Information Exchange in The Construction Industry. The Particular Case of Green Buildings

Adhamina C. Rodriguez, Swinerton Builders, San Francisco, USA
(arodriguez@swinerton.com)

Summary

Construction is a conservative industry that over the last twenty years has experienced drastic changes in the way that interdisciplinary teams interact to design and execute a project. In this article we offer a general overview of how the main participants cooperate in the different phases of a construction project, and which are some of the main areas for communication improvement. We also explore the communication tools used in the exchange of information, and identify the main causes of information breakdown. The general framework of this study is of application to both standard and green projects. At the end of the article we discuss the peculiarities of green buildings.

Our goal is to offer a series of industry insights derived from the perspective of a general contractor aimed at identifying the areas where contributions in computing and information exchange could have a greater impact on the successful completion of a project.

1 Main participants

From the original concept to the implementation of a construction project, there are many participants involved and their number and degree of involvement varies across projects. However, we can differentiate three broad groups based on their role in the project: the owner's team, the design team and the construction team (see figure 1).

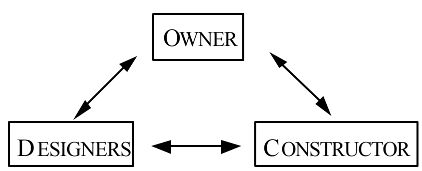

Figure 1

Owner's team

The owner is the financial source of the project and the ultimate responsible for the payment of the costs incurred by all other participants. The owner may need lenders or donors to support the project.

The owners may represent themselves in a project or hire a third party as their representative, which is commonly known as the "construction manager". The construction manager typically offers industry expertise to the owner and may substitute or support the owner's involvement in the construction process. If there is a construction management group in a project, the flow of information to the owner will be directed through it. We will refer to the owner and construction manager as "the owner".

Design team

The second main team includes architects, engineers, and specialists in response to the owner's needs (landscaping, signage, furniture, etc.). Each one of the members of the design group develops a part of the set of documents that the construction team follows for the execution of the project.

Construction team
The construction team is lead by the "general contractor", from now on "contractor". The contractor manages the construction crews at the jobsite to execute the design proposed by the design team, and ensures payment to the different trades. The contractor might self perform the work and/or hire subcontractors to do it. The subcontractors are specialized contractors that provide their skilled manpower and purchase materials from vendors.

2 Phases of a project

Most construction projects begin with the recognition of a need for a new facility. From this point forward the project develops in several phases. The number of phases, timing, and participants involved in each step depend on the project; however, we can group them into two main phases: preconstruction and construction. Within each one we can distinguish three sub phases (see figure 2).

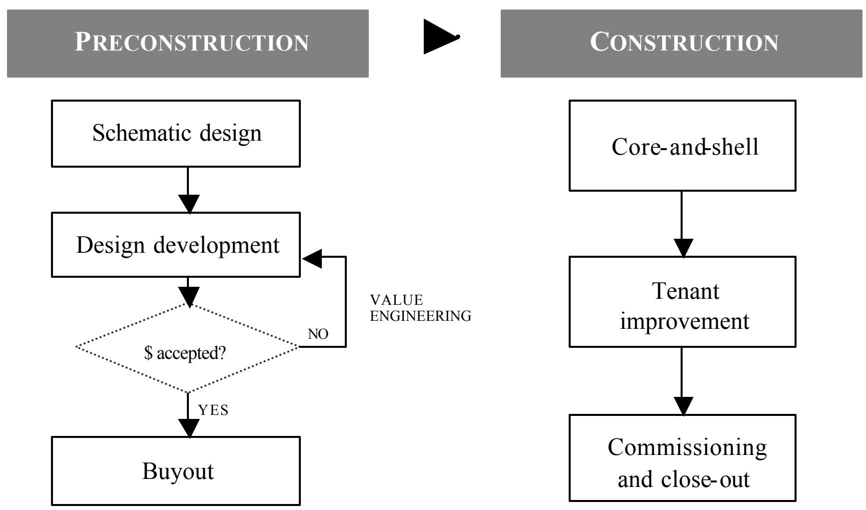

Figure 2

2.1 Preconstruction

Within the preconstruction phase, the **schematic design** stage is aimed at developing the main program for the project. This program includes the specific needs that the facility should fulfill, as well as the expected project budget and schedule.

