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Challenges for Implementation of a New Model of Collaborative Design Management: Analyzing the Impact of Human Factor

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Abstract: The ineffectiveness of current design processes has been well studied and has resulted in widespread calls for the evolution and development of new management processes. Even following the advent of BIM, we continue to move from one stage to another without necessarily having resolved all the issues. |CAD design technology, if well handled, could have significantly raised the level of quality and efficiency of current processes, but in practice this was not fully realized. Therefore, technology alone can´t solve all the problems and the advent of BIM could result in a similar bottleneck. For a precise definition of the problem to be solved we should start by understanding what are the main current bottlenecks that have yet to be overcome by either new technologies or management processes, and the impact of human behaviour-related issues which impact the adoption and utilization of new technologies. The fragmented and dispersed nature of the AEC sector, and the huge number of small organizations that comprise it, are a major limiting factor. Several authors have addressed this issue and more recently IDDS has been defined as the highest level of achievement. However, what is written on IDDS shows an extremely ideal situation on a state to be achieved; it shows a holistic utopian proposition with the intent to create the research agenda to move towards that state. Key to IDDS is the framing of a new management model which should address the problems associated with key aspects: technology, processes, policies and people. One of the primary areas to be further studied is the process of collaborative work and understanding, together with the development of proposals to overcome the many cultural barriers that currently exist and impede the advance of new management methods. The purpose of this paper is to define and delimit problems to be solved so that it is possible to implement a new management model for a collaborative design process.

Key words: BIM, Collaborative Design, IDDS, Design Management.

1. INTRODUCTION

Collaborative work would lead to better results for professionals and design companies, whether that collaboration is internal or external (Akintoye, McIntosh et al. 2000; Bresnen and Marshall 2000). However, it is still a big challenge for everyone to achieve effective collaboration.

Companies are often investing resources in the implementation of new technologies without necessarily understanding the changes which it can enable or which it may even create through the act of adoption. As argued in Owen, Palmer et al (2009) ,the technologies are there to support processes; the processes are there to support the creation and maintenance of coherent and relevant information; and that is there to support the collaboration of people in a shared endeavour.

Collaboration is one of the central issues in studies for improving the design process, but it's important that we look at this concept more accurately.

(Kvan 2000),(Gert-Jan de Vreede 2005), compare the concepts of *cooperation*, from the Latin *cooperare* (work with others)and *collaboration,* from the Latin *colaborare* (work in agreement with others)and define the main distinction between these two words is that in *collaboration* the holistic and creative work aspects are hard to achieve and maintain, while working *cooperatively* like bees and ants is easier.

The word *cooperation* was initially used by economists during the first half of the XIX century, and its concept was formally defined by (Marx 1890) as:

"[...] multiple individuals working together in a planned way in the same production process or in different but connected production process".

Collaboration requires bigger commitment than cooperation for achieving a common goal, and therefore risks are increased, implying on a deeper level of trust between the actors of involved groups.

(Kalay 1998), defines *collaboration* as an agreement between the actors on sharing their abilities in a particular enterprise to achieve the goals of this enterprise.

According to (Leicht 2009), three elements define *collaboration*:

- *Collaboration* is a process;
- *Collaboration* requires interaction between two or more people;
- People need to be working together towards a common goal.

2. STUDIES ON DESIGN COLLABORATION IN BRAZILIAN PROJECTS

Several Brazilian and foreign researchers have developed studies on the design process: (Melhado 2004), (Manzione 2006), (Kalay 1998), (Austin 1999), (Kvan 2000),(Hammond, Choo et al. 2000), (Carlos Formoso 1998), (Reinerstsen 1997), (K.T. Ulrich 1999).

As in other countries, the need of severe reformulation in the traditional design process is identified in Brazil; BIM technology and collaborative work have been considered the next stage to be reached in this evolution line. However, we must study collaborative work in the light of four key-resources in order to understand it: people, processes, technology and information.

