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Towards an organizational model of BIM practice based on collaborative engineering

Abstract For several decades, digital technology has revolutionized the world of construction. The advent of BIM (building information modeling) has attempted to solve the problem of project management between collaborators. After an extensive literature review on the adoption of BIM we have identified a major problem in the management of construction projects: lack of communication and collaboration between stakeholders. In this article we will try to solve this problem by applying a collaborative engineering method on an architectural project using BIM to solve the problem of collaborative work. To do this we are proposing, with the help of a collaborative engineering method, models to organize the work of the actors by defining the phases and modes of intervention and their temporalities.

Keywords Collaborative work, BIM, Collaborative engineering.

Introduction

Since construction is a major component of the city, a lot of research is being conducted to ensure its management. In recent years BIM (Building Information Modeling/Model/Management) is being increasingly adopted in construction. BIM is defined by Kubicki et al. (2019), ‘Building Information Modeling (BIM) is both a technology and a process emerging in the architecture, engineering, and construction industry. It is based on digital representation and information exchange that facilitates access to all relevant data throughout the life cycle of a project’.

Many researchers have been interested in BIM around the world, according to their results several difficulties have been encountered during its adoption by architects and project managers in different phases of the construction project.

After a broad literature review, several works identified problems with poor communication and information flow between project participants in all hierarchical levels of project management (Jupp 2017). According to Jupp (2017), poor information flow is due to fragmentation of work among project participants and inconsistencies in information transfer, storage, accessibility and redundancy.

Nicał and Wodyński (2016) in their article on ‘Improving Facility Management with BIM 6D’ locate several challenges (from the literature) of BIM implementation from the practitioners' perspective such as: roles and responsibilities are unclear in the BIM model, Data requirements – level of development (LOD) needed. Interoperability problem of information exchange and transfer; Resistant attitude to change.

The study by Gless et al. (2019) shows that BIM is still not properly implemented in France, and France is not among the leaders in this field (Hochscheid, Halin 2018). Construction is a field considered as an ecosystem that takes into account several technical, legal and practical aspects. In this article we focus on the practical aspect and more specifically on the practice of BIM in agencies in the conception phase.

Through a literature review, we found the problem of poor communication and collaboration between stakeholders that constitute one of the major obstacles in the application of BIM in offices and architectural agencies (Jupp 2017). Because of this, in this work we try to answer the following question: ‘How can the collaborative engineer contribute to the organization of the work of the construction actors and define the roles of the stakeholders, the accesses to the model, their temporality and their tasks during the conception phase?’

Methodology

A construction project is composed of three parts: technical, practical and legal. Any public or private construction project brings together a large number of stakeholders (Joss, Rinquet, Domer 2017). The construction stakeholders are contractually bound to the different project phases according to the construction law (public and private law) which differs from one country to another.

In this article, it has been chosen not to address the legal side and types of contracts. Instead, we are interested in the relationships between the stakeholders in the architectural practice in the first phase of the project – the conception phase.

To do this, the previous research was chosen to buid up a base. What is more, feedback from two agencies in France (conception office + project management office and general Construction Company) in order to have a general model that can be applied to several projects and modified according to the type and size of the project was taken into consideration.

Several researchers have tried to solve this problem by proposing management methods. In their work Gless et al. (2019) propose three agile practices for architectural conception with the aim of improving communication in a collaborative work group.

In this paper a collaborative engineering method proposed by de Vreede and Briggs (2018) was chosen. This method is the result of 20 years of research and has been successfully applied in different industries. Collaboration engineering (CE) is an approach that 'conceptions collaborative work practices for recurring high-value tasks and deploys these conceptions for practitioners to perform on their own without the ongoing support of professional facilitators' (de Vreede, Briggs 2018).

First of all, the 7-level collaboration approach presented by Briggs et al. (2009) should be incorporated. This collaboration engineering model provides a guide for modeling collaboration activities. Being applicable to our case (construction project), it simplifies the modeling by allowing to detail the phases of construction projects, the objective of each phase and the relationships between the stakeholders. In this work, the first three levels are sufficient to build an organizational model of the architectural conception process.

Table 1 describes the levels of collaboration that will be applied to the conception phase of the construction project. For example, consider the first level 'Objective'. It is defined as the outcome or goal of the work and can be a group or individual goal. At the next level, the 'Product' level describes the tangible or intangible results produced by the group's work. The 'Activities' level contains the subtasks whose completion generates the products that satisfy the objectives. The other levels are: 'Collaboration Models', 'Techniques', 'Tools' and 'Scripts/Scenarios'.

Table 1. 7-Level Collaboration Method for Collaborative System Conceptioners from

Levels of collaboration (Briggs et al. 2009)	**Description**
Objective	A goal is a desired state or outcome. Deals with group goals, private goals and goal congruence – the degree to which individuals perceive that working toward group goals will be instrumental to attaining private goals. Collaboration is defined as joint effort toward a group goal. Addresses motivation, group formation, commitment, productivity, satisfaction, and other goal-related phenomena
Product	A product is a tangible or intangible artefact or outcome produced by the group's labour. Deals with issues of quality, creativity, effectiveness, efficiency and other product-related phenomena.
Activities	Activities are sub-tasks that, when completed, yield the products that constitute attainment of the group goal. Deals with what groups must do to achieve their goals: sequences of steps that constitute decision-making and problem-solving approaches.
Patterns of collaboration	Patterns of collaboration are observable regularities of behaviour and outcome that emerge over time in teamwork. Researchers address six general patterns of collab-oration: Generate Reduce, Clarify, Organize, Evaluate and Build commitment.
Techniques	A collaboration technique is a reusable procedure for invoking useful interactions among people working toward a group goal. Deals with invoking useful outcomes predictably and repeatably across a wide range of circumstances.
Tools	Collaboration tools are artefacts or apparatus used in performing an operation for moving a group toward its goals. Deals with conceptioning, developing, deploying and using technologies in support of group efforts.

Scripts / scenario	A script is everything team members say to each other and do with their tools to move toward the group goal. Scripts may be internal or external, tacit or explicitly captured as documentation. Deals with tacit and explicit procedural guidance for the group. Small variations in structured scripts can yield substantial variations in group dynamics.

Source: Briggs et al. 2009.

From the previous model, we organized our work in three main steps:

Step 1: Proposal of new limits of the phases of the architectural project on which the work will be carried out. Through a bibliographic work, it was found that the limits of the phases of the architectural project are different according to the authors, so new limits to the need of this article were proposed.

Step 2: Definition of the objectives and tasks to be performed in each phase and sub-phase of the project with BIM. By defining objectives, they will be possible to understand and it will be possible to have the list of stakeholders that will be involved in each sub-phase of the project.

Step 3: Definition of the stakeholders in each sub-phase and their roles with BIM. Indeed, several stakeholders can participate in the sub-phases of a project without producing significant results (documents, plans). They can agree or disagree on the feasibility of the project to anticipate changes. For this all the people involved and their roles in each phase of the project have to be specified.

Step 4: Determination of the previous steps, relationships and interactions between the stakeholders around each task in order to establish an organizational model of each sub-phase with BIM following the 7-level collaboration model of Briggs et al. (2009).

Application of Collaborative Engineering in Construction

Step 1: Definition of the conception phase

Before working on the conception phase of the architectural project we began by defining it because we found that the sub-phases of the project are the same but the definition and limits of the project phases differ from one author to another, as such we proposed to make a comparison table, we took as an example in Table 2 four documents: (Fernandez, Lavigne 2009) in their book they divide the architectural project into four phases.

From the perspective of INRS (2017) the main stages of an architectural project are divided into five phases and they are different from the five phases cited in (‘The stages of a project RT2012’ 2012).

The table presents actors, stages of conception and construction (CAUE92 2018) which divides the phases of architectural project into two phases.

Table 2. Phases of the architectural Project according to several authors

(Fernandez and Lavigne 2009)	(INRS 2017)	(‘The stages of an RT2012 project’ 2012)	(CAUE92 2018)
1. Programming (or formulation of the problem) **2.** The conception (or formalization of the solution) **3.** The realization of the site (or concretization of the solution) **4.** The use of the equipment (or the appropriation of the solution)	**1.** Stage of opportunity and feasibility of the project **2.** Programming **3.** Conception (sketch, preliminary draft APS, final preliminary draft APD, technical studies) **4.** Achievement **5.** Commissioning	**1.** Filing of building permit **2.** Final preliminary conception (FPC) **3.** Business Consultation File (BCF) **4.** Execution of works **5.** Works receipt	**1.** Conception stage (from the preliminary study and programming to the business consultation file) **2.** The stages of construction (preparation and VRD until delivery)

Source: author’s own work on the basis of: Fernandez, Lavigne 2009, INRS 2017, RT2012 2012, CAUE92 2018.

After comparing different sources in Table 2, a table according to the needs of this study, adopting the same project sub-phases as the other research and dividing them into three phases was created. This proposal was made, according to the actors present in each phase, the transfer of information, their cooperation and their locations and roles.

The first phase is the conception phase, where the parties work on the project in the office and do not need to go to the site, the second is the construction/execution phase, where the work of all the actors is linked to the construction site and where new actors intervene (subcontractors and construction companies), the third phase is the exploitation/maintenance phase, a post-construction phase where a large number of actors will not intervene.

The three proposed architectural project phases and their sub-phases are represented in Table 3. In the conception phase the sub-phases from programming to the submission of the building permit has been integrated. In the second phase of execution the sub-phases that require the intervention of a larger number of actors and that will mostly intervene on site from the execution plans to the sub-phase of scheduling, coordination and piloting SCP have been grouped. The third phase is composed of the sub-phases which start at the delivery of the project.

Table 3. Phases of an architectural project

Project stages	**Conception phase**	**Construction phase/execution**	**Operation/Maintenance phase**
Sub-phases	Programming and preliminary studies. Competition or sketch. Preliminary Draft Summary. Detailed Preliminary Project. Building Permit.	Project (execution plans) Company consultation file. Contract file, signature of the contract. Management of the execution of the works Site management Scheduling, coordination and management of the site;	Delivery of the building to the client. Assistance to Reception Operations. File of Executed Works, as-built plan

Source: authors' own work.

Step 1: Objectives and outputs of the construction project sub-phases

With the digital revolution and the advent of BIM, architectural firms have begun to adopt a structured BIM approach to ensure collaboration between all stakeholders. This approach is based on 4 elements (Aroichane 2017):

● BIM Charter: a document edited by the project owner in which it defines its general policy and values. It may include several parts to address the technical and organizational issues of the project;

● BIM specifications: it defines the requirements and objectives of the successive participants in the project;

● BIM Convention: according to the order of architects, it is the set of collaborative procedures, the steps to be taken by all stakeholders to produce, calibrate, validate and transmit the data constituting the model;

● The BIM execution plan: it translates the BIM requirements in accordance with the BIM Convention and the BIM specifications. It is implemented by the Company.

These 4 elements of the BIM process differ from one agency to another and from one project to another.

Objectives and tasks of each sub-phase of the project with BIM

In this section the tasks and objectives of each sub-phase with BIM. We have based ourselves on the guide of the project owner of the interministerial mission for the quality of public construction in France were determined (Lamour 2016). In addition, the level of detail (LOD) obtained by the realization of each sub phase according to the City GML 3.0 conceptual model (Kolbe et al. 2020) was associated with the objectives. Table 4 presents the first sub-phase which is the preliminary study. In this sub-phase, the essential elements for its realization are the choice of the project, the data relating to: the site, the area and existing (topographic plans, network plans...). From these elements, the participants can create a digital model including a functional and urban analysis [if the area already exists] and calculate the global cost. The level of detail is therefore LOD 0; the objective of this sub-phase is to carry out a feasibility study, choose the area and define the program proposal.

Table 4. Objectives, products and inputs of each sub-phase of the Project with BIM

Sub-phases [Design]	**Objectives, products and inputs of the sub-phases**	**Level of detail**
Preliminary studies and Programming	**Sources/inputs** Choice of project; Data relating to the site, the ground, the existing ones (topographic plans, network plans, etc.). **Realization of the digital model including:** Functional, urban analysis (if the land already exists). Global cost analysis. **Goals** Feasibility studies. Choice of land. Proposal of a program.	LOD0: 'Real-world volumetric objects (Spaces) can be spatially represented by a single point, by a set of curves, or by a set of surfaces'

Source: authors' own work.

