A COMPLEX VIEW FROM THE DESIGN PROCESS.

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ABSTRACT

Building Information Modeling (BIM) includes tools, processes and technologies based on the digital documentation of a building, its efficiency, its planning, its construction and later on, its operation. Bim enables to access a wealth of information that would remain hidden in traditional processes, by generating a model in which it is reproduced as a future reality, which contains all the information regarding the project and the processes. However, composing a model from such information, following the traditional methods, leads to incompatibilities or undesired simplifications. Such incompatibilities are a result of the lack of a systemic view in the project and in its development process. Traditional science (positivist paradigm), is based on the assumptions of simplicity, stability and objectivity. In contrast the new paradigm of science (the paradigm of complexity), recognizes and accepts the complexity, instability and subjectivity in science. This study aims at identifying the interconnection between the theoretical paradigm of complexity and the design process, specifically the one that uses BIM. Therefore, we start from the hypothesis that the design process is complex and it must be modeled as such. This paper has a theoretical approach, based on bibliographic research of the topics in the epistemology of science and the design process. This is identified as major existing incompatibilities between the theoretical underpinnings of positivism and the design process. It extends the existing theoretical basis of the management construction and the design process. Future work will be able to model the design process, based on the assumptions of the paradigm in complexity.

KEY WORDS

Complexity, design process, BIM.

INTRODUCTION

The study of civil construction as a discipline, has increasingly taken a scientific approach, replacing the simple reproduction of empirical daily practices. The theories applied to it come from different areas of knowledge, such as production engineering, administration, marketing, microeconomics, among other subjects. From these and other areas, concepts and principles are extracted (or, in many cases, only tools and

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techniques), which are systematically arranged and adapted in order to generate the theoretical field of civil construction.

This exercise has been fruitful and thanks to it, civil construction currently has principles to drive their practices. As an example, it can be mentioned that the successful Lean Construction principles migrated from Lean Production, originated in studies of manufacturing and its diffusion has been increasingly widespread. However, the patchwork of multiple concepts that composes the studies on civil construction, still lacks more cohesive and coherent theoretical basis.

By focusing on the project management field, it is noticed that the evolution of this area has facilitated the establishment of concepts of concurrent engineering and the dissemination of the Building Information Modeling (BIM), both aiming to the Integrated Project Delivery (IPD). BIM includes tools, processes and technologies based on digital documentation of a building, its efficiency, its planning, its construction and its eventual operation (Eastman et al., 2008). From BIM, it is possible to access a wealth of information, which would remain hidden in traditional processes, by generating a model that is reproduced as a future reality, containing all the information regarding the project and the processes. However, the attempt to compose a model based with such information, following the traditional principles and methods of development and project management, will probably lead to incompatibilities or unwanted simplifications. Such inconsistencies are a result of the lack of systemic vision in the project and its process of development, as well as management.

This research is part of those which seeks the scientific foundation of civil construction in a paradigmatic level.

The traditional paradigm of science, which even if implicitly guides the traditional methods of project management, is based on the assumptions of simplicity, stability and objectivity. On the flip side, the new paradigm of science recognizes and accepts complexity, instability and subjectivity in science (Vasconcellos, 2002). These latter assumptions have revealed more appropriate problems solving methods, associated with the design process, specifically the one that makes use of BIM.

METHODOLOGY

This research has a theoretical approach based on the research of literature in topics, pertaining to the major areas: science epistemology and design process.

In this article, we will be specifically addressing the issues of complexity and Building Information Modeling, in the context of the new paradigm in science and design process, respectively.

This paper aims at composing a theoretical basis that interrelates the concepts approached herein, namely: complexity and design process. This contributes to a better understanding of the question in this subject matter and allowing an expansion of discussion about it in academia.

Therefore, it starts with the hypothesis that the design process is complex and it must be approached as such.

NEW-PARADIGMATIC SCIENCE

Vasconcellos (2002) uses the term "emerging new-paradigmatic science" or just "new-paradigmatic science", referring to post-modern science (XX century).

According to the author, there are three basic assumptions that distinguish it from traditional science (or classical, Cartesian, Newtonian, modern - XVII to XIX centuries). These assumptions are presented in summary form on Table 1:

Table 1 - Assumptions of Science. (Source: Adapted from Vasconcellos, 2002)

Assumptions of traditional science	Assumptions of the new-paradigmatic science
Simplicity: separation of the world into simpler pieces, analysis attitude, search for simple causal relations.	Complexity: contextual, search for recursive causal relations.
Stability: the world is stable, the phenomena is predictable, controllable and reversible.	Instability: the world in the process of becoming. The phenomena is unpredictable, irreversible and uncontrollable.
Objectivity: to know the world as it is in reality; unique version of knowledge.	Intersubjectivity: impossibility of the objective knowledge for the world, multiple views of reality.

