ACCELERATING INTERACTIONS IN PROJECT DESIGN THROUGH EXTREME COLLABORATION AND COMMITMENT MANAGEMENT – A CASE STUDY

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ABSTRACT

Extreme Collaboration (XC) is a methodology originally pioneered by the NASA Jet Propulsion Laboratory to accelerate the conceptual design of space missions from months to a few days. XC has been adapted for application to AEC projects showing its potential for reducing cycle time and improving quality in construction projects. XC teams are cross-functional, co-located groups enabled with high performance computer modeling and simulation tools, large and interactive graphic displays, shared models and special organization, culture and training to support the design process.

This paper reports on the experimentation by the authors to accelerate the design process of a multidisciplinary team that is expected to simultaneously optimize the architecture, structural design, energy efficiency and cost of wood houses. The authors adapted the XC concepts to the context of the project team and combined them with Phase Scheduling, which manages the commitments of the design team members.

This paper describes the adapted methodology and the preliminary evaluation by the project team. The team, 20 designers from 5 disciplines, evaluated different aspects of the methodology, including speed, quality, effectiveness, team work, modeling support, and planning reliability. The results are promising and have encouraged the authors to continue using the adapted methodology in future projects.

KEYWORDS

Extreme collaboration, phase scheduling, commitment management, last planner system, lean project delivery system

INTRODUCTION

"Sufficient thought and time does not seem to be given to ensuring, either as a design team brief or during the designing process, that all who must contribute understand the common objective similarly and fully. There is seldom a full awareness of all the steps

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necessary to realize an optimum overall outcome without loss of time, and the means of ensuring coordination is often not clear". (Higgin and Jessop 1965)

In the last two decades, efforts have been made to improve the design process by identifying ways to prevent waste (e.g. Coles 1990, Tzortzopoulos and Formoso 1999, Alarcón and Mardones 1997, Ballard 1999, Ballard 2000a, Freire and Alarcón 2002). It is not an exaggeration, however, to say that the management of design and engineering is one of the most neglected areas in construction projects (Koskela et al. 1997).

To improve the management and execution of a design project, the methodology, Extreme Collaboration (XC) was originally pioneered by the NASA Jet Propulsion Laboratory. The main goal of XC is to accelerate design processes, in the same place and in real time, through the coordinated work of multidisciplinary teams--intensively supported with Information and Communication Technologies (ICT) (see Mark, 2001; Chachere et al., 2003) which focuses on the achievement of objectives and concrete results in each work session, pursuing waste reduction and incremental quality control. XC teams are cross-functional, co-located groups enabled by high performance computer modeling and simulation tools, large and interactive graphic displays, shared models and special organization, and work culture raining.

The use of XC has been adapted to AEC projects, showing its potential to reduce schedules and to improve construction quality, common objectives to lean principles. The main differences between the traditional XC as used by NASA and the application of XC to AEC are related to the way sessions are developed and the team composition. In traditional XC, one to three sessions take place per week. The team is composed by a team leader and engineers with expertise in particular subsystem for space mission design. The work of the sessions is very technical. Each member works in design and moves freely around the room looking for information or knowledge to resolve problems. When a situation concerns everyone, the work is stopped and the whole team resolves the situation. In the XC model for AEC, there are cycles of sessions according to the phase of the project. The time between each session of the cycle should not be longer than two weeks. The team is composed by a team leader, designers, constructors, client, and suppliers: all the stakeholders as long as they are needed. The sessions are a political instance of agreement intertwined with technical work. In the sessions, each stakeholder group has an instance to present and negotiate its interests according to the session objective. Ex: A supplier presents a new product that s/he thinks might improve the performance of the structure. Architects present other alternatives they have been studying between sessions. The technical work is done in work tables. Each table has a specific objective to achieve during the session. The distribution of the participants is defined previous to the session, according to the objective of each table. In both cases, each session lasts 3-4 hours.