To achieve a precise definition of the problems to be solved, we should start by studying the usual design bottlenecks that will have to be overcome by new technology and management processes, and evaluate the impact related to the human factor, constantly present in the process.

Based on professional experiences as a Design Coordinator, between the years of 2008 and 2011, the first author studied factors related to people and processes that were considered obstacles for the implementation of collaborative design process. Eleven designs were evaluated, with diversified scopes(residential, hospital and office buildings), most of them in the city of Sao Paulo – Brazil, and all involving the participation of several designers of different specialisations.

Based on these case studies, the main obstacles to collaboration between design management and the design team are listed below:

Table 1. Main barriers to Design Collaboration in Brazilian Projects

Obstacles referring to Project management:		
Fragmented and Sequential Process	Low interaction between actors involved	Design coordination is often confused with design compatibility
Planning with inadequate method: control of deliveries and not the process	Lack of communication	Different goals and values for each of the agents involved
Obstacles related to people (design team)		
Resistance to collaborative work	Resistance to planning	Unstructured work process
Heterogeneity of conflicts involving the design team	Resistance to using IT	IT as an expense and not as an investment
Little relevance given to building performance	Lack of quality control of the process	Failure in the design company management

The related problems occur frequently in the traditional design system, and they configure obstacles to collaborative work in an environment where BIM doesn't exist, demonstrating the inefficiency of the design management process and pointing to the need for evolution in design management.

In that context, BIM can be considered a collaborative work revolution, for it will change *how* actors collaborate, *when* they collaborate and the *contractual base* in which they work(Brandon and Kocaturk 2008). But we have to analyse whether we are not moving to a new stage without dealing with the current issues in design management.

3. ASPECTS OF COMPUTER SUPPORTED COOPERATIVE WORK

Computer Supported Cooperative Work (C.S.C.W.) is a concept created by Greif (1988) as an abbreviation for referring to a research line that studied how to support multiple actors working together in computer platforms.

Researches on this subject develop from two viewpoints: the first, focusing on technology, try to develop technologies to support the collaborative work, while the second focus on the production, emphasizing the understanding of work processes and systems (Mills 2003).

We can find references for production/work focused study lines in (Anumba, Ugwu et al. 2002), (Mohsen Attaran 2002), (O.O. Ugwu 2001), who describe collaboration processes based on classifications of space and time:

Table 2. Patterns of Collaboration (Anumba, Ugwu et al., 2002)

	At the same time	**In different moments**
At the same place	Face to face collaboration	Asynchronous collaboration
In different places	Distributed Synchronous collaboration	Distributed Asynchronous collaboration

(Winograd 1986) raises questions related to people behaviour in their work according to different perspectives. According to him, while working people perform the following acts and these affect design:

- Process information and make decisions;
- Fulfil their functional roles according to stable rules;
- Create and maintain authority structures;
- Negotiate and promote interests competition;
- Establish personal relationships that are expressed through their activities;
- Act through languages.

Winograd (q.v.) also defines several questions concerning collaborative systems development, considering that when designing them for usual situations we have to concentrate efforts on issues related to its context and application more than internal structure and operation of the computer system.

On the other hand, the design of collaborative systems is ontological, meaning that when a computer-based management system is introduced, we're not only designing its structure and function, but participating in a broad organizational design: designing a work system and not only a tool.

Therefore, when describing and building a system, we are being guided by a perspective that determines the type of questions that will be raised and the type of solution needed.

Groupware is the name given to several user-collaboration software products, and it is often confused with collaboration itself.

Authors such as Baldwin, Sehn et al.(2009)ponder the word collaboration refers to a broad meaning of established working social relationships, while *groupware* has a more purely technological focus, and therefore shouldn't be used as synonyms.

Bannon and Schmidt (1989)consider the groupware concept to be restricted to a technical problems approach and human-computer interface, while the central issues in Computer-Supported Cooperative Work (CSCW) are to achieve the following aspects in collaborative work:

- Articulating collaborative work;
- Sharing an information space;
- Adapting technology to organization and vice versa.

