Building Information Models as the Basis of Business Strategy: A Case Study of an Integrated BIM-Based System for Construction Management

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Abstract
The low performance of Construction Industry in the last few decades indicates the need for changes in the current management model of construction companies. As the result of an increasingly competitive market and the permanent demand for better quality, cost-effectiveness and greater productivity, new technologies are being developed and applied to design, manage and execute building projects.
Into this setting, Building Information Modeling (BIM) represents a changing paradigm since it provides greater information reliability for construction management. From a business perspective, BIM facilitates the process of strategic, tactical and operational decision-making through its interaction with other traditional organizational processes.
This work describes a case-study of a BIM-based management system implementation which integrates the core activities of a property developer and construction company. BIM models have become the main source of information to support construction processes, from the office to the site, enabling automated data collection for budgets, schedules, and purchase and supply management. All the required information for proper execution can be accessed on tablets at the site, where employees also report progress data, quality control and non-conformities that may require further intervention.
The paper discusses the following topics: BIM implementation process and its impacts on the company organization; main components of the developed system for the integration of models and data, as well as some results achieved immediately after the beginning of its functional testing.
It is believed that the data generated from this research can contribute to further investigations with respect to BIM as the basis of Business Strategy, serving as a reference to both the academic and the business sector.

Keywords: Building Information Modeling, construction management, business management

1 Introduction
Founded in 1997, the company studied is the real estate development and construction branch of one of the largest privately-held organizations in Brazil. The company started its activities through real estate, expanding its operational focus in 2012, when it began

performing in all phases of the project lifecycle, from business development to construction coordination and maintenance.

In an industry such as construction, with standardized and little innovative processes, these strategic changes allowed the company to identify multiple improvement opportunities on its construction management practices:

- Greater site information control and reliability;
- Improved visibility of actual progress of core business activities;
- Increased assurance on strategic, tactical and operational decision-making;
- Conception of planning practices for managing the operational routine at workface;
- Ensuring on schedule deliverables and contractual milestones;
- Minimizing costs due to reworking and rescheduling, etc.

The above mentioned objectives originated from the analysis of everyday activities of the company, aiming to improve resource management and project progress tracking in a multi-project environment. This resulted in a new internal management model which identified Building Information Modeling (BIM) as the ideal basis of the information required for its operation.

The use of BIM enhances trade coordination as it turns architectural and engineering design and management disciplines of cost estimating, time scheduling, constructability analysis, risk management, procurement, etc. into parallel and integrated processes (Kousheshi & Westergren, 2008). BIM can become the center of information infrastructure of Architecture, Engineering and Construction (AEC) enterprises by its integrative nature (Dunwell, 2007). As foreseen by Eastman et al. (2011), “The next step for construction will be the integration of specialized enterprise resource planning (ERP) software with construction building information models. Models will become the core information source for quantities of work and materials, construction methods, and resource utilization. They will play a pivotal role in enabling the collection of automated data for construction control.”

At this point, AEC industry faces many problems related to the need of a high level of automatization, especially as far as handling of information and integration of data and information systems are concerned (Babič et al., 2010). The aim of this paper, thus, is to introduce a practical approach to overcome these limitations. Further details towards the integration between models and business activities are presented below.

2 Building Information Modeling as the Basis of Business Strategy

A new management system was conceived to integrate all relevant information and core business activities of the company, bringing into a single platform the following areas: Budget, Project Schedule, Resource Histograms (labor, equipment and materials), Internal Controls (Projects), Supply Plan, Quality Control, Risk Management, Construction Progress Tracking, and Production Financing. This integrated project management system was called “SIGPRO” - *Sistema Integrado de Gestão de Projetos*.

According to Mêda & Sousa (2012), the process of adopting new methodologies or Information Technologies (IT) is iterative and requires a careful definition of all the requirements and implementation stages, in order to validate/perform corrections on the developments. This task is never easy, especially if the ambition is to manage all the processes involved on construction projects. The development of SIGPRO involved, therefore, multidisciplinary teams and consisted of several phases, as shown in the following flow chart (Figure 1).

Figure 1 Development phases of SIGPRO

2.1 Current model mapping – "as-is"

The first step towards the change was the understanding of all the processes at work in the company, as well as mapping the tools that were used. As a result, it was noticed an overlap of responsibilities among departments, evidenced by data duplication and rating inconsistences.

Thus, throughout the entire business life-cycle, it was clear that the company had low levels of control over construction processes and little predictability of the final results of a building project.

2.2 Future model definition – "to-be"

In order to deal with the above findings, it was proposed a model to integrate all work fronts involving the construction management into a single computing environment, as shown in Figure 2. Together, all input and output data and tables will feed the Business Intelligence (BI) module, which is "a collection of decision support technologies for the enterprise aimed at enabling knowledge workers such as executives, managers, and analysts to make better and faster decisions" (Chaudhuri et al., 2011).