There are other collaborative design models (e.g., Emmitt et al 2005, Emmitt et al 2004, and Thyseen et al 2008) that are based in established workshops. The main difference with XC for AEC is that the Workshop Model is focused on decision-making in the workshops and that the workshops are predefined in the model. In the case of XC for AEC, the sessions aim is decision-making and design execution by all stakeholders. Also, the objectives of each session are not predefined in the model. Instead, each organization receives guides to define the number of sessions they need and the objectives they need to achieve, according to their own design process. Besides that, XC for AEC includes the use of ICT during the sessions.

During an implementation of XC in an AEC project, after the development of two collaborative work sessions using XC, the authors realized that one of the main obstacles to its implementation was the lack of commitment to accomplish the inputs required to work in the XC sessions. This fact largely affected the achievement of the objectives outlined for each session, due to the delays that generated in the flow of activities. Therefore, the authors used the Phase Scheduling (PS) (see Ballard 2000b and Knapp et al. 2006) and commitments control (CC) methodologies, such as Last Planner System (LPS), to overcome the above problems. The integration of these three methodologies was based on: the structure of Lean Project Delivery System (LPDS) focused on Project Definition and Lean Design (see Ballard 2000c, Ballard and Zabelle 2000, LCI White Paper-5 1999, Ballard et al. 2001); LPS as production control module; PS as tool of work structuring module; XC to integrate stakeholders in product and process design decisions and execution; and XC to intensify ICT use in the design stage. This paper describes this experience and the benefits found by the design team, together with the main implementation barriers and recommendations for possible solutions.

DESCRIPTION OF CASE STUDY

The case study considered a work team of more than 20 AEC professionals who are developing constructive solutions suitable for industrialization using radiate pine, either as a main material, or as part of other housing constructive systems (masonry or concrete). This project also considers experimental validation and the study of constructive solutions applied in housings prototypes.

In order to facilitate an integrated analysis of design variables such as cost, structural and physical-environmental behavior, quality and constructability, as well as the optimization of industrial production and evaluation at the innovation level, the project team considered pertinent the implementation of a new work methodology to overcome the flaws occurred during the execution of a previous project, with similar technical characteristics, and the same staff. In the previous experience, designs and prototypes, were never evaluated by others since the team was not able to achieve adequate progress in terms of work, definitions and agreements. This ineffectiveness was due to the lack of a clear orientation towards the achievement of results and the objectives accomplishment. Considering this, XC was proposed by us, the Interface Management Team (IMT) from the project, as a possible solution, opening the way to its implementation in the project. Figure 2 shows the development of the described intervention.

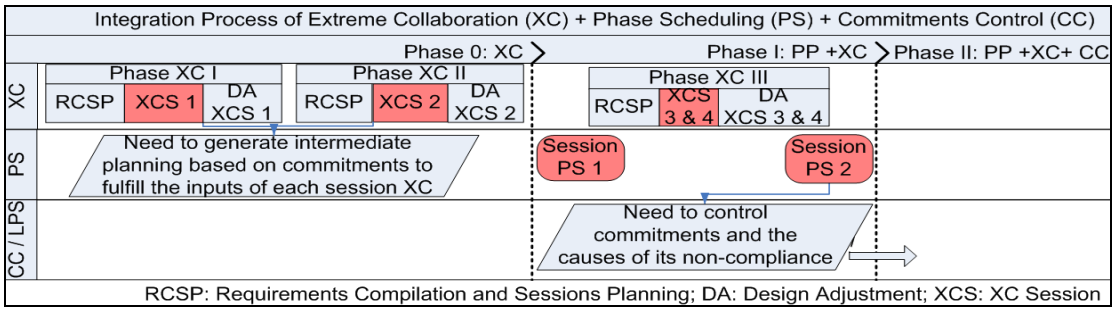

Figure 1: Implementation Process Pilot Case

XC EXPERIENCE AND DEVELOPMENT

In the studied project, four XC sessions have been implemented so far. It is necessary to highlight the fact that the work team has partial involvement with the project development; therefore, XC sessions have been made with at least two weeks of separation. It is relevant to mention that XC sessions 3 and 4 were planned in PS session 1 with the whole team. Due to the lack of experience of the team in collaborative work, it was necessary to state the sessions as presentations, discussion tables and global consensus instances. Figure 2 summarizes the activities performed in the XC sessions.

