ISSUES AFFECTING THE FLOW OF INFORMATION DURING THE DESIGN PHASE OF AFFORDABLE HOUSING DEVELOPMENTS

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ABSTRACT

This paper presents the results of a research project that investigated the major issues affecting the flow of information during the design phase of affordable housing developments in Southeastern Mexico. A qualitative approach was selected for the research. Specifically, the case study mode of inquiry was chosen to investigate a contemporary phenomenon within its real-life context, based on the following sources: *documentation*, *archival records*, *direct observation*, and primarily, *in-depth interviews*.

The findings indicate that the design process of affordable housing developments follows informal channels of communication, does not promote participation from other professionals involved in the process, does not incorporate lean or constructability concepts, and shows evidence of errors and generation of waste. Furthermore, the flow of information is perceived differently by each member of the design team, lacks a framework of reference, and primarily, shows substantial evidence of informality. Based on the results of the study it was possible to identify information flow patterns within the design team, and most importantly, to develop an information framework for the process, which was validated by the design team. This study provides direction for experimentation and creation of new design practice in affordable housing developments.

KEY WORDS

Information flow, Design, Affordable housing, Case study.

INTRODUCTION

This paper reviews the complexity of the overall process and proposes that the majority of those problems originates during the earlier stages and is primarily caused by the way the information flows between the participants. A case study presents the results of a research project that investigated the major issues affecting the flow of information during the design phase of affordable housing developments in Southeastern Mexico.

THE DESIGN PROCESS

Different writers and designers have outlined the design process in as few as 5 steps or as many as 25. As portrayed by Asimow (1962), design is a sequential process consisting of many design operations. From this perspective, it becomes evident that the genesis of the process is information. This has been generally acknowledged in design science. For instance, Hubka and Eder (1998) state:

> *"Engineering Design is a process … through which information in the form of requirements is converted into information in*

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the form of description of technical systems …".

In a similar vein, (Mistree *et al.* 1993): "Designing is a process of converting information that characterizes the needs and requirements for a product into knowledge about a product."

Each operation requires information, some of it is general technical and business information that is expected of the trained professional and some of it is very specific information that is needed to produce a successful outcome. Dieter (2000) recognized that, although acquisition of information is vital often it is a very difficult step in the design process. However, Dieter also recognized that it is a step that usually becomes easier with time, a maturing process that he called process experience.

The simple model shown in Figure 1 illustrates a number of important aspects of the design process. First, if there is no information there is no design process; second, even the most complex design can be broken down into a sequence of design objectives; and third, each objective requires evaluation and it is common for the decision-making phase to involve repeated trials or iterations. Design is a creative process, and all new creations of the mind are the result of trial and error. The iterative nature of design provides an opportunity to improve design on the basis of a preceding outcome.

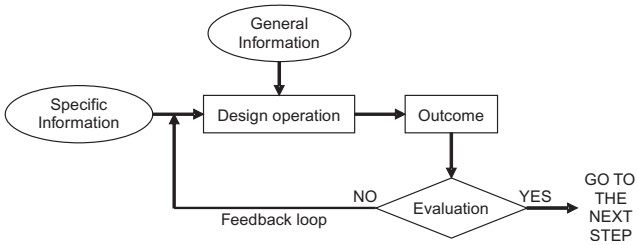

Figure 1. Basic Module in the Design Process

INFORMATