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The need for a new systemic approach to study collaboration in the construction industry

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Abstract

An important particularity of the construction industry lies in its fragmentation and the fact that the various actors involved in construction projects come from different organizations and have to work together temporarily in order to achieve a common objective. Thus, a good collaboration is critical for the projects' success but remain challenging in the industry despite much research effort. The rise of Building Information Modeling (BIM) approach is full of promises but to fully benefit from such disruptive technology, it is necessary to understand how it impacts all the aspects of the construction industry. Unfortunately, the traditional analytical modeling approaches only present a static and mono-perspective image of a highly dynamic industry where many perspectives of the same situations cohabit, and mutual adjustment remains important. This article proposes a discussion on the need for a new systemic approach to complement the current analytic approaches in order to better understand the complexity of collaboration in the construction industry. It uses a systemic triangulation according to different levels of study (industry, project, firm and activity levels) in order to derivate the main relevant components to consider in the study of the construction industry as a complex system.

Keywords: Systemic approach; Systemic triangulation; Collaboration; Construction industry; BIM

1. Introduction

It is not a new fact that the construction industry, characterized in particular by high fragmentation [1], is considered to have low productivity compared to other comparable industries [2]. Some decades ago, Winch was asking "why the construction of housing and other built products has been so resistant to the virtuous cycle of

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simultaneous cost reduction and quality improvement that has benefited most other industries over the last century" [3]. One of the main issues in the industry is related to collaboration and information exchange [4]. Indeed, while other discrete manufacturing industries have found a way to optimize their production process in order to achieve optimal results, collaboration in construction remains problematic despite much effort devoted to understanding and improving it.

The recent technological developments of the Building Information Modeling (BIM) approach are full of promises. By providing a three-dimensional model as a central component of the construction projects, BIM gives construction the tools to better manage its duality of process and product. The model of the product can, therefore, be more finely analyzed upstream in order to better think the construction process. However, in current BIM practices, collaboration and sharing of information remain very fragmented, even if several advances have been made (technological interoperability, execution planning, etc.). In addition, the BIM approach highlights contradictions related to current methods of managing collaboration in construction projects (e.g. discontinuity between information flow and activity flow).

Current trends for improving construction collaboration are based on good practices from other industries such as aerospace and automotive. Unfortunately, the construction sector differs fundamentally from these industries and the recurring failure could be explained by a lack of knowledge of the specific systemic nature of the construction industry [5]. This systemic nature has been discussed in the literature [3,5–7] but has not yet received the deserved attention. Since BIM is a disruptive technology, it impacts all the 'construction system' and the new optimization issues highlighted by the implementation of BIM force researchers to re-query these theories in order to find the missing links for a better collaboration on BIM projects.

This paper proposes a discussion on the need to complement current analytical approaches with a new systemic approach in order to better understand the complexity of collaboration in the construction industry. It provides a view of how a systemic triangulation could be helpful to determine the main dimensions to consider when studying collaboration in the construction industry.

2. Related works

Seeing the construction industry as a complex system is not new. In his discussion about construction research funding in 1997, Gann [8] proposed a view of the 'construction system', with activities and actors. The proposed model identifies five main components with corresponding activities and actors: regulatory framework, supply network, project-based firms, projects, and technical support infrastructure (Figure 1).

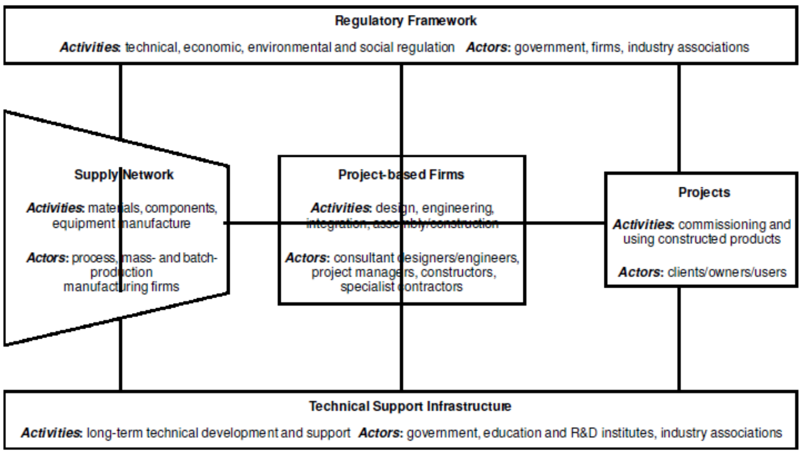

Figure 1: Construction system – activities and actors [8]