XC Session 1

Objectives

1. Qualitatively estimate and evaluate each proposal in terms of: cost, structural and physical environment behavior , constructability, property developer and suppliers interests, and finally, innovation and patent generation.
2. Generate scheduling of the project until the XC session 2 with commitments and responsibilities.
3. Evaluate performance to date and lessons learned.

Key Points

- Just objective N°1 was fulfilled.
- The electronic analysis was not saved on the network in real time.
- The exchange of information among different specialties is not present on the work table.
- The sharing of assessment and improvement occurred in a collective forum for discussion, where different views were collected, and then a final consensus was reached about design hypothesis. These hypothesis were the base to continue with the design process.

Participants:
22 specialists in:
- costs
- structures
- planning
- physical-environmental behavior
- architecture
- 7 representatives of supplier companies

Time duration:
Planned: 6 hrs.
Real: 8 hrs.

XC Session 2

Objectives

1. Quantitative assessments by modeling of the design assumptions of the XC session 1.
2. Selection of final design assumptions through qualitative and quantitative assessment of both sessions.
3. Generate scheduling of the project until the XC session 3 with commitments and responsibilities.

Key Points

- None of the objectives were completed.
- Extensive analysis and discussions have resulted in loss of focus on the objectives.
- The objectives were finished independently by each specialty area, using a traditional method of working.

Participants:
23 specialists in:
- costs
- structures
- planning
- physical-environmental behavior
- 5 representatives of supplier companies

Time duration:
Planned: 4 hrs.
Real: 5 hrs.

XC Session 3

Objectives

1. Determine the relative influence of each area on a quality function.
2. Rate the design solutions by each specialty.
3. Get a ranking of design solutions studied in previous sessions, using weights and scores.

Key points

- All objectives were met.
- The pre-delivery documentation was a major factor in the success of the meeting.
- No work was done on virtual basis, since it had been a limiting factor in previous sessions. A team member should digitize all of the evaluations and then make the necessary analysis.
- Sometimes some team members wanted to return to work done in previous sessions. The intervention from the facilitator was crucial to mantaining that the point had already been settled and that the work should continue according to the planned objectives in the present session. However, valuable time was spent in explanations to the members of the session who had not attended in previous instances.

Participants:
23 specialists in:
- costs
- structures
- planning
- physical-environmental behavior
- architecture
- 5 representatives of supplier companies

Time duration:
Planned: 4 hrs.
Real: 4 hrs.

XC Session 4

Objectives

1. Based on the ranking established in the XC session 3, determine the necessary tests to perform in each scenario in terms of structural design and physical environment.
2. Determine what will be tested by considering the cost of the tests set out in Objective 1 and what the budget allocated for this activity will be.
3. Perform preliminary design of the specimens tested.

Key points

- 3 objectives were met in part. The test plan was carried out only in terms of structural tests and not in terms of the physical environment.
- This session took place two hours after the session XC 3, so there was a significant level of participants fatigue.
- The inclusion of a tablet pc for the test design, enabled the team to work in digital form directly, avoiding overproduction of work and generating a more dynamic workflow.

Participants:
6 specialists in:
- structures
- planning
- physical-environmental behavior
- architecture

Time duration:
Planned: 3 hrs.
Real: 1,5 hrs.

Figure 2: XC Sessions

LESSONS LEARNED AND RECOMENDATIONS OF XC

Benefits and limitations observed by the project team were evaluated through the Plus & Delta[4] methodology shown in figure 3. The evaluated criteria were: General comments concerning methodology, interactions value and level among areas, teamwork, and, finally, electronic network and use of models.