The second phase of the preconstruction, **design development**, focuses on validating the proposed solutions to the program established in the schematic design phase. The conceptual design accomplished by the architect in the prior phase is open to discussion. Now, the interdisciplinary project team of owner, architect, engineers, specialists, and contractor study the feasibility of the idea. As a result of this interaction, each member of the design team issues his or her respective documents that complete the *project set*.

The first coordinated set of plans, called *permit drawings*, is sent to the local permitting department for review and approval. During the approval period, the contractor surveys the site, reviews the documents for constructibility and develops a preliminary project budget and schedule. If the budget exceeds the owners' expectations, the project team starts a new brainstorming session to look for alternatives. This process of accommodating the project to a given budget is called *value engineering*.

The third and last main sub-phase of the preconstruction, the **buyout**, starts with the correction of the permit drawings after the plan checker's[1] comments. The design team addresses the requirements from the permit department and the result of this coordination is a new revised set of documents for construction called *construction drawings*.

Once the construction drawings are issued, the contractor starts the buyout. The contractor develops pricing packages by trades, issues a mutually agreed bidders list, and sends the documents out for bids. After analyzing and leveling all the bids, the contractor establishes the contractual construction cost and final schedule for owner's approval. The issuance of the construction permits by the city, the authorization to proceed by the owner, and the release of the subcontractors to commence the construction, completes the preconstruction phase.

2.2 Construction

The construction phase starts with the mobilization to the site of the general contractor and subcontractors. The construction of buildings in northern California is usually divided into: core-and-shell, and tenant improvements. The separation between these two phases is so strong in commercial buildings that many times each one has a completely different project team and separate set of documents.

Core-and-shell is the first comprehensive phase of the construction and covers: foundation, structure, vertical transportation and main parts of the mechanical, electrical and plumbing systems (MEP) for the building —the "core". Also in this phase, is completed the "shell", a waterproof enclosure of the building.

After the building is watertight the **tenant improvements**, from now on "interiors", begin. The interior construction includes the internal partitions, finishing of the MEP systems and application of architectural finishes.

Toward the end of the construction we can distinguish a third and last phase, **commissioning and close out**. During this stage all the installed equipment is started up and tested in a meticulous and critical process of testing and verification called *commissioning*. The commissioning process is essential to ensure the functioning of all systems and equipments installed within the building.

The end of the construction is also a document intense period for the construction team in which they issue final costs, provide operation, maintenance and warranty documentation, and demobilize the jobsite offices. The construction phase ends when the final building inspector walks through the site and signs-off the construction permits authorizing owner's occupancy.

We have briefly reviewed how a construction project develops over several different phases. We next explain how the different participants interact during these phases.

3 Team interaction

3.1 Generic construction projects

The simplest possible interaction among the diverse members of the project team is the linear flow of information represented in figure 3. The owner assigns the program for the project to the design team. Then, the design group develops a coherent set of plans and specifications. Finally, a complete set of documents is handed to the contractor for construction. In this sequential representation, each party completes their work before the following starts.

OWNER → ARCHITECT → ENGINEERS → SPECIALISTS → CONTRACTOR

Figure 3

There is a certain degree of truth in the linear interaction shown above, in that each party has specific tasks. However, the synergies and conflicts among the interrelated disciplines make this linear scenario unrealistic. For example, the architect might have to adapt the original design to a buildable structure. Other factors that make this linear approach impracticable are the lack of a clear program for the project from day one and unforeseen field conditions. In order to complete a coherent and feasible set of documents, it is necessary a more global team collaboration (see figure 4). Next we study how the different teams interact in the various phases of a project and how the criticality of this interaction varies with each phase.

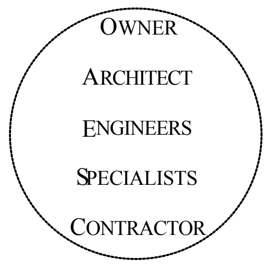

Figure 4. Global team

3.1.1 Team interaction in preconstruction

During the **schematic design** phase the architect starts the conceptual design of the project and the interaction mainly occurs between the owner and the architect, having the architect the heaviest workload (see figure 5.a). At this stage of the project, the other members of the global project team oversee the process from outside waiting their moment to contribute.