Collaborate work articulation, the first main theme in CSCW, assumes a big effort in activities, schedules and resources coordination, besides implicating a large number of intermediate tasks, mediation and control of individuals, definition of quality and time criteria, and precise description of what needs to be done.

In semi-structured production of design tasks also consider uncertainty and interactivity, making them harder to plan (Manzione 2006), and turning the coordination process into a continuous negotiation and renegotiation effort between the actors (Melhado 2004).

A complex and creative process is involved in the elaboration of a design to meet the common vision accepted in the many typical bureaucratic organizations, where people develop their activities according to a group of 'procedures', which are well specified and developed by the central administration as effective and efficient ways to achieve certain goals.

In this traditional model, deeply entrenched in the AEC sector, many assumptions are made on a rational basis, meaning to achieve common goals between the employees and the organization. According to this vision, the traditional chart indicates the real authority lines and specifies the 'correct' pattern for information and communication flow(Bannon and Schmidt 1989). However, such an approach is typically discreet and fails to appropriately incorporate the dynamic requirements of a complex system.

Computer systems that try to rigidly answer these patterns tend to fail for not taking into account the informal social relationships that exist in companies and that are not represented in the formal company chart.

The informal interactions that occur in workplace environments have an essential role in conducting routine work and processes, and its importance should be considered in the study of improving collaborative processes.

An evidence of that is that when people work "by the book", which is commonly called in Brasil "standard operations", the results are mediocre and inefficient.

But what does this imply in system development?

Systems whose goal is just the workflow organization neglect the necessary coordination for making this workflow possible, and may fail,(Bannon and Schmidt 1989), (Mills 2003).

The development of a shared information space, the second theme in CSCW, is strongly influenced by the intensity of collaborative work relations, for it requires interaction between people and the conceptual structures of a diversity of decisions, originating concurrent situations and control problems in applications for multiple users.

For this reason a shared information and decision space needs to be transparent and clear, implying the need for deeper research in issues such as authorship, propriety, origin identification and adopted strategies for the production of the information contained in the shared space, such as the responsibility involved in its propagation.

The notion that organizations are monolithic entities that can be unified through a database model is quite naïve; the idea of a transparent accessible database seems to be unrealistic when we consider human nature factors (Ciborra 1985).

Instead of that, and on the contrary to a traditional Cartesian view, it seems more realistic to believe that an organization is a continuous and dynamic mixture of collaboration and conflicts, of transparency and hiding.

Much of the information created and processed in companies can be considered inappropriate, as it may have been generated and communicated in a context of goal incongruence or motive and interests disagreement. Still, the need for transparency is amplified by this contradiction and the transparency must be more delimited. An employee engaged in a cooperative decision process needs to have the skills to control the propagation of the information relevant in his work: What should be revealed, when should it be revealed, for whom and how? These realities in organizational life need to be investigated, and ignoring the differentiation between strategies and incongruences of conceptual structures reduces the problem to the technical nature of multiuser systems, being only a technology oriented approach, with all its approximations and limitations.(Bannon and Schmidt 1989)

The third CSCW theme is the reciprocal adaptation between technology and the organization. Understanding the complex interactions between technical subsystems and work organization requires a social-technical approach as part of the approach for overcoming obstacles in the implementation and improvement of collaborative work systems.

(Bannon and Schmidt 1989)raise some reference issues to be considered in this analysis:

- The privilege and losses in task distribution;
- Institutional ways of expressing and regulating conflicts of interests;
- Social control in work environment;
- The impact of the company role in the social economic system;

We also consider as a necessary reference the study of process(es) impact and their relationship(s) with other processes linked with actors of the company supply chain.

4. THE COMPLEXITY OF BIM IMPLEMENTATION IN A COLLABORATIVE CONTEXT

Amor and Owen (2011)observe the tendency to utilize BIM more as a technology, which he defines as simple BIM (sBIM), and less as an integrated intelligent process, defined as iBIM, although in this second form there are many more financial advantages, especially if connected to lean construction processes and new forms of collaboration processes, such as the IPD (*Integrated Project Delivery*).Several points of view have shown the need of deeper researches on the improvement or management methods. They also recognize that a new tendency between advanced users and industry leaders to look for a new concept already exists, on account of the observed tendency of users of using BIM only as a design technology.