Step 2: Construction Stakeholders with BIM

Stakeholders in construction in the BIM era

In order to identify the stakeholders of construction in the BIM era the book by Hoyet et al. (2016) was taken into consideration. All the actors that intervened in the conception sub-phase (Table 5) were classified. To indicate whether an actor intervened a 'yes' was put in the corresponding box with the mention (data exchange in IFC). When the actor acted on the digital mockup or transfered files in open format to integrate them in the digital mockup.

In addition to the classic construction trades, BIM has created new professions, According to Aroichane (2017):

● BIM Manager: is the person responsible for the creation and application of methods and processes that allow the creation of digital models of the project;

● BIM Coordinator is the person responsible for the BIM process and its use in the modeling team that implements the digital model of the project;

● BIM Modeler is the person who models with BIM modeling software the different parts of the model. He is appointed by the BIM Manager under the supervision of the BIM coordinator.

Nb: The actors and the beginning of their interventions can vary according to the type and size of project but the general case in this study by integrating all the actors were taken into consideration.

Table 5. Construction stakeholders in a BIM project

Construction actors (Hoyet et al. 2016)	Preliminary studies and Programming
The owner (public or private): The user if known and the operation manager (in the case of a public project) AMO BIM (BIM project management assistant) The maintenance or operations manager	Yes (data exchange in IFC)
The technical controller	Yes
The programmer	Yes (data exchange in IFC)
The surveyor	Yes (data exchange in IFC)
The project manager The architect	Yes (data exchange in IFC)
The structural engineer	No
The landscaper	Yes
The Humanities Consultant	No
The hydraulic engineer	No
The Economist	No
The acoustician	No
The thermal engineer	No
HVAC engineers	No
The fluid engineer, energies, networks, environment	No
Electrical engineer	No
Construction and industrial companies.	No

Source: authors' own work.

Step 3: Organizational Models of the Conception Phase

After defining the objectives and stakeholders of each project sub-phase, we apply the Collaboration Engineering (CE) method proposed by Briggs et al. (2009). From the definition of the collaboration levels an organizational model that explains the work process on the conception sub-phase of the project was proposed. Then we detail each activity with the stakeholders and their roles to determine their interventions and facilitate the management of the project.

In the first sub-phase (Preliminary Study), the actors involved in this sub-phase are:

● The project owner and his BIM assistant, the surveyor [exchange in IFC] and the project managers (BIM Manager, architect [exchange in IFC], Engineers [exchange in IFC]).

Table 6 shows the application of the collaboration engineering method of Briggs et al. (2009) on the pre-study sub-phase with BIM.

The first level of collaboration (objective):

● The objective of this sub-phase is to obtain a project definition and feasibility.

The second level of collaboration (product):

● The products obtained by the actors are the definition of the project at the functional, symbolic and urban level. In addition, the financial choice and the choice of actors are realized. All this information is integrated into a level zero digital model (BIM part).

The third level of collaboration (activities):

● The BIM Manager prepares the file on which the actors will work as well as the BIM agreement.

The actors working in this phase define the nature of the project, find the appropriate land for the nature of the project, make an estimate of the project, study the financing possibilities and choose the actors for the following phases.

In addition, they do the analysis and study with software using open IFC (Industry Foundation Classes) formats. They integrate all the information and data into the digital model.

Then, the same method for the programming sub-phase by defining the actors and then applying Briggs' 7-level collaboration method by defining the objective, products and activities was followed.

