of BIM implementation, there has not much difference between product development flow from organizations A and B, beginning with programming based on strict organizational needs, preliminary studies, work planning, design and project development, scheduling and budget development in order to start future procurement process.

With BIM implementation, design development has shifted from a sequential process to a matrix collaborative process in which all professionals started to participate. BIM team itself has been developing construction components and architectural and engineering templates for their own use, following BEP with the consultants' aid and supervision.

Design process became then under a "development-analysis-discussion meeting-design" revision cycle. Coordination meetings were held at the end of each design phase with participation of the BIM team, their managers and their clients by videoconference. The meetings have been used for solving design decisions, for deciding about project cost estimate (based on preliminary BIM models) and discussing the next steps of the project.

Until now, lack of modern engineering software imposes DXF and proprietary file formats as preferred interoperability standard. On the other hand, all files and models follow a strict organization in network, separated by design phase and design discipline. All models also follow a collaboration scheme, where each team professional is responsible for only one design model, as showed in Fig. 5.

Nowadays, although project is still in draft phase, with development of the first discipline models following Fig. 5 scheme, information regarding to 4D planning, quantity take-off and operation has been added to federate model. Budget planner has got access to all design models since programming phase, with which he already develops construction site simulations, budget estimates and the first schedule forecasts.

Expectation in the future is to use acquired software suite at full potential, including dynamo procedures for enhancing it in structural and mechanical, electrical, and plumbing (MEP) designs. Only after reaching this milestone, acquisition of more modern architecture and engineering BIM tools would happen, considering in-depth study of consultant team.

What one must have in mind is that the presented framework contains only general procedures. All its

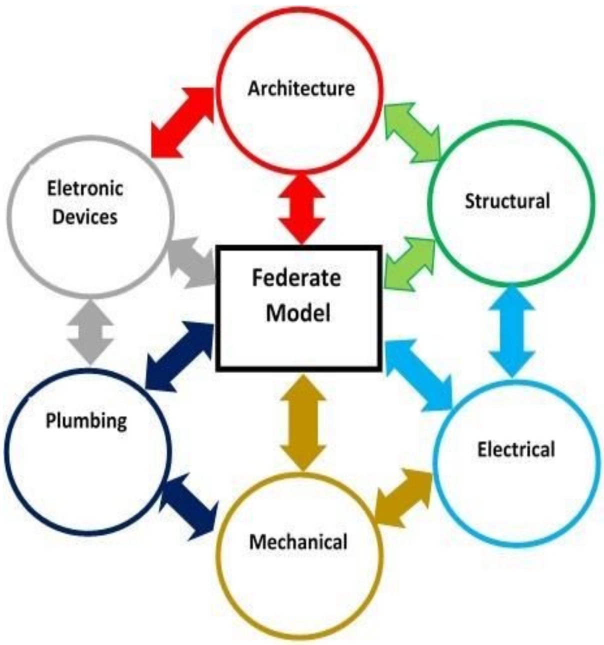

Fig. 5 Coordination scheme for CP2.

procedures must be detailed in depth, considering all organizational culture and public environment constraints involved.

6. Conclusions

The aim of this article was to develop a conceptual structure that would contain all main factors that would guarantee an optimized development of a construction project with the use of BIM.

Conceptual structure can be divided into three groups: model management, product management, and governance management. Each group has a defined sequence: while model and product management follow a strict sequence of processes, governance management includes all public administration processes, without which other two groups can not be developed.

In general, BIM implementations described in both CP followed the framework described in Fig. 3. Public administration processes permeate all product and model processes.

In summary, three described groups constitute parts of a suggested tri-axial conceptual structure where each axis has a deep relationship with each other, so that a harm of one of the axes compromises project management in some way.

One can remark that BIM has already been adopted in both organizations A and B. However, it was totally based on software acquisition and basic training, not considering characteristics of product and management organization processes.

Any BIM implementation should then consider the "tri-axial relationship" among model management group, product management group and governance management group, so that each group procedure could be contextualized to the public and organizational environment.

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