The Gann's model is somehow similar to the model proposed by Winch [3] who differentiates the systems' integrators (the principal architect/engineer and the principal contractor) from the innovation superstructure (the clients, the regulators and the professional institutions) and the innovation infrastructure (the trade contractors, the specialist consultants and the component suppliers).

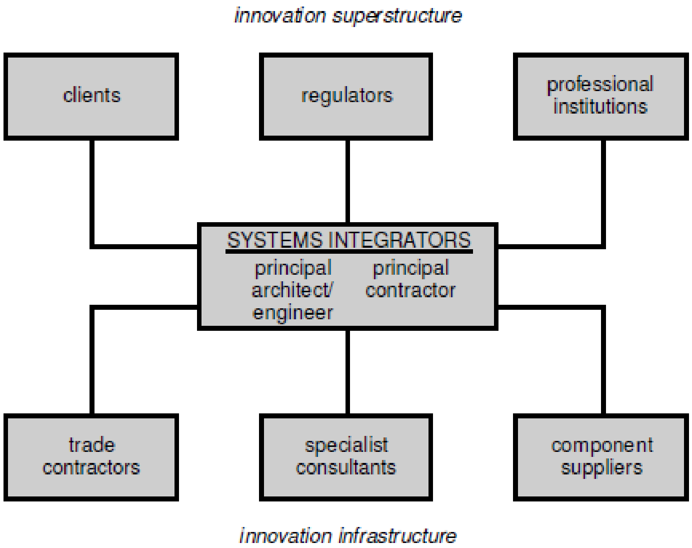

Figure 2: Construction as a complex systems industry [3]

In 2002, Bougrain and Carassus [7] introduced the notion of a sectoral system of construction, which is defined as "the complex and organized set of relationships between productive and institutional actors involved in the production and the management of the construction of facilities and the service delivered by these facilities throughout their entire life cycle" [7]. Around this central notion, they implemented a method to analyze construction, with an emphasis on the productive problems to be solved, the groups of activities, the modes of profit formation, the productive configurations of actors, and the institutional regulations. To be able to identify the construction subsystems in a consistent way, they used four criteria: the nature of the facility, the nature of the market (international, national or local), the nature of the client (households, companies or administrations) and the size and the nature of the construction firms. These criteria enable them to identify 5 sub-systems. Three of these sub-systems are dominated by large firms (the international construction sub-system, the national road construction sub-system, and the national non-road civil engineering subsystem). Two of the sub-systems are dominated By SMEs and craftspeople (the subsystem of buildings' projects with companies and administrations as clients, and the subsystem of buildings' projects with households and sole proprietorships as clients).

One of the most known modern theoretic approaches in construction production is the TFV production theory [9]. It considers three important views for production management: Transformation view, Flow view and Value generation view [9]. The transformation view decomposes the total transformation (of inputs to outputs) into elementary tasks in order to carry out the tasks as efficiently as possible. The flow view considers production as a flow which encompasses with the transformation, some moving and inspection stages. According to the value generation view, the production aims at ensuring that the product designed corresponds to the customer needs. These three complementary views co-exist, so managing production equals to managing tasks, flow, and value. In practice, Bertelsen and Koskela [9] proposed to focus on three main management functions: contract management (contract, claims, success criteria, etc.), process management (production flow, cooperation, planning methods, etc.) and value management (customer satisfaction, process related value, etc.).

More recently, Fernández-Solís [5] proposed a discussion about how the construction industry differs from other industrial sectors by its specific systemic nature. The work considers construction industry as a "loosely coupled system with process as its primary axis of attention and product as its secondary axis" [5]. Unlike manufacturing industries (tightly-coupled systems), this system is characterized by enormous possible combinations and number of permutations; complex, inefficient and sub-optimized operations; overlapping specialized and time-sensitive interdependent activities; on-site work, changing site conditions, uncertainty and reworks. Based on different authors, Fernández-Solís [5] derived 18 characteristics that make the construction industry a complex system. These characteristics are grouped using headings from Shingo (Operations, Value, Process) [10] and the corresponding headings from the Koskela's TFV production theory (Transformation, Value, Flow) [11].