	+	Δ
GENERAL COMMENTS ON XC	• Smart Methodology, very effective despite the difficulties. It serves and is necessary. • It exceeded expectations by far. • Help to better internalize the project. • Collecting information for later work is more fluid. • It has clear milestones in the progress of the project.	• Improve coordination and management in upstream and between sessions. • Look up the planned time in the session. Be less tolerant of poor use of time. • Greater commitment and formality in the work: no smoking, eating, etc.
INTERACTION VALUE AND LEVEL AMONG AREAS	• Good interaction during presentations and within work tables. • Great value in sharing information and the diversity of experts: suppliers, costs, constructability, design, etc.	• Interactions between work tables are almost nil. • Define the optimal room size. If it is too big, interactions between tables lessen.
TEAMWORK	• It is a good methodology for teamwork. • Greater closeness and understanding in the group: communication is better. • Everybody is informed and involved in decisions. Encourages debate. Each one has a chance to speak out about the project technically. • The team is concerned to achieve the tasks. You see results. • Get to know people in other areas than our own. • Change in the attitude of members; it is easier to accept a different position.	• Differences in training background and mentality generate different rhythms. • Give time to the team to get used to this new way of working. • Analyze deeper who has to be in the XC sessions.
ELECTRONIC NETWORK AND USE OF MODELS	• Good for this stage. Can be strengthened further. • Modeling shortens working time. • The inputs of the models are simple and outputs are what is needed. Give greater dynamism to the calculations. • The model is a good tool to evaluate designs in a more technical way and leave the speculation.	• Develop stronger skills to virtual system users. • Implement electronic displays other than PC and projection screens. Ex: Tablet PC, interactive whiteboard, etc. • Not enough time for models application. Lack of practical use. • Make the electronic network a critical element during the session. Require predefined electronic results.

Figure 3: XC Plus & Delta Evaluation

According to experts, the acceleration of a process can be measured in terms of the objectives achieved versus the time taken to accomplish it. In the pilot case, the work done during the XC sessions never would have been accomplished if they had continued using the same work methods. Taking into account the partial acquisition of the objectives in some sessions, in spite of found difficulties, the methodology worked to accelerate the design process, mainly due to two factors: 1) XC sessions inside the planning process became clear milestones setting different phases of the project progress; 2) the objectives of the work sessions attempted to develop in a few hours all the monthly work. Given the interaction of all the specialists, this highly reduced information latency.

RECOMMENDATIONS FOR DELTAS

Preliminary Remarks About Methodology

Lack of control in the fulfillment of inputs, as well as the accomplishment of results in scheduled time, were large incidence factors in the partial achievement of the

[4] Plus/Delta is a simple inclusive strategy enabling everyone to consider what went well and the deltas that would ideally be changed.

objectives of each session, due to the delays that were generated in the flow of activities. Little consideration of time limitations was observed - in the previous and posterior stages as well as during each session - which can be related to the lack of necessity or pressure to achieve tasks in the established terms (a situation which generates delays in the sessions as well as on the general project. As a solution for this problem, the IMT has established a commitment-based system of planning and control.

Additionally, as Chachere et al. (2003) described, due to the fact that a 4 hour-meeting of intensive work and high intellectual demand in an XC session produces high levels of fatigue, the team performance gets reduced. As a result, activities delimiting a maximum duration are recommended by the IMT. The IMT also recommends that the first sessions set as a main objective a third of the initially considered work, increasing tasks as the team acquires experience with the methodology.

If work sessions are focused toward the same project stage (conceptual design, preliminary architecture design, etc.) the IMT recommends that time among them should not be longer than two weeks, since one observes forgetfulness of progress achieved in previous sessions. Recollection of the progress takes additional time and subsequently delays the flow of activities.

Interaction Value and Level Among Areas

The lack of experience of the team on collaborative work affects the level and value of interactions. This is mainly observed during formal presentations, which are almost worthless for the rest of the team when tasks are segregated according to trade specialty. The development of an iterative dynamic between presentations and specialty trades is proposed, though strictly when interaction is not generated in a natural way among the tables. Since "presentation-only" does not add value to the objective accomplishment, it constrains the workflow, delaying its achievement. Furthermore, there is a risk that the team will not be capable of spontaneously producing interactions, which is the main requirement for good XC development.