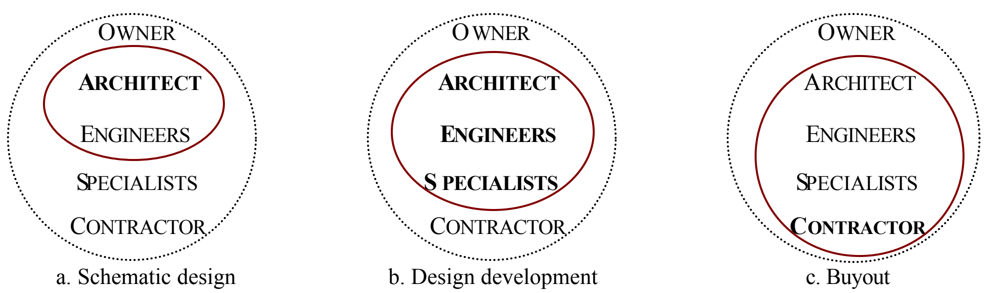

Figure 5

During the **design development** phase the entire global project team starts intense interaction with brainstorming and validation sessions. Usually at this stage, the project team establishes weekly or biweekly meetings to monitor the progress of the work. The most arduous workload and interaction at this phase occur within the design team (see figure 5.b). The owner and the contractor also attend the meetings, but for different reasons. The owner wants to ensure compliance with their project requirements, and the contractor acts more as building consultant than as a member of the team with voice to modify the design.

In the **buyout** phase, after the plan checker's comments, each member of the design team works independently on the required modifications related to their scope of work. Then, the issuance of the construction drawings triggers the work for the contractor. From this point forward the critical roles are inverted. The contractor will now carry most of the workload and the rest of the project team will oversee the progress of the work acting mostly as an external support (see figure 5.c).

3.1.2 Team interaction during construction

During the construction phase the contractor coordinates the trades in the field, ensures jobsite safety, and is the ultimate responsible for the submission to the owner of a quality product within the given budget and schedule.

During the preconstruction phase it is important to have a smooth and timely flow of information, but the cost or schedule impact of a communication breakdown is still low. It is during the construction stage when the flow of communication becomes highly time-sensitive. For example, say the design team decides to change the layout of a wall. If we are at the preconstruction phase, the consequence of this decision is shifting a few lines on the drawings, and delaying the notification of this change does not have a serious impact on the project. However, if we are at the construction stage, transmitting this information immediately to the construction team is critical; otherwise, the wall might get built and it would then require demolition and new construction to reflect the revised layout, which has time and cost implications. The same logic applies to materials that may have already been ordered, equipment rented or working crews booked.

Another driving reason for the criticality of information flow during the construction phase is the increased number of participants. The project team is no longer constrained to owner, designers and contractor, but it is now extended to a myriad of subcontractors and suppliers that are only connected to the global project team through the contractor (see figure 6). Since any decisions at this stage of the project have to reach a much larger number of participants, the chances of a communication breakdown increase exponentially.

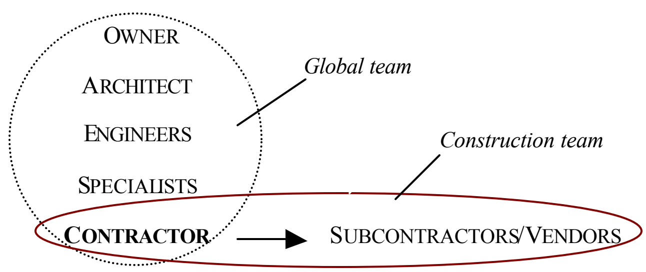

Figure 6

During the **core-and-shell** stage of the construction, communication is greater between contractor and engineers than among any other members of the global team. However, during the **interiors** work, the contractor mostly communicates with the architect and specialists. Another difference between core-and-shell and interiors resides in the pace of this communication exchange. While at the core-and-shell stage the engineers might have days, weeks or even months to address a situation, at the interiors stage the architects have hours, days at the most, to address an issue. The difference in pace is usually driven by tied sequential work, and shortened construction durations imposed by leasing agreements.

In the last stage of construction, **commissioning and close out**, the communication requirements become less time sensitive. In spite of this, without a proper flow of information at this stage, the closeout of a project can be dragged for months or years. An improperly addressed closeout can cause big losses of money in personnel's time to all the members of the project team.