(Rekola, Kojima et al. 2010)and (Moum, Koch et al. 2009), identify that developing improvements for the interorganizational and efficient use of BIM requires changes in fields other than technology, and for realising the benefits of the BIM technology, companies need to coordinate and develop interoperability in their business processes.

The AIA(*American Institute of Architects*), according to Fallon (2006), identified the lack of understanding of industry members on how to obtain the integration of workflows through an integrated technology as the number one obstacle for using interoperability

(Rekola, Kojima et al. 2010)mention that there is still little understanding of how workflows and business practices can be aggregated for IT-supported interoperability for obtaining the benefits of BIM in the AEC processes. They also select as a problem in their research the understanding of BIM low development rhythm, and how to help the industry to solve problems that prevent the transformation of their processes towards adopting the IDDS philosophy. This research concludes that the lack of new Design Process Management knowledge is one of the greatest barriers to achieving integrated projects using BIM, and that its slowness is caused by the bottlenecks in the combination of technology, processes and people. He comments that there are a lot of factors involved and that some mechanisms are still missing; tools and rules to select what and when to optimize the cost-benefit relation in a project using BIM, changing its optimization into a hard task. In addition, BIM imposes many challenges for activities planning, meaning that the planning of the BIM design process is hard to be elaborated, on account of the complexity of information exchange and involved processes.

In practice, the design process management needs more information to be collected from new researches, aiming for the construction of a stable basis for design process planning decisions and the development of new human competences for managing BIM designs.

5. THE IMPLEMENTATION OF BIM IN THE IDDS PERSPECTIVE

CIB (International Council for Research and Innovation in Building and Construction) defines IDDS (Integrated Design and Delivery Solutions), as:

"[...]Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects(Owen, Palmer et al. 2009)".

IDDS is intended to integrate the CIB's other priority research themes and to help provide a unifying focus to the majority of their Working Commissions and Task Groups through development of research trajectories, thus helping to steer the four to five thousand active CIB researchers through an interactive process.

Owen, Amor et al(2010)comment that innovations such as BIM and the IPD have been developed in an isolated way and without righteous consideration of the global relations between people, processes and technology.

The authors identify the four biggest issues do be solved:

- Collaborative processes across all project phases;
- Enhanced skills;
- Integrated information and automation systems; and
- Knowledge management.

As examples of the changes to be made, the authors comment that whilst the diffusion of BIM technology is increasing, in many cases its implementation happens analogously to what happened in CAD technology implementation, as it reproduces a current process practically unchanged.

To maximize BIM technology potential, an analysis and reengineering of the affected processes are required, as is the re-evaluation of the role of professionals in all of these processes. The same conclusion is shared by Taylor (2009) and Kiviniemi (2008).

These researchers understand that the cultural aspects to be modified are challenging, especially when it comes to developing trust inside a suspicious and risk shedding environment such as the AEC sector.

In AEC, culture and mentality remain isolated, and exchanges occur only based on a direct link between professionals, and also within the supply chain, where information exchange is disordered and based on low intelligence processes.

Decisions are frequently made autonomously and without multidisciplinary participation between the actors, and lack a holistic and precise comprehension of the whole team.

The use of an interactive design process developed from the client's needs is virtually impossible to achieve in the current structures,(Owen, Amor et al. 2010).

Taking human factor into consideration, Prins and Owen (2010)comment that interoperability between platforms and team partners is frequently remembered for the effective use of BIM technology.

However, to achieve the new technologies' whole potential, team members should be capable of using technology to adapt to new forms of collaboration and integrated practices, and it will only be effective when this ability is incorporated in organizations in an institutional context for every actor, it also being absolutely necessary that all members have approximately the same maturity level.