To achieve this distinction it is important to understand the concept of paradigm.

According to Morin (2007), paradigms are "supralogical" principles of organizational knowledge. These are underlying principles that govern our outlook on things and on the world without being aware of it. To Vasconcellos (2002), paradigms “act as filters that select what we perceive and recognize which lead us to deny and distort the data that do not match the expectations created by them"(p.30). The aforesaid filters can be useful due to the fact that they make us focus on certain information, however, on the other hand, they prevent us from seeing other aspects of reality.

COMPLEX THINKING

The word "complex" carries a semantic load that leads to confusion, uncertainty and disorder. Morin (2007) defines complexity as "a tissue of heterogeneous constituents inseparably associated (...), it’s actually the fabric of events, actions, interactions, feedbacks, determination, chances, that constitute our phenomenal world"(p.13).

Simply put, it does not exist. What exists is the simplified. The object is extracted from its complex environment by science, which puts it in non-complex experimental situations. Science is not the study of the simple universe, it is the simplification imposed in order to trigger certain properties.

The paradigm of traditional science, which Morin (2007) calls paradigm of simplification, attempts to find the perfect order behind the complexity of the phenomena. To do so, it reduces the complex to the simple, it isolates objects from their environment (it does not consider, for example, the relation between the observer and the observed), and it eliminates what is unique and individual in order to retain general laws, as well as simple and closed identities.

After this is given, Morin (2007) highlights three principles that constitute the paradigm of simplification: disjunction, reduction and abstraction. The principle of disjunction separates what is connected and the principle of reduction unifies what is different. Thus, the simplicity only sees the one or the multiple.

Applying it to construction, the principle of disjunction makes us split the building into parts, such as structural system, hydraulic system, electrical system, among other parts. The principle of reduction makes us use the same code to represent different things, like the two parallel lines representing a wall in architectural design. However, not all walls are equal, even two masonry walls, for example, may have different properties, such as covering, structural behavior, thermal behavior, etc. The principle of abstraction isolates the objects from their environment. Hence, each one of the parts of a building is set individually.

In opposition - or in addition, once complexity does not lead to the elimination of simplicity - the complex thought consists of dialogic, recursive and hologramatic principles.

The dialogic principle combines two complementary and antagonistic terms. Vasconcellos (2002) argues that "instead of thinking about the strict compartmentalization of knowledge, it becomes the focus to the possible and necessary relations, between the disciplines and the effectuation of contribution between them, characterized by interdisciplinarity" (p.114).

The principle of recursion breaks with the idea of linear cause and effect, with the idea of retroactive circular causality. In a recursive process, the product and the effects are both causes and producers of what is produced, therefore, becoming a self-constitutive cycle, self-organizing and self-producer (Morin, 2007).

The hologramatic principle tells us that the whole is in parts and the part is in the whole. Thus, knowledge of one leads to the knowledge of the other.

The three principles, though presented separately, form a group in which the very hologramatic idea is connected to the recursive idea, which in turn is linked to the dialogic idea, meaning Vasconcellos (2002), arguing that the system is both more than the sum of its parts and less than the sum of its parts. By adding the parts, it appears qualities inherent to the relation between them while others inherent to the parts, independently disappear.

Considering the design process a decision-making process, it is important to highlight the work of Kurtz and Snowden (2003). These authors have detailed three assumptions that prevalent in decision support.

- Order: one can produce a prescriptive and predictive model that allows us to define the right and ideal way of doing things.
- Rational choice: one makes rational decisions based on the trade off of pain and pleasure.
- Intentional capability: the actions are result of intentional behaviors based on the capabilities.

The authors consider that these assumptions are not always true. According to them, the complexities made visible by relaxation of these assumptions. They proposed a framework based on the complexity theory establishing that the order is not controlled, but emerges through the interaction of many entities.

The following item is more specifically related to this complex thinking applied to civil construction.

THE COMPLEX THINKING ON CIVIL CONSTRUCTION

Even if punctually, the issue of complexity has been studied associated to construction.

Baccarini (1996) has reviewed the literature on complexity in building design, with emphasis on project management. He shows that construction projects are invariably complex and that since the Second World War they became progressively more often. He goes on to say that the construction industry can be considered the most complex of the industries. However, the sector has great difficulty dealing with the growing complexity of major construction projects. Therefore, an understanding of the project complexity and how it can be managed, has significant importance. However, his research reveals that the concept of project complexity has received little attention in management literature.