3.2 Fast track projects

So far we have assumed an ideal linear sequence of the two main phases: preconstruction finishes before construction starts (see top of figure 7). Unfortunately, this is not possible in the so-called *fast-track* projects. In fast-track projects the construction starts before the design documents are completed. The main reason behind this decision is to reduce the overall duration of the project; however, the cost of these projects is usually higher than the ones following the lineal sequence. I wanted to mention this kind of projects to stress the even greater importance of unbroken and timely communication during the overlapping period (see bottom of figure 7).

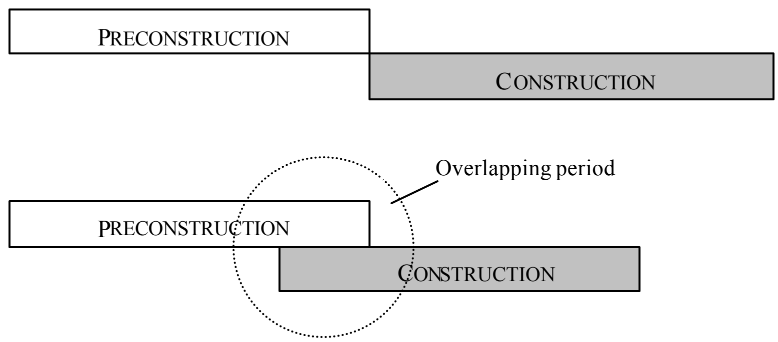

Figure 7

4 Information exchange tools and breakdowns

4.1 Information exchange tools. Our recent experience

The fast adoption of computers over the last twenty years, lead to speculations about web-based management tools that found a market during the internet rush.

In 1999 the internet business grew to historic levels and several e-businesses emerged providing a new collection of tools for the construction industry to manage the lifespan of a project via the web. Some of the giants in northern California were BidCom, Buzzsaw, and Cephren. Several corporations decided to invest in the new technology and incorporated the experimental tools into projects. The fundamental theory was commendable, but the software still needed further development.

In May 2000 the stock market crashed and internet stocks started their rapid descent. On November 2000 BidCom and Cephren announced their merger with Citadon Inc., Buzzsaw managed to survive, but many of the new e-business closed their doors[2]. As a result of the depression of the market, the high expectations on the e-business dropped and the construction industry, traditionally conservative, lost the confidence on the new web-based technology. Although some of the companies survived and improved their tools, web-based construction management tools still remain far from an industry-wide standardization.

Nowadays traditional tools complement existing technology. For many colleagues, traditional tools like personal interaction (face-to-face meetings), phone conversations, faxes or regular mail will always supercede any other way of communication. However, something did remain from the internet era to stay: *email*.

4.2 Information breakdowns

The smooth flow of information among the different teams during the development and implementation of a project is critical for its successful completion. By information breakdown we refer to a fault in this flow of communication, which generally cause schedule delays and cost overruns. Next we identify some of the main causes of information breakdowns.

4.2.1 Information content

Communication breakdowns might be caused by the absence of necessary information, or by the wrong information being conveyed. In many instances, this situation is a direct result of a faulty preconstruction phase or changes in management. An unproductive preconstruction leads to misunderstandings and incongruences in the design documents, which will require an excessive amount of clarifications at a later time. Regarding management changes, whenever possible, the same person should lead each team from the beginning to the end of a project. A new person managing a team can read the documents to date, but will always lack the history behind each solution and this may result in incomplete or wrong decisions.

4.2.2 Information management

Another major source of communication breakdowns is mismanagement of information. Some examples of these breakdowns are: information sent to the wrong person, and email overload. Since electronic mail does not charge a fee for each member to be copied, like the stamps with standard mail, many members of the team create group addresses and copy everyone in long chains of conversations that might not need to be read by everybody. It is just faster to direct an email to the group than to select the specific members that you intend to convey the information to. We seem to be forgetting that one the reasons why there are so many members in the construction industry, is because a single person cannot process all the complex and varied information involved in a project. The fact that we have the technology to share the information does not justify doing so. Creating an excessive and unorganized flow of emails —or for that matter any other flow of information— diverts the awareness of the appropriate teams away from the critical activities that need immediate attention.