Table 1: Characteristics of the construction industry as a complex system [5]

KOSKELA: TRANSFORMATION	VALUE	FLOW
SHINGO: OPERATIONS	VALUE	PROCESS
1.1 Autonomous agents	2.1 Undefined values	3.1 Non-linearity
1.2 Non standard	2.2 Fitness landscape	3.2 Emergence
1.3 Co-evolution	2.3 Non-uniform	3.3 Attractors
1.4 Self-modification		3.4 Phase changes
1.5 Downward causation		3.5 Unpredictability
1.6 Self-reproduction		3.6 Instability (variability)
1.7 Mutability		3.7 Learning organization
1.8 Fuzzy functions		

These proposals are highly relevant as important milestones towards a comprehensive understanding and theorization of the construction industry. Unfortunately collaboration remains challenging in the industry, mainly because of the flexibility that characterizes the construction dynamics and the importance of subsequent informal processes. Indeed, "in the AEC industry, cultural and organizational boundaries tend to stifle collaborative work and joint problem solving even with contractual agreements meant to foster a team environment" [12]. De Blois et *al.* [6] explored the project processes (formal and informal ones) from different perspectives (organizational levels, project stages, etc.). Based on a four-year case study and an empiric approach, they observed how the evolution of such processes seems in contrast with the linear approach traditionally used to analyze construction projects. In order to address all the complexity of the interaction among project structures and processes, they have recourse to the systemic theories as described by Le Moigne [13]. Their research showed that the processes actually unfolded are significantly different from the planned ones; that linear processes are overshadowed by the iterative ones; and how "informality and 'iterativity' eventually end up as self-, eco-, and re-organizing projects and organizations, confirming that projects (re)create the very processes and structures that initiate them" [6]. Moreover, Homayouni et *al.* have identified in 2010 that approximately 80% of the strategies needed to develop skills towards an integrated team environment in BIM projects are social [12].

3. Why a new systemic approach in the construction industry?

3.1. The systemic approach

The systemic approach consists in applying the systemic theory based on the definition given by Le Moigne [13]. The systemic theory here has to be differentiated from the general systems theory proposed by Ludwig von Bertalanffy [14]. According to Le Moigne, the term "*la systémique*" was forged in France in the 1970s to try to avoid confusion with "general system" as suggested by Bertalanffy [15]. However the systemic as an approach is inspired by the general systems theory and proposes an alternative modeling theory to analytical modeling [15]. Donnadieu et *al.* defines the systemic approach as "a new discipline that brings together theoretical, practical and methodological approaches to the study of what is recognized as too complex to be dealt with in a reductionist way and poses problems of boundaries, internal and external relations, structure, emerging principles or properties characterizing the system as such, or problems of mode of observation, representation, modeling or simulation of a complex whole" [16]. The systemic approach tries to understand the complexity by the mean of four basic interacting concepts depicted in Figure 3 (the system, the complexity, the wholeness, and the interaction) and a dozen complementary, more technical and action-oriented concepts including the information, the finality, the retroaction, etc. [16].

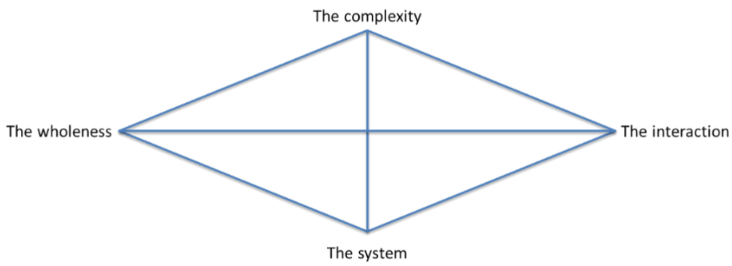

Figure 3: The four basic concepts of the systemic approach (adapted from [16])