Integration was enabled through the creation of an integration engine that centralizes, handles and redistributes the key parameters to the entire business chain, enabling critical analysis of deviations on cost, time, quality, resources, scope, safety and health, supplies, projects, etc. This integrator element was called "Sistema de Ordens de Serviço" (Service Order System) or simply O.S. System.

The system was inspired on the union of concepts and methodologies like BIM and the knowledge areas of project management proposed by the Project Management Body of Knowledge (PMBOK®) Guide. It was developed as a client-server solution, with modular operation similar to an Enterprise Resource Planning system (ERP), with a 3-tier architecture:

- Client tier (access to system functions);
- Enterprise tier (business rules, functions, logic and applications that act on the information);
- Resource tier (database with specific language for the manipulation of information).

Santos (2009) states that this system architecture offers many advantages for ERP implementation. It enables, for example, the use of different database management systems (DBMS) on the database layer (Resource tier). Besides that, each tier can be upgraded without interfering with the functioning of the other layers.

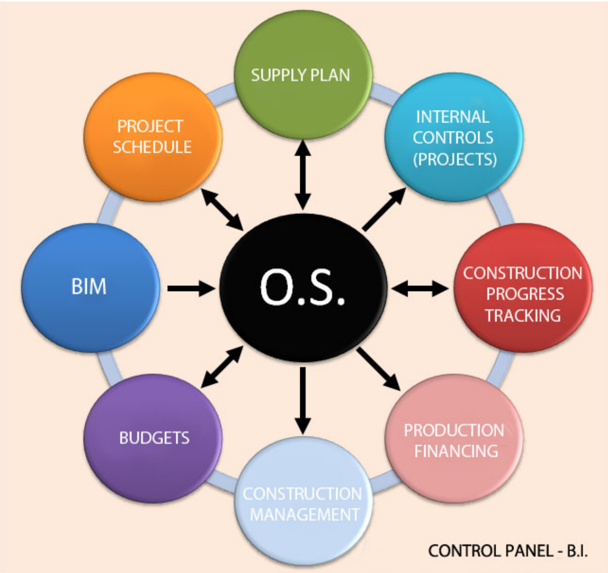

Figure 2 O.S. System Information Flow Diagram

2.3 Organizational changes

The new management model was accompanied by profound changes in internal processes and procedures of the company. It involved training professionals, the selection of technological solutions for each construction process and, finally, the establishment of a new kind of relationship with suppliers, giving priority to business partnerships.

BIM adoption had a fundamental role to these changes, since it requires integrated and collaborative procedures instead of the old fragmented processes. This was possible thanks to a careful and structured approach at all levels, starting with executive vision and sponsorship and was carried out by the organization's leaders and its project workforce.

2.4 Isolated operation

As suggested by Eastman et al. (2011), before moving to an integrated process, each subsystem has been tuned until it had a good performance autonomously and each professional could exploit the specific potential of each piece of software.

Immediately after that, it was studied how each solution would work if, instead of launching data directly into the software, it was possible to import data from an intermediary database. Electronic spreadsheets were extensively used at this task.

Figure 3 Interface between subsystems through Microsoft Excel

2.5 Integrated operation

When the process was already steady and professionals were comfortably using their specific software, automated links were created to connect to the databases (interfaces), and manipulate data in order to extract appropriate and useful information for each stage of the process. This integrated operation was possible due to the development of the O.S. System, whose flow of information is represented in Figure 4.

Figure 4 O.S. System automating the connection between subsystems

3 Pillars of the O.S. System

The O.S. System has three important information inputs: A standard Work Breakdown Structure (WBS), a BIM model and a Service Catalog with unit cost compositions for each service described in the WBS.

The three pillars of the O.S. System have been exhaustively discussed and detailed, since they are responsible for the quality of all data to be extracted and manipulated. After more than 1800 man-hours (mh) working with all the teams of the Engineering Department, the foundations that enabled that integration were created. These foundations were materialized in a BIM Modeling Guide, which describes how each element should be modeled on the BIM authoring software, including which parameters should be used, and what is the default naming of files and elements.

Armed with these three data sources, the company has now a system able to extract all quantities of a building in a few minutes, and properly handle the information in the O.S. System to meet the demands of almost all corporate areas. In addition, using management software with 2D and 3D environments combining mobile technologies with cloud-based collaboration and reporting, updated data are available directly at the job site, helping to ensuring that field activities are properly executed. (Figure 5).

These three pillars of the O.S. System are further detailed below.

Figure 5 Mobile technology for on-site operation

3.1 Work Breakdown Structure

One of the first requirements for an automatic process is to have a system that follows a desired structure for the organization of information (Monteiro & Martins, 2013). As a way to ensure full accounting of services without duplication, all projects are divided into manageable parts for easier planning and control of costs and schedules. The PMBOK (2008) suggests the use of a hierarchical decomposition oriented to the work to be performed and designate it as a Work Breakdown Structure (WBS).