Bertelsen (2003) is emphatic in affirming that construction is indeed a complex phenomenon, nonlinear and dynamic, which usually occurs on the edge of chaos. So it is difficult to the production management, dealing with this reality, since it aims to minimize variations to keep productive activities under control, i.e. avoiding complexities and uncertainties (Bertelsen and Koskela, 2005).

Gidado and Wood (2008) developed a research to identify what makes a building project (as an enterprise) complex. Some of the factors that define complexity on a project are as follows: high independence between the parties; high levels of interaction between the parties; continuous changes and developments; many interconnected parts; high levels of nonlinear interaction with the environment; difficulty of execution for individual activities that composes a process, among others.

Pennanen and Koskela (2005) argue that the nature of complexity varies with the construction progress. The authors present concepts and practices with which the project management should promote complexity when needed to reduce complexity, and when it is unnecessary in order to create value and manage time, as well as costs. The management of complexity has to be adjusted on every stage of the project.

This idea seems consistent when it is considered that complex thinking is multidimensional, but it is not complete and it does not lead to the elimination of simplicity. It also means that, at times, simplistic thinking is needed, especially when it is important to understand the parts.

THE ACTUAL STATE OF THE PROJECT PROCESS

Before dealing directly with BIM and its innovations, the benefits brought by it and its implications in the design process, it is important to characterize the current state of the design process, which includes its development and management.

The assertive of Koskela et al. (1997, p.02) is symptomatic, when they state: "It is not an exaggeration to say that the management of design and engineering is one of the most neglected areas in construction projects. Findings from research, unanimously indicate that planning and control are substituted by chaos, improvised in design."

The nature of the design process is complex; it involves thousands of decisions, sometimes over a period of years, with numerous interdependencies and in a highly uncertain environment. A large number of participants are involved, such as architects, project managers, engineers and market consultants. Trade-offs between several competing design criteria must be done throughout all the design process, often with insufficient information, budget constraints and under intense pressure in the work schedule. The project phases are notoriously difficult to assess and to control. Therefore, with no physical results, such as drawings, it is difficult to measure the amount of work realized and being left in a given task, within the project as a whole. Furthermore, feedback from production and building operation takes too long to be obtained, and tends to be ineffective. (Freire and Alarcon 2002)

Eastman et al. (2008) states that currently, the process is fragmented; it depends on paper based communication means, which are susceptible to errors and omissions that cause contingencies and result in costs, as well as delays; it causes difficult access to information regarding the project, such as cost, energetic performance, structural performance, among others; it needs systems to manage the exchange of information and to enable the team to be synchronized; it hampers the planning, resulting in long lead times and delays; and it generates rework, such as updating the project according to what was built (as it was built).

Recent researches with the goal of improving the design process point to the Lean Design, which is the application of the lean production principles, namely the elimination of waste and activities that do not add value to the design process. This requires analyzing the process from three perspectives: transformation, flow and value generation. These perspectives are reported below as presented by Freire and Alarcon (2002).

The point of view of transformation is essential to discover what tasks are necessary to the design process. However, it is not especially useful for finding out, how not to use unnecessary resources or how to ensure that customer requirements are attended in the best way. In summary, this point of view is effective for the management, and not for improvement, when considering that in isolation, it has caused many problems in the design process, resulting from the fragmentation of activities and from the search for the improvement of individual activities, without observing the interaction between them.

Conceptualizing the design process as a flow of information, leads to the reduction of waste, by reducing the time spent to inspect whether the information is in accordance with the requirements, for the purpose to rework the information, and to move information between the project agents. Additionally, conceptualizing the design process as a flow of information, allows a interdependent flow coordination and a project integration with other stakeholders.

In the model of value generation, the emphasis is on achieving client requirements and converting those requirements into finished products. The project improvement consists in the reduction of the loss in value, which arises when the client's requirements are not captured or are not well communicated throughout the process.

According to Koskela (2000), the three concepts presented herein, are partial and complementary, however, due to a greater relationship with the client in the design stage, the concept of value is more significant for the project, compared to the concepts of transformation and flow. Traditionally, it is through the point of view of the concept in transformation that the design process has been explicitly modeled, managed and controlled. Following this concept, the design process is treated as fragmented, linear and sequential parts.