4.2.3 Information technology

As complexity and load increase, handling information increasingly relies on technology to support the information exchange. In order to avoid information breakdowns, we need to consider problems driven by both hardware and software.

Breakdowns driven by hardware

As an example of communication breakdowns driven by hardware we can list: phone lines not working, email lost in the server, computer crashed or stolen, computer frozen by insufficient memory, etc. Unfortunately, jobsite offices are especially prone to hardware problems due to the temporality of the support systems and office setting, a fact often overlooked. Although we will always have the likelihood of a hardware breakdown, new technologies should reduce their frequency. Given that cellular phones partially solved the problem of setting up landlines, and thus represented a considerable step to improve the flow of communication, wireless internet seems to be a necessary next step for jobsite computer accessibility.

Breakdowns driven by software

Software can cause information breakdowns due to failure of the program, or by simply lacking the right one to open a given file. However, paradoxically, our biggest challenge and cause of information breakdown driven by software is email. Email has become as a fundamental communication tool and it has certainly made faster the exchange of information, but it has also brought new problems that need to be addressed.

One of the main problems related with email is the unmanageable amount of messages that each member of the team might receive every day. This is partially a failure of the sender, as seen above, but it also relates to the way the email software handles and discriminates information. Given the fact that everyday the construction industry involves a larger group of participants, we foresee an increase, more than a decrease, in the number of emails that we will exchange daily during the construction process. Therefore, there is an urgent need for software tools that make email a more effective communication tool.

Let me finish the information technology point by illustrating the situation with an example. Let's assume that I, as a general contractor, receive an email from the architect called "Bulletin 4" with ten AutoCAD files attached. I have to read the document, understand the implications of the changes, and forward the information to the subcontractors affected; all before any of the old elements get built at the jobsite. In order for this communication tool (the email) to be useful, we need to assume the following points: 1) the architect's server will accept the size of the email to be sent; 2) my server will accept size of the email to be received; 3) I have the software to read the CAD files; 4) the subcontractors have email addresses and access to email, 5) the subcontractors' servers will accept the size of the email; 6) the subcontractors will have the software to read it; 7) neither one of the servers will misunderstand the attachments as viruses stopping the transmission; and 8) the time that I, or any other person in the communication chain, have to wait to receive or send the message is below a reasonable range and does not freeze the computer. From own experience I must say that many times all eight assumptions do not hold true at once often causing a communication breakdown.

5 Need for technological advances

As mentioned above, wireless internet represents a step forward to avoid some of the hardware driven communication breakdowns. However, it is in the software where we may find more long-term solutions to improve the communication among the different parties.

5.1 Electronic-mail manageability

Before digital technology was incorporated in the construction industry, most of the communication exchange was done by standard mail and fax. At that time, the project assistant helped sorting arriving documents. Nowadays email is the primary tool to receive information, but it is generally conceived as a personal tool that only the receiving person reads and processes. As mentioned in the prior section, the amount of messages can be overwhelming.

The email software commonly used in the construction industry provides some features that allow sorting, filtering or rating of the messages, but they are still limited and do not have common use. There is a big need for an organizational tool that can help sorting arriving electronic data by categories such us criticality, due date, or person due for action.

5.2 Document management

When addressing communication breakdowns driven by software, we should not only search for a solution to the number of unorganized emails, but also to the problems caused by the use of attachments in those emails. The size of the attachments, or the lack of the right software to read them, might cause a failure in the communication.

One solution to manage electronic documents (drawings, specifications, pictures, etc.) is having a centralized point of information, a webpage, where all members can access the documents, read them, print them, or download the files as necessary. Having a common site with all the information also would avoid hardware problems such as memory limits in personal computers or loss of information after a computer has crashed or has been stolen.

As expected, having a document management tool is part of the advantages offered by some of the web-based systems that are already available in the market. However, many of them have limited editing or downloading capabilities, and other problems that we consider in the following sections.

5.3 Web-based tools with flexibility in features and accessibility

When considering the services of a web-based project management tool, we should remember that many of the potential clients are big corporations and that they usually already have internal systems and standardized procedures to manage their projects.

The web-based systems available in the market offer a series of useful features, like the documents management tool mentioned above; however, they also offer many others tools that might not be necessary, or applicable, to every project. Many firms would gladly embrace some of the features offered, but they will not pay for the complete package if they are not planning to make use of all of the features. Also, before contracting web-based systems, firms have to evaluate if the size and duration of the project compensates the necessary training of the personnel and the unavoidable learning period.

The lack of flexibility of the existing web-based tools is not only in the selection of features, but also in the access. Most of the web-based systems have a secured access protocol managed by the selling company. Whenever a new person is added to any of the teams, the data of this person has to be inputted into the system. During the preconstruction phase this sequence does not represent a big problem because there is a manageable number of people involved that does not vary significantly. However, during the construction period the number of members involved increases dramatically with subcontractors and vendors, as seen in section 3.1.2, and having restricted access to the project webpage becomes a real inconvenience, that might lead to failure in the flow of communication.

By offering flexibility in the features to buy and the participants capable to access the site, the e-businesses might get a better chance to reach the standard construction industry. For the time being only big projects with a very large budget and schedule can take advantage of the new tools.

5.4 Legal acceptance

Since the mid nineties emails can be introduced into court like any other piece of written communication and are subject to the same rules of evidence[3]. However, prime contracts often have terms that note in writing to be signed by particular parties and sent to certain addresses. Therefore, formally printed hard copies and wet signatures are still the main tools of communication for contracts and documents of similar legal importance like change orders or invoices.

The validity of electronic contracts and digital signature has been enforced in many U.S. courts, but some judges still refuse to enforce them. In order to avoid a communication breakdown in this area, we should learn ways to improve the legal and common acceptance of electronic documents in the event of a dispute. I believe that in the middle term future construction contracts will be electronic documents, but I also think that contracts, along with material samples, will be the last items to abandon the traditional communication tools.

6 Particularities of green buildings

In addition to the common framework applied to generic construction projects, we must consider the special needs of *green buildings*. Green buildings are those that are designed and built taking into consideration their impact both on the environment and humans. Green buildings reduce the environmental impact of building on the Earth, minimize natural resources consumption, and ensure occupants comfort and health. The singularity of these projects is related more to their novelty within the industry than to intrinsic conceptual complexities. The lack of long-time used green industry standards and the general inexperience in developing green buildings demand even greater and better information flows.

The discussion set in prior sections applies to green projects. Having said that, we will now build up on that framework to study the main differences of this kind of projects. Next, we review some of the particularities of green buildings regarding information exchange.

6.1 Parties involved

The design of a green building starts with a thorough study of the site's unique characteristics and the surrounding environment and climatic conditions. This study is critical for the development of the program and requires a comprehensive involvement from the beginning of many different disciplines. In green projects, the global team is supported by an increased group of specialists that, depending on the project requirements, might include: biologists, climatologists, mineralogists, toxicologists, sociologists, regulatory specialists, green building consultants[4], etc. (see figure 8).

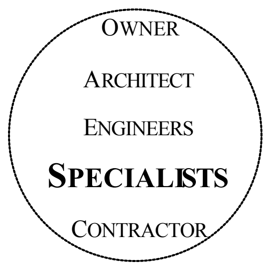

Figure 8

6.2 Phases of a green project

As any other project, green buildings have two important phases: preconstruction and construction. However, green projects add a third phase: postconstruction. This completes a process that is viewed as *life cycle analysis* (see figure 9).

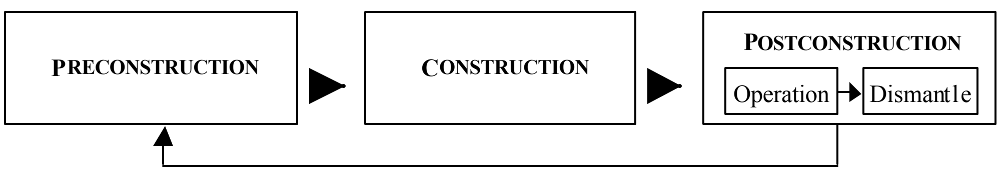

Figure 9. Life Cycle Analysis

6.2.1 Preconstruction

In the preconstruction phase the global team prepares the design documents that will be executed during the construction phase. The communication tools and sources of breakdowns in the exchange of information do not vary significantly from standard projects. However, in green projects, the larger number of disciplines and participants involved boosts the importance of the preconstruction phase and will now require a more efficient exchange of communication than a standard construction project.