Table 6. Application of the IC method (Briggs et al. 2009) to the preliminary study and programming phase

Actors	**Preliminary study**	**Programming**
	Project owner Assistant BIM project owner The surveyor [exchange in IFC] Project managers (BIM Manager, architect [exchange in IFC], ING [exchange in IFC].	**Actors:** Owner BIM project manager assistant Project management (BIM Manager, architect [exchange in IFC], ING [exchange in IFC], programmer, sociologist,)
Application of the CE 7-level method		
Objective	Implementation of BIM+ Project definition + feasibility	Define a program of spaces
Product (tangible/intangible work result)	LOD 0 model in which it will be necessary to introduce: Functional, symbolic and urban definition. Financial choice and choice of actors.	Introduce in the Model LOD 0: Determine a program with the spaces and surfaces of the project.
Activities (subtasks)	All information with numerical data: Define the nature of the project. Find the appropriate site for the nature of the project. Make a project estimate. Choose the actors. Investigate funding opportunities. + Analyse and study software in open formats +The BIM Manager prepares the file on which he will work + the BIM agreement according to the nature of the project with the actors.	Functional programming. Carry out detailed technical programming + enter all the information on a digital file.

Source: authors' own work.

Organizational model of the work of the actors during the preliminary study and the programming:

In Figure 1, the form of an organizational model, the work of the actors of the building during the first two sub-phases of the project which is the preliminary study phase and the programming according to Table 6 was presented.

The preliminary study sub-phase:

Setting up the BIM: the project owner writes a BIM charter. The project manager begins by choosing the participants (prime contractor, companies, etc.) according to the needs of the project. Then he establishes the contracts for the interventions. The assistant to the BIM project manager writes the BIM specifications and the BIM agreement for the project manager. The project manager and the BIM manager prepare the collaborative platform on which they will create the digital model.