Having this said, we suggest the incorporation of a concept still neglected in the approach presented, being the complexity. Fabrício (2002) considers that the design process has ever more a collective nature. It involves several specialists with distinct objectives. This diversity increases as the building becomes functional, aesthetically and technically more complex. The author points that "the mobilization and articulation of professionals and knowledge areas refer to the Cartesian model of splitting a problem into smaller problems" (Fabrício 2002, p.112)

The action of different professionals, with their respective sets of knowledge, lead to the need for social processes and technical support to expand the intellectual capacities. Fabrício (2002, p.121) cites, as examples, algorithms, calculation methods and computers to amplify the information processing capabilities of individuals, texts and files to extend the possibilities of memory to preserve and accumulate unlimited amounts information, and computer graphics programs to enhance the capability of representation of abstract ideas and allow to integrate image numerical algorithms in order to generate simulations.

THE BUILDING INFORMATION MODELING

The BIM Handbook Glossary (Eastman et al. 2008, p.467), defines BIM as "a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later on its operation." Through BIM, a precise three-dimensional model of the building is digitally constructed, using parametric information.

The parametric information makes objects “intelligent”. In these cases, a wall, for example, is not only defined by two parallel lines, in fact it is defined by a series of attributes that characterize it, such as geometry, materials, specific weight, structural behavior, thermal behavior, among others. Moreover, this same wall object can be subdivided into other objects that compose it, with their respective attributes.

This feature makes BIM, being the emphasis greater on the data than on the drawings themselves. For Smith and Tardif (2009), the main feature that distinguishes BIM from previous project technologies, is not the three-dimensional modeling, but the systematic information that can be organized, defined and is interchangeable. The non systematized information is difficult to identify, manage and exchange. Therefore, to work with non systematized information can make difficulties for the effort not becoming worthwhile. For the sake of illustration, the same author uses the metaphor of a needle in a haystack. The work of finding it can be so great that it outweighs the price in which it will be sold.

Ruschel et al. (2010) cite three fundamental aspects of BIM that allow the project to be treated as multidimensional: "the parametric modeling to the ‘unique model' development, the interoperability for integration and collaboration, as well as the information exchange among the ones involved, added to the possibility of managing and evaluating the project throughout its life cycle" (RUSCHEL et al. 2010, p.138).

Eastman et al. (2008) list a number of benefits brought by BIM, highlighting those related to the design process:

- design view with greater foresight and precision;
- automatic correction of the changes made to the project;
- accurate and consistent generation of 2D drawings at any stage of the project;

- anticipation of the collaboration between multiple project disciplines;
- easy checking of the project requirements;
- cost estimations during the design process; and
- improving energy efficiency and sustainability.

With so many benefits, it seems incoherent that BIM is still not the dominant process in project development and management. However, it is still not so, due to its implementation, which demands structural changes in the construction industry, since this requires both a process change and a paradigm change: from 2D-based documentation and process divided into stages with the digital prototype and collaborative workflow.

BIM as a tool enables systematization and facilitates the handling of information, regarding the infinity of variables which compose and are interconnected into complex systems. Therefore, it should have been the result of the need for something that facilitates the interaction between the design disciplines and the manipulation of its variables. And yet, the order was in reverse. The design process is approached as a linear and a compartmentalized sequence of activities. Improvements in the process as a whole were seen as the improvement of the parties individually. With the advent of BIM tools, it is now discussed how to integrate these parts so that we can take a better advantage of this said tool.

For a real approach of BIM, as a process, and not just as a tool, it is necessary to understand and to consider the complexity of the design process, which is surrounded by a high level of instability and interaction between its component parts.

The instability can be accepted, if it is considered that the systems are extremely complex and that the infinite numbers of variables do not allow it to be a perfect predictability. Thus, one can understand that by applying complex thinking and assuming the largest possible number of variables, which were previously neglected, the accuracy of forecasting and planning increases. BIM is essential for this, as there is a certain limit of information from which we as humans, can handle with.

The development of BIM, according to Succar (2009), aims to reach the IPD. IPD integrates people, systems, structures and business practices in a single process in which all participants work adding value, reducing waste and maximizing its efficiency. In it, the BIM is used for different analysis and evaluations by individual participants to optimize project results. This occurs in order to involve all stages of the life cycle of the project, which leads to greater interaction among agents, their inputs and outputs.

CONCLUSIONS

The literature review on the subject of the paradigm in complexity and in the design process, has shown the existence of conceptual relations between them. Therefore, it was possible to identify the interconnections between the design process and the theoretical assumptions of the paradigm in complexity more specifically, as well as the major inconsistencies between the theoretical basis of traditional science and the design process.

A practical approach must be undertaken through a case study, with the intention of learning how BIM is being applied in the project development and in the management process, along with what are its implications. This is aimed to identify how those incompatibilities undermine the process from the point of view of Lean Thinking.

It is expected that the study of information from this approach, enables the formulation of a project development and a management process model, that will make use of BIM, considering the theoretical assumptions of the paradigm in complexity.

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