6.2.2 Construction

During the construction phase the contractor manages the construction of a green building with a greater emphasis on: reducing the environmental impact of the construction activities on the site's surroundings, noise and dust control, recycling of construction debris, and meticulous commissioning. However, in the subject of information exchange we do not find special requirements in the construction of green building that vary significantly from the standard industry, except when the owner seeks a *green certification*.

The green certification of a building is third party validation of achievement according to an established green building rating system like, e.g., LEED[5]. Green buildings seeking certification require a more intensive team cooperation during the construction period than traditional buildings in order to gather and coordinate all the documentation required for the certification. One of the most common measures taken for the additional coordination effort is the establishment of weekly or biweekly meetings for this specific purpose.

6.2.3 Postconstruction

Green buildings are designed taking into consideration the complete life cycle of a building, from concept to dismantle. This requires the building not just to be built and then forgotten, but also to periodically monitor its performance to ensure proper functioning and eventually, handle its demolition or dismantle. In order to meet this demand it is necessary to ensure that information is developed and stored for a longer term and more periodic use than required in traditional projects. While none expects the global project team to be around for the complete life span of the building, green buildings do usually have longer project duration[6].

I wanted to point out that although objectively green buildings will require an extra effort in planning until the building industry is familiarized with the procedures and becomes standard, I have found a stronger union of the project team with a common feeling of accomplishment for 'doing the right thing'. It is possible that this commitment may help overcome some communication problems.

The importance of this discussion is given by the recent and significant introduction in the market of this kind of project. There is a good possibility, and so we hope, that in a near future all new construction will be socially and environmentally responsible, i.e. 'green'. For the time being we wanted to draw researchers' attention to some of the needs regarding information exchange in this rapidly developing area of the construction industry.

7 Conclusion

Information technology has significantly changed the traditional practices of the construction industry, by providing a new set of communication tools that has made faster the exchange of information. This has facilitated specific changes such as: higher expectations on quality and delivery of results; greater team diversity across different disciplines, cultures, and geographic locations; and, added complexity to the projects[7].

In this article we have first identified three major groups of participants in the design and implementation of a project (owner, designers, and contractor) and three major phases (preconstruction, construction and postconstruction). Then, we have analyzed the criticality of the exchange of information among participants during the different phases of the project. Finally, we have identified the communication tools most commonly used, and the most frequent sources of breakdowns in communication. We have concluded that there is a need for more efficient tools to improve the exchange of information at all stages of the project, but mostly during the construction phase, and suggested that information management tools (e.g., email and web-based systems) is a key area for improvement.

Technology has demonstrated the potential to improve the construction industry by allowing greater team diversity and a more efficient interaction among teams. As a result, construction is continuously evolving and yielding astonishing achievements such as intelligent and environmental responsible buildings. Above, we have provided some industry insights regarding the challenges still encountered when exchanging information during a construction project. We would like to conclude by encouraging researchers to continue exploring solutions for this exciting and challenging field, taking into account the lessons that can be learned from the industry.

8 Endnotes

1) We call *plan checker* the person within the permitting department of the city assigned to review the permit drawings.

2) "10 stories that shook the Net". December 22, 1999. http://www.cnn.com/1999/TECH/computing/12/22/standard.10.stories.idg/index.htm

3) A short history of "digital signature" and "electronic signature" legislation: http://bradbiddle.com/history.html

4) The green building consultant figure is included as a response to the lack of knowledge of the traditional industry on the preparation of drawings, specifications or bid documents with environmental provisions. Once the building industry has adopted the environmental requirements as standards, we might not need additional support in this area.

5) LEED™ (Leadership in Energy and Environmental Design) is a green building rating system developed by the USGBC (U.S. Green Building Council, www.usgbc.org) in 1995. LEED has become the most widely used green building rating system in the U.S. and it has now reached other countries within the recently founded World-Green Building Council (www.worlgbc.org).

6) When talking about "project duration" we refer to the period of time from acknowledgement of the need of a new facility until the day that the warranty of the building expires. The construction duration (time to build) of a green building does not vary significantly from any other standard building.

7) The overreaching changes in science and technology have complicated the program requirements for buildings, for example by adding new necessities like server rooms, telecommunication cabling, complex security systems, media display, monitoring systems, recycling areas, etc.

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