Team Work

The limited experience of participants in a team work environment affected the development of the session in two ways. First, the decision-making process was delayed due to repetitive discussions of areas of disagreement which were generated by the different approaches of each trade specialty. This aspect should improve when all stakeholders are familiar with this new work model. This assumption was confirmed by the IMT when the gradual change in some members of the team was observed. Second, it was difficult to deliver digital outputs, since participants were normally used to nothing but discussion meetings – where the tangible work was nil or very little--lacking spontaneous initiative to produce deliverables altogether. To be successful, it is necessary to state specific goals with clear outputs, which offers a guideline of the expected results in the assigned time, beyond the general objectives.

The stability of the teamwork in a cycle of sessions, together with its exclusive dedication is regarded as crucial by the IMT.

Better results have been observed in reduced-size teams. A maximum of 5 people per table is recommended. For this consideration, it is necessary to determine

carefully which members of the team should participate, according to the objectives outlined for each session.

Electronic Network and Model Use

Most team members showed little self-discipline when it came to doing the digital work with the support of intranet. This causes frequent loss of relevant information and a lower speed in the work flow. As a solution, the IMT has suggested predetermining the deliverables in content and digital format, according to each of the stated objectives, demanding their inclusion in the network before the end of a session.

PHASE SCHEDULING EXPERIENCE AND LESSONS LEARNED

Phase Scheduling (PS) was incorporated into the work methodology to accomplish a high level of execution in the previous and later stages of the XC session. In the project, two PS sessions have been implemented so far. XC sessions 3 and 4 were planned in PS session 1 and during PS session 2 a fifth XC session was planned.

The development of PS allowed us to determine commitments of clear, medium-term activities, sequencing the work in an integrated and coordinated fashion with all the trade specialties, even before the implementation of the commitments control and the recognition of reasons for non-completion. Since each team member has a formal record of commitments kept in a visible place, higher pressure has been generated to get results in the committed term. Moreover, members can describe reasons for non-completion more precisely, due to the fact that there is an explicit awareness of having to accomplish the commitments. The PS sessions have also gotten the entire team better involved with the project master plan, the ignorance of which we have seen as a recurrent problem before.

During the PS sessions it is important to make an evaluation of the closing phase, immediately before the planning development of the next one. Its purpose is to consider problems and errors, avoiding them in the new schedule.

According to the observed performance, in the near future it will be necessary to apply a management tool to improve short term planning –such as the Last Planner System© (LPS) - which will allow for better results of general fulfillment and for facilitation of the rescheduling of pending activities, saving time in the planning of the next phase.

INTEGRATED METHODOLOGY TO DESIGN STAGE

Even though XC has helped the design team to accelerate the process and reach the objectives in each one of the sessions, it is important to take into account the relevance of commitment definition and control of previous tasks, as well as the effective completion of the pending activities which arise in a session.

Three of the main difficulties identified in the pilot project were: the non-completion of inputs of the XC sessions, the lack of commitment to the objectives with respect to time, and the general team ignorance of the master plan. All these problems are governable with a management system based on reliable commitments, PS sessions and commitments control.

The IMT suggested integrating these three methodologies into one, according to the LPDS essential features presented by Ballard 2000c. To improve the design process, it is necessary, first of all, to control variability of the process through LPS,

so we will be able to obtain a greater reliability level with what we plan. Once the variability in the process is controlled and we know the process better, we can orientate the work structure to maximize value, minimize waste and do the job (Ballard et al. 2001) through PS. Finally the execution of process and product design is made by a cross functional team with downstream stakeholders participating actively in the same room, minimizing interactions and latency through XC. Each methodology has its one feedback tool: LPS with its non-completion analysis. In each PS session there is an evaluation of the finishing phase before planning of the next phase starts. For XC, a tool has been created to evaluate the session work plan and get the feedback from all the participants.

To integrate PS with XC, the IMT has suggested coordinating a planning phase with an XC phase (figure 4). The XC phase begins with the antecedent summary and the preparation of the XC session, and it ends with the adjustment of the obtained results stage. Depending on the quantity of work to develop, it can be implemented by more than one XC session, producing a cycle of XC sessions (keeping in mind the recommendation of maintaining a maximum distance of two weeks between sessions).