As a practice, the systemic approach uses mainly the systemic triangulation and the systemic modeling tools. Systemic triangulation consists of observing three different but complementary aspects of the system studied: the functional, the structural and the dynamic aspects. The functional aspect is relative to what the system does, that is to say its purpose. According to Donnadieu et *al.* [16], it is a matter of spontaneously answering the questions: what does the system do in its environment? What is it used for? The structural aspect concerns the structure of the system itself, i.e. how it is composed. This aspect is rather close to the usual analytical approach but the emphasis here is on the relations between the components rather than on the components themselves [16]. The dynamic (or historical) aspect concerns the evolutionary nature of the system. Donnadieu et *al.* [16] note that only the history of the system will often make it possible to understand some aspects of its functioning. These authors also propose to start the social systems study by this historical aspect. According to Le Moigne [17], the systemic modeling is based on three fundamental hypotheses: a "phenomenological" hypothesis (as opposed to the ontological hypothesis of the analytic method), a teleological hypothesis (as opposed to the traditional deterministic hypothesis) and a hypothesis of procedurality of the rationality [17].

3.2. The need for a new systemic approach to study collaboration

An important problem of research in the construction sector has been the lack of theoretical basis [11]. Of course, several seminal works laid the foundations for the study of information technologies in construction [18,19] but BIM is a breakthrough technology and it is still difficult to connect the current issues with this theoretical basis. The study of BIM-supported collaboration must take into account not only its technological aspects but also the procedures and organizational dynamics [20,21]. Four theoretic levels are generally used to study the construction industry: the market, project, firm and task levels. The current approaches are of course very relevant for each of these levels. For example, while the TFV [11] approach is very relevant to study the construction production at a project level, the recent work from Succar and Kassem [22] is full of potential and provides new avenues to study construction at the level of the industry, and Halin et al. [23] have shown that understanding the collaborative tasks can be helpful in order to adapt IT tools to the practitioners' business needs.

The current missing links in the study of collaboration in the construction industry seem to lie, not only in the understanding of these four levels themselves, but also in the complex relationships between the levels. Indeed it appears necessary to explore how and to what extent the formal and informal processes and structures (re)created by construction projects [6] could be explained in a large proportion by the bidirectional relationships between some factors from the different levels considered (Figure 4).

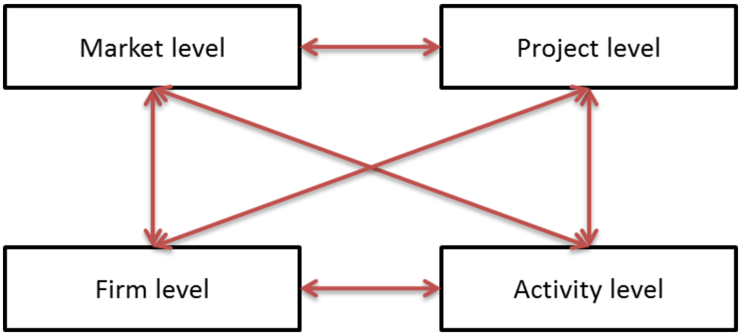

Figure 4: Bidirectional relationships between the different levels generally considered

In order to understand these relationships, a systemic triangulation can be particularly helpful if it can integrate the structural, the functional and the historical aspects [16] and be declined according to the four main levels described above: the industry, the project, the firm and the activity levels (Figure 5).

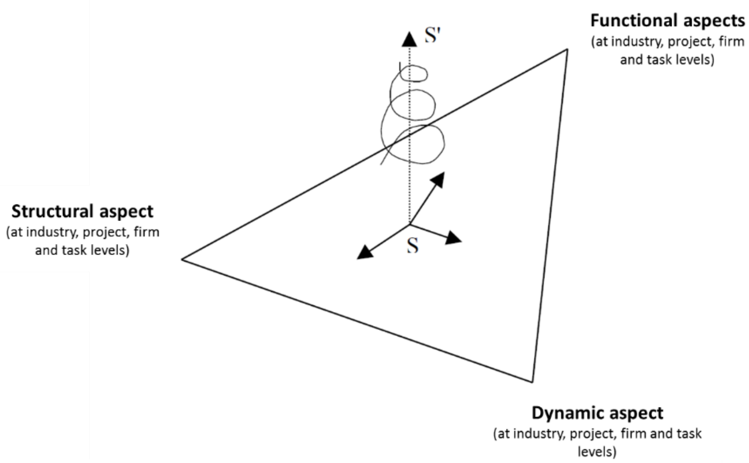

Figure 5: Construction systemic triangulation (Adapted from [16])

Table 2 shows a resulting matrix from such systemic triangulation and provides a view of the different elements to consider. The main aim here is to identify the main elements and factors that could explain the complexity of the relationships between the different levels.