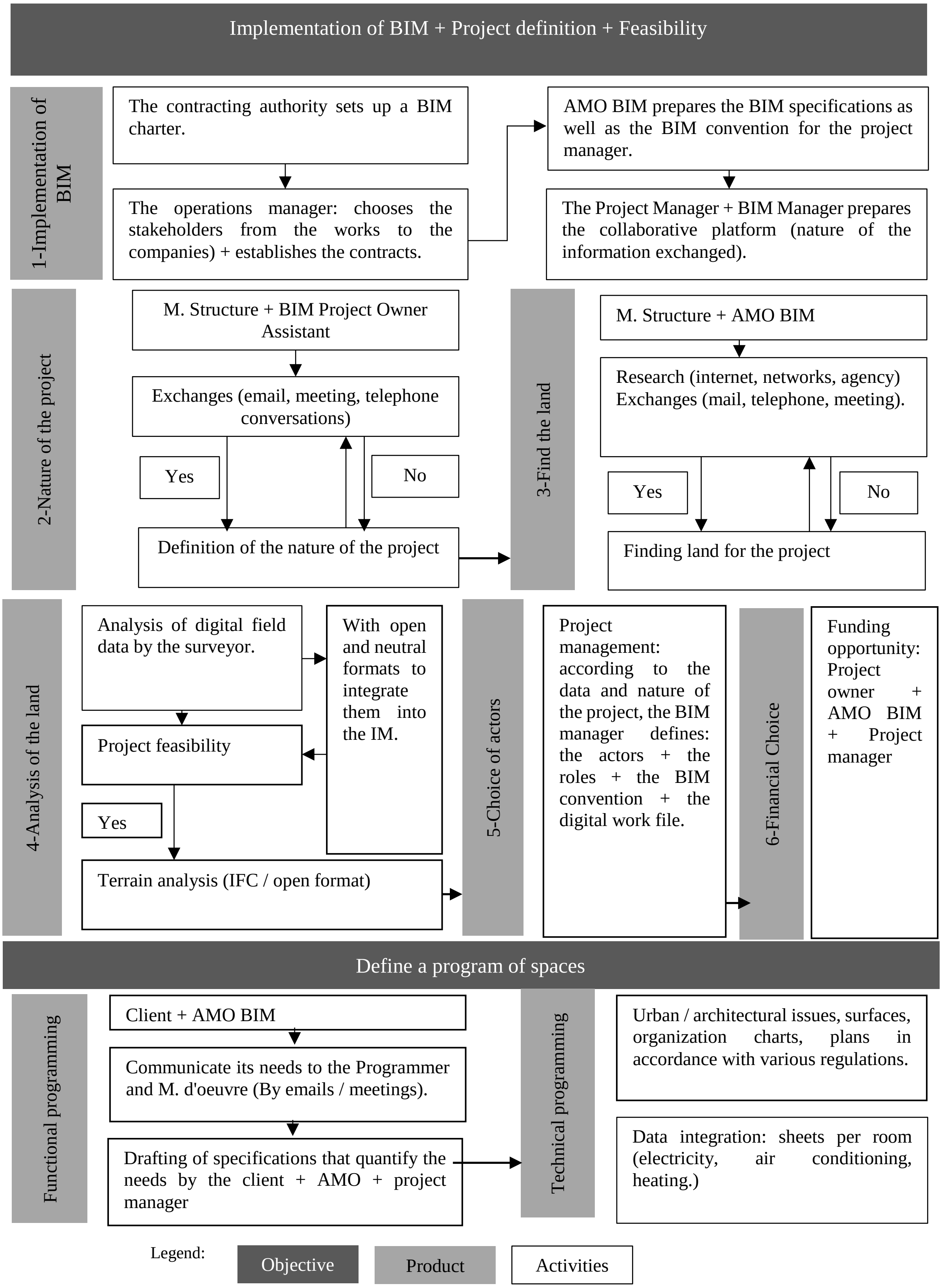

Figure 1. Organizational model of the work of the actors of the construction during the preliminary phase and the programming
Source: authors' own work.

The definition of the nature of the project: the actors involved are the project owner and his BIM assistant. The exchange between the participants is done by email, in a meeting or by telephone conversation. If they manage to define the nature of the project, they move on to the next step. If not, they continue to exchange until they define the nature of the project, in order to move on to the next activity.

The search for a suitable site: the actors are the project owner and his BIM assistant. The search is done on the internet, in the agencies, in their social networks. They exchange information by e-mail, during meetings or by phone. If they find a suitable site, they send all the information to the surveyor. If not, they continue to search and exchange information until they find a suitable site.

Site analysis: the surveyor analyses the terrain with open and neutral formats to integrate them into the digital model. Then he sends the terrain analysis to the project manager (IFC format).

The choice of actors: the project manager defines the actors and their roles according to the data and the nature of the project. The BIM manager writes the BIM agreement and prepares the digital work file.

The financial choice: the project owner and his assistant BIM manager meet to determine the possibilities of financing the project. If it is a large project, they can turn to the project manager or, if they need his agreement, go through a bank.

The programming sub-phase:

Functional programming: the client, with the help of his BIM assistant, transmits his needs to the project manager by email or during a meeting in which they draw up specifications that quantify the client's needs.

Technical programming: the project manager collects all the information, the urban and architectural issues, the surface areas and produces flow charts and diagrams, then integrates all this data into a digital model file.

Discussion

This organizational model is a proposal to answer the question that was initially posed in this article: ‘How can collaborative engineering contribute to the organization of the work of the construction actors and define the roles of the actors, their access to the model, their temporality and their tasks during the conception phase?’

In this paper it was proposed to represent in the form of organizational models the sequence of tasks of the different actors during the conception phase in a theoretical and standard way, based on the models without BIM + the overlay of the estimated results with BIM. Using a collaborative engineering method an overlay of the objectives and products and activities of the architectural project on the levels of collaboration of Briggs et al. (2009) was made and it was possible to build a work process with BIM.

These models will be used to implement BIM in agencies during the conception phase. These models are likely to evolve (some actors may not be involved) depending on: BIM conventions, architectural practices of each agency, size and type of project.

The next step will be to build models for the other phases of the project and to propose them to the architectural agencies in order to apply them to the case study and possibly improve it.

Conclusion

One of the main problems in the application of BIM is the collaboration and communication between construction stakeholders and the lack of a model to organize the work. In this paper, an attempt was made to answer the question ‘How can collaborative engineering contribute to the organization of the work of the construction actors and define the roles of the actors, their access to the model, their temporality and their tasks during the conception phase?’ Wht is more, a model for organizing the work of construction actors for the first two sub-phases of the conception phase: preliminary study and programming, according to the collaborative engineering model (de Vreede, Briggs 2018) was proposed. The future work will consist of completing the proposed model for all phases of the construction project. It will need to be applied on case studies to evaluate its relevance.

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