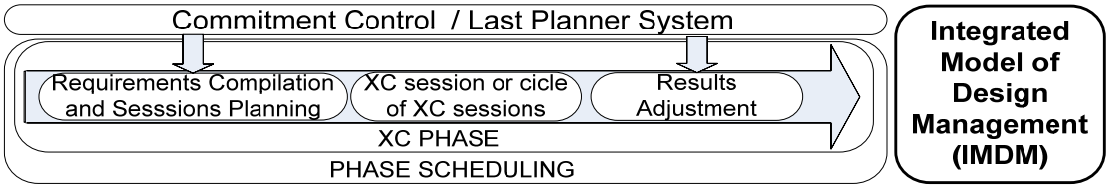

Figure 4: Integrated Model of Design Management (IMDM)

Following the PS process (see Ballard 2000b), the integration of XC sessions should be carried out between the development of the phase activities network and the determination of its best sequence, scheduling then the XC sessions. Figure 5 shows a guide for this procedure.

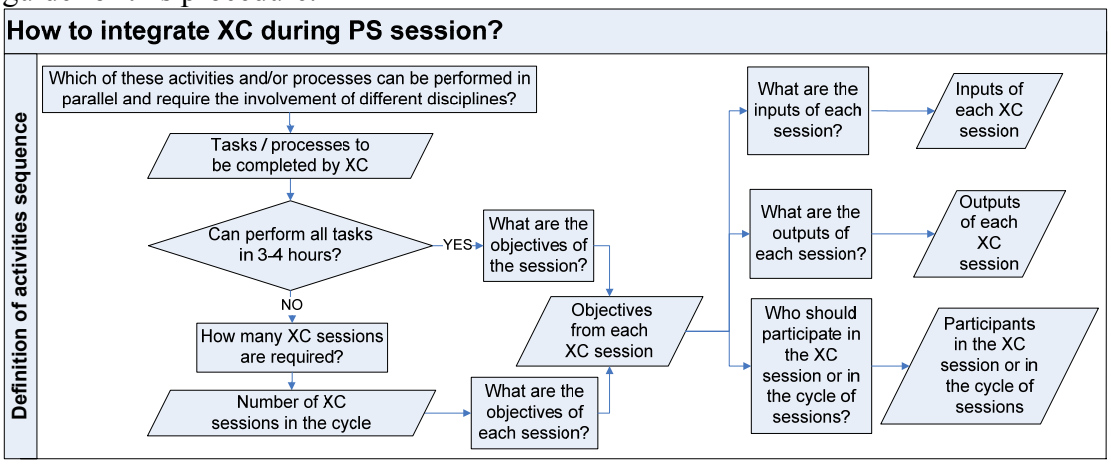

Figure 5: Diagram of XC and PS Integration

The theory beyond this process is based in buffering and LPS theory (Alarcón and Ashley 1999, Tommelein et al 1999, Tommelein 1998). What IMT is looking for is to generate a buffer of information and inputs until the last responsible moment (Ballard 1999) (Figure 6). This generation of information and inputs focuses just on release restrictions (just like is done with LPS) that could affect the downstream workflow

during the session, reducing uncertainty and waste. This action allows the XC session participants to start the effective design process later. XC sessions accelerate the objectives achievement through latency reduction. The interactions in real time among all stakeholders with ICT allow this latency reduction and enable the team to reach more value in design outcomes by the study of multiple choices of design at the same time.