Table 2: Matrix of functional, structural and dynamic aspects according to the different levels

	Functional aspect	**Structural aspect**	**Dynamic aspect**
Industry level	Environmental changes	Market (as fragmented social network)	Industry policies and techniques evolution
Project level	Building (as a product)	Project (as temporary supply chain)	Project lifecycle evolution
Firm level	Firm strategy	Firm (as permanent organization)	Firm historical evolution
Activity level	Building (as a process)	Activity (as practice)	Generally accepted practices evolution

At the industry level, the role of the construction market as part of the local and/or global economy is considered. According to Sunke "it is a major sector in most national economies and a major contributor to environmental changes, both in terms of designing the built environment as well as in terms of anthropogenic effects on the environment" [24]. At this level, the system is structured as a social network made of integrators bodies (all architects, engineers and contractors), superstructure bodies (all clients, regulators and professional institutions) and infrastructure bodies (all trade contractors, specialist consultants and component suppliers) identified by Gann [8] and Winch [3]. This network evolves according to the industry policies but also according to the bidirectional interaction between the technological innovation drivers.

At the project level, the purpose of the system is the building as a product. At this level, the system is structured as temporary supply chain made of some of the bodies identified above. The common goal of this supply chain is the beginning of the life of the product (planning, design, and construction phases). Depending on the specific project delivery method used, the different bodies will be temporarily involved in different activities during the product lifecycle stages. They have to combine their effort in order to achieve the overall common objective: the product. But besides this common goal, it is important to note that each firm involved has its specific objectives and perspective of the product.

At the firm level, the strategy of a firm is considered. The strategy here encompasses both corporate strategy and business strategy. According to Cheah and Garvin [25], the corporate strategy is related to the entire organization operations while the business strategy is about individual business units' ventures. In its historical evolution, the firm is working to achieve and to maintain a competitive advantage [26]. In the framework of a construction project, the firm perspective is intrinsically linked to this competitive advantage and not only to the instant economic interest. It could be a matter of acquiring new experience or technology, of improving reputation and portfolio, of developing or experimenting new processes and technologies. This also contributes to the way the firm is perceived and perceives other in the community, with some consequences on the inter-firms dynamics.

At the activity level, the building (as a process) is considered. The activity here can be seen as a subset of the project in the form of a collaborative practice. Halin et *al.* [23] defined collaborative practices as "the behaviors of groups of actors working together in various organizational situations according to business objectives" [23]. Some generally accepted practices exist in the industry and are the basis of the collaborative practice. They evolve according to the evolution of construction techniques and technologies.

While some of the different components identified above have been more or less discussed in the literature, their interrelations have been less addressed. Studying these interrelations (future work) will provide key elements to better understand the collaborative work in the construction industry at the age of BIM.

4. Conclusion and future work

The quality of cooperation among parties is critical and is one of the main success factors of a construction project. While much research effort has been dedicated to its improvement in recent years, it is important to note that the current analytic approaches are not sufficient to study all aspects, especially the social and the informal processes which are very important at the construction phase.

This article presented the first results of a more comprehensive work aiming at proposing a new systemic approach to complement current analytic approaches currently used. It proposed a discussion on the need for a new systemic approach in order to better understand the complexity of collaboration in the construction industry. With this perspective, the main components of the construction system dynamics are identified using a systemic triangulation. The structural, the functional and the historical aspects have been declined according to the industry, the project, the firm and the activity levels.

Future works will focus on deepening these components and to study the interrelations between them as premises for a systemic modeling approach. A consistent case study will also be identified and used in order to evaluate and validate the proposals.

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