In the AEC industry, there are currently several WBS available, organized according to different classification systems such as MasterFormat, Uniformat and OmniClass. In Brazil, a national standard similar to OmniClass was developed for the classification of construction information (ABNT, 2011), and adopted in the O.S. System.

In the case of the studied company, a list with a complete set of activities related to all types of buildings belonging to its business focus was developed, compiling the existing specifications into a single WBS Standard. At the beginning of a new building project, specific tasks are selected in order to create a unique WBS for it. Each element of the WBS is identifiable by a specific code, in accordance with the Brazilian standard, which is also registered in each BIM element as a parameter.

3.2 Building Information Model

BIM models are in fact the main source of information for the entire designed solution. The development of models follows the standards defined in the BIM Modeling Guide in order to enforce a single coordinate system, the non-existence of duplicated elements in the models, the naming rules of the elements and other general recommendations.

The models are then automatically validated (with respect to modeling guidelines) through a plugin developed using the Application Programming Interface (API) of the Autodesk Revit® software which, in turn, extracts quantitative data from the model and feeds it to the O.S. System.

Based on predefined patterns, BIM models provide a list of quantities containing general amounts of all materials, equipment and systems related to the building project.

3.3 Service Catalog

The Service Catalog is a list of all the necessary items (materials and labor) and their quantities to execute each service unit described in the WBS (cost line items). The following information is set for each item:

- List of materials and services;
- Decision about modeling or not modeling an item;
- Classification codes of materials and services (ABNT, 2011);
- Material or service execution cost;
- Productivity;
- Scheduling rules;
- Hiring and measurement criteria;
- Quality assessment criteria;
- Related work instructions (execution, safety and environmental procedures).

Initially in the form of an electronic spreadsheet, the Service Catalog feeds all other systems, in order to enable budgeting, supply plan preparation, schedule planning, and also expected productivity calculations. All this information is provided regarding the lowest level required by System, as the following example (Figure 5):

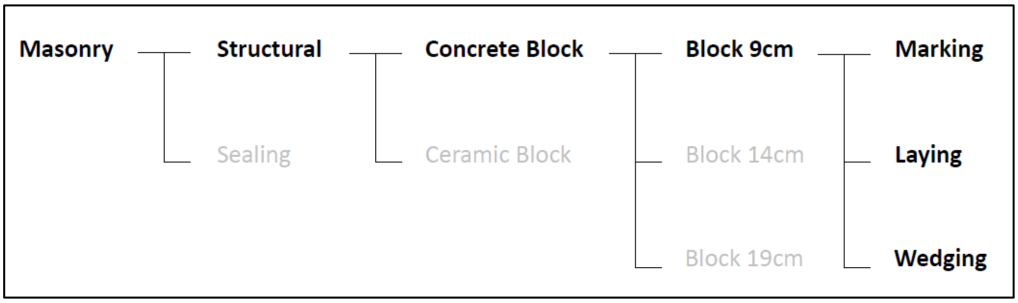

Figure 5 Example of the lowest operational level of a service in the O.S. System

4 Results

Although the deployment of the developed system is recent in the studied company, positive results could already be observed, including:

- Early detection of design problems by the job site team, which also participates in the discussions related to the design;
- The achievement of greater than 90% adhesion to the defined and regularly audited quality standards;
- The certification of the company in international reference standards on quality (ISO 9001), environment (ISO 14001) and occupational health and safety (OHSAS 18001);
- Increase of 16% in the available time of the site work team for the field;
- Reducing the consumption of paper at the site;
- 96% of conformity between scheduled and executed work in 2015;
- 98% of conformity between estimated and realized costs in 2015;
- It is anticipated that projects using the new System will be completed under budget and ahead of schedule.

According to the company's Director of Engineering , in practice, issues identified at the construction site through mobile devices have been worked upon with greater synergies between the concerned areas, enabling a more participatory, reliable and quick decision-making process. The greater integration between field and office allows better management of cost, time and quality of work, improving productivity and resources utilization.

5 Conclusions

The main product of SIGPRO is the O.S. System, an integration engine that centralizes all information required for every organizational business process. It works through the interaction of three sources of information – a WBS, a BIM Model and a Service Catalog - in order to feed the BI module to guide decision-making and control during the construction project lifecycle. This BIM-based system implementation process required the involvement and commitment of all areas of the company, since the benefits were also shared. It was noted at the outset that a computerized system would not be functional without the definition of processes and standards.

Even before any effort of information technology (IT) being mobilized, several teams were involved in discussions about scope, objectives and priorities that the O.S. System would include.

Although the paper had a focus on the BIM technology and its integration with organizational processes, it is actually as much about people and processes as it is about technology. The development of the O.S. System had, at the same time, a bottom-up and a top-down approaches, once it has involved from the operational levels up to the chief executive officer (CEO) himself, which was essential to engage people in the adoption and diminish any potential resistance to change. In parallel, the company invested in training its staff in order to successfully apply the new management strategy implemented by SIGPRO.

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