Prins and Owen (2010) conclude by certifying that the present research focus is on construction IT, and not into new ways of producing, collaborating and sharing knowledge, and that besides that, IT tools will have to provide more knowledge sharing capability, instead of just allowing the exchange of information, aggregation and storage

6. SURVEY: FACTORS THAT IMPACT AEC PROFESSIONALS

With the goal of evaluating the factors that impact AEC professionals, a survey was elaborated in order to study collaboration-related issues. The survey received responses from thirty-five professionals in the Brazilian AEC sector.

The results and the detailed questions are available for consultation at the link: https://files.me.com/lmanzione/94h3ei

This survey is a part of the PhD thesis of the first author, whose primary goal is to propose a new management model for the collaborative design process using BIM.

- From the researched sample, 72,1% are architects, 18,6% are engineers and 9,3% are professionals of other specialities.
- The whole research group, 100%, is either using or understanding BIM as a design tool, which was observed even among professionals that didn't work directly with design (48,8%). Most part of the group (51,2%) still isn't working with BIM, while (48,8%) are already implementing it.
- From the BIM users, approximately 50% intend to expand their services by adopting BIM to management related services, building performance analysis or construction management.
- Half of the BIM users are already using BIM in all of their designs, whilst another 25% are using it in try-out designs.

Three levels of maturity of BIM implementation were defined from Succar's (2009) model, given the reduction and simplifying needed for use in this survey. It is of our understanding that the use of the whole of Succar's model can only be appropriate to a study of the whole AEC sector, and with a wider breadth of interviewed participants. According to the Brazilian reality, the use of this model would need refining and the introduction of other sublevels of granularity before stage 1 is achieved, as it is defined by this researcher.

The following stages were defined from the simplified model and submitted in the survey:

Stage 1: Basic modelling knowledge, BIM designs only in your design expertise, file exchange through email or collaborative extranets, BIM design process still unstructured, BIM used as a 3D and clash detection tool, low level of design details, design contracts haven't been reformulated for BIM, BIM used only as a design tool, not enough hardware with the minimum configuration for supporting BIM software, few software licences, lack of performance indicators to measure quality or productivity improvement.

Stage 2: Model development supports 2D and 3D Exchange, IFC format and other file format exchange between different design disciplines is supported, there's already a model breakdown structure allowing the whole team to work simultaneously, the information Exchange is based in a model Server in a local net, equipment and licenses fully answer the demand, the design company has the BIM design process structured internally, BIM is already understood as a methodology that changes processes, design quality and productivity indicator have begun to be defined.

Stage3: The exchange between different design disciplines is usual and with only little interoperability problems, information exchange is processed through a model Server in a WAN, interorganizational work processes are defined including client participation, BIM is understood as a process changing methodology by the whole design team, work procedures are already structured and detailed in operational level and design performance indicators are already defined.

The results shown that more than 75% of the researched group is still atStage 0 (48%) or 1 (55%), demonstrating that BIM is still in its very early stage understanding or of adoption by the interviewed professionals.

- About the understanding of collaboration, 63,6% were found to understand this concept only as "respecting design deadlines and scope", demonstrating lack of comprehension of the concept, which can lead to failure in their relationship with the other process actors, as shown in the first author case studies referred in this paper's second topic. The same percentage of professionals interviewed consider as collaborative the alerting of the client when problems are found in other design disciplines' production, when only 54,5% worried about warning the design authors.
- About the perception of design management process, most of the researched group (63,2%) sees it as only keeping up to the assigned dates, which reinforces previous studies that define the most used design process as delivery based (Manzione 2006), (Austin 1999).
- Only 15,8% shared schedules with other design partners, indicating low collaboration from inside the company level.
- Productivity and quality increases are the most perceived benefits from using BIM (73,7% and 68,4% respectively)
- Even though 60% realize BIM will allow work through a shared working model, 30% see the new process as a repetition of the 2D model, where work production will remain isolated and the disciplines will only exchange their designs for clash detection specific purposes.
- From the professionals that still don't use BIM, 60,0% blame this decision on the fact that their design partners from other disciplines also don't use it, showing low initiative, risk aversion or lack of competitive incentives. 48,6% understand that software investment is too high and 34,8% think the biggest restriction is the low number of component families designed for Brazilian parameters, which leads us to believe that they understand that BIM is only a change of software and design tools and will try to maintain the same work methods adopted in the 2D system. Only 22,9% answered that they don't use BIM because their clients don't see any benefits or won't pay them accordingly.

- Among those who have adopted BIM technology, the biggest identified difficulties were: 78,9 %difficult collaboration between partners, 36,8% low number of component families designed for Brazilian parameters, and 26,3% see trouble related to the necessary changes that will occur in their work processes, which could be interpreted as high resistance to adoption, but we find this result is associated to the lack of understanding that these process changes will happen.
- 71,4% of the interviewed that still don't use BIM would feel motivated to implement it as a clash detection and 3D visualization tool, while 20,0% would use it if it were a requirement from a client (showing design contractors still don't see BIM as a priority. As this survey isn't directed to design contractors, this conclusion is a speculation).
- A total of 26% of BIM non-users have scheduled its implementation from 1 to 5 years from now. Another 21% still don't intend to adopt it.

7. RESULTS DISCUSSION

The survey showed preliminary results that confirm this paper's hypothesis and point to the need for deeper research and the development of specific collaborative design process methodologies.

The lack of specific and standard methodology for BIM adoption remains without a clear solution, although we recognise that such adoption should consider the specific business practices of the adopting organisation, even though these practices will inevitably change during or soon after that adoption.

It also shows that people and process-related obstacles defined in the literature and the case studies are likely to be reproduced in BIM environment.

With the management methodologies yet to be defined, design indicators will be necessary to evaluate the stage of the companies and the level of BIM process implementation they have reached. We will call them Key Performance Indicators (KPIs)

These KPIs should be divided in two branches:

a) Objective KPIs that will measure information flow and lean design aspects, as shown by Sacks (Sacks, 2010), relating to conventional design environments but that could be transposed to BIM;
b) KPIs related to social and technical aspects, where the measurement will happen through case studies, as shown by (P. Coates, et al. 2010).

We have developed provisional social and technical KPIs, based on the main impact factors developed from the survey results:

- **Commitment Level:** Foreknowledge of the commitment level of the design team by defining selection criteria to be achieved prior to contract definitions and hiring of the design team.
- **Collaboration Level:** Should evaluate the intensity and quality of collaboration during the process, e.g.: control of the amount of contribution by each actor in developing the model, as in how much information is associated to them as author of the model, and if there were any commentaries or suggestions given to partners during the process.
- **Solution Integration Level:** Should measure the extent that the BIM process is being developed in an integrated way. e.g.: evaluate the main decisions and model systems and verify if they were accessed and/or created by more than one actor; measure the number of updates made in the central model from the several designers.

- **Level of BIM utilization:** Should measure how broadly and how deeply each BIM analysis and output is being adopted. e.g.: measure the level of detailing, interoperability achieved, integration with 4D and 5D applications.
- **Productivity:** Should measure productivity improvement that could be associated with the integration and reach of the process. e.g.: measure how long it would take to complete a design phase or determine definitions between several disciplines, that in opposition to the traditional process, can update the basis of their design with the information their partners are developing simultaneously in one single command.
- **Client satisfaction and retention** (P. Coates, et al. 2010)
- **Employee skills and knowledge development** (P. Coates, et al. 2010)

8. CONCLUSIONS

This study explored the human aspects within the design collaboration problem. According to the literature and case studies, the design management issues were related to poor collaboration among involved actors.

The main conclusions of this paper related to collaboration problems are the following:

a) BIM is still primarily understood only as a design development tool.

b) In its present state of development, BIM can be read as a construction information technology with no defined design management methodology.

c) The development of new management methodologies should include key performance indicators in their proposition that will allow their performance evaluation.

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