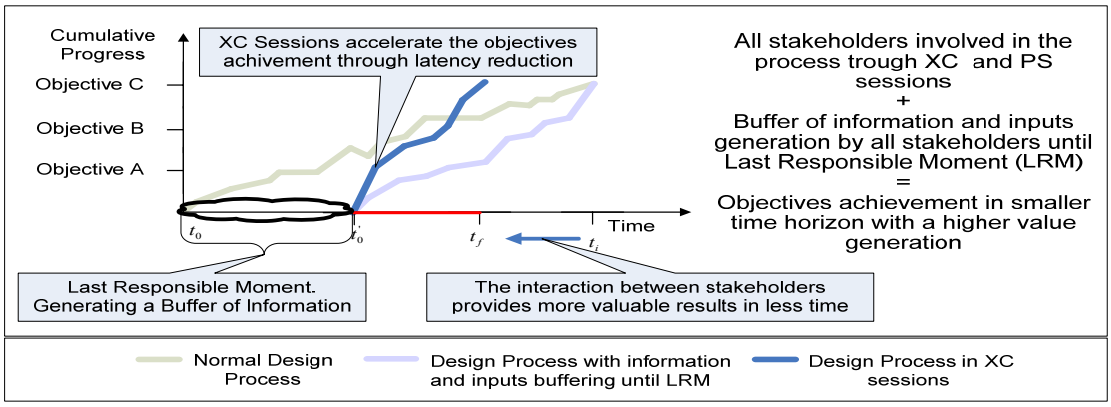

Figure 6: XC Impact on Accelerating Design Interactions

After the integration of XC with PS in the project, an increment on the objectives fulfillment in the sessions XC has been observed by the IMT (session XC 3 from now on), due to a positive impact on the three main application difficulties of the XC (described at the beginning of this section). It has generated a better accomplishment of the previous tasks to the XC sessions (inputs), as well as a greater awareness of the need for reliable schedules (commitment with fulfillment of scheduled objectives), due to the understanding of the accomplishment impact in the development of the rest of the phase in the project (knowledge of the master plan). Also, by using XC, the team has been able to generate agreed-upon products, non-existent in the previous project results.

During the case study, XC was implemented first, then the commitment management system. The IMT has suggested making the inverse process for this methodology of integrated work to obtain better results of XC implementation. Teams previously familiarized with PS and commitments control (using the LPS) could adopt XC more effectively. The suggestion flows from the huge influence of the inputs accomplishment for the success of the XC sessions, as well as the importance of a continuous workflow to its development. It is important to reduce variability and structure work first, to release work and information for execution design and decision making at XC sessions.

Although it is difficult to isolate the outcomes produced by each methodology change, we were able to estimate these outcomes since the implementation of the changes and their integration were done at different times. Figure 7 describes the most relevant relations between changes and outcomes.

	ACTIONS	OUTCOMES
XC	XC Sessions Establishment	• Clear Milestone • Agreement withih the group and Stakeholders
	Collaborative work by stakeholders	• Latency Reduction • Maximize client and stakeholders value
	Computer Modeling and Public Display Support	• Analysis and decisions are made more objectively • Design work gets faster
PS	PS Sessions Establishment	• The work sequence is well know by everybody • Structuring work to add value to the process. XC phase is pulled • Reliable commitments
	Integration of XC stage planning in PS Session	• Inputs, objectives and participants of XC sessions get clear in PS session • XC session workflow is maximized. Restrictions are released
CC/ LPS	CC/LPS Incorporation	• Variability reduction. Scheduling realibility improvement along the PS sessions • Production control • Non-completition reasons

Figure 7: Most Relevant Relations between Changes and Outcomes

CONCLUSIONS

XC is an effective tool for the acceleration of the cycle times in design projects. However, to further improve, it is necessary to take complementary actions before and after the XC sessions.

The Commitments management by using PS offers a solution for this requirement, improving the inputs accomplishment and facilitating a continuous workflow after each XC session. Furthermore, PS promotes integration and team work, generating a permanent connection of the different disciplines along the whole design process, facilitating the collaborative activities essential in XC. In this way, the integrated model of design management (IMDM) offers a solution of high potential to optimize and accelerate design projects.

In this research, it has been determined that the main barriers of XC implementation rest in the human factor. In the case of teams which have never worked in a collaborative way, besides implementing the commitments management, the development of teamwork abilities is highly desirable, through dynamic and collaborative training methodologies. The same training recommendation is valid when team members have a low level of knowledge or experience in the ICT use.

The members of a suitable team for the use of IMDM should be highly familiarized with the software and ICT use, and very dynamic personalities with tolerance for work under pressure, but mainly they should be of great orientation and motivation for teamwork and the achievement of pre-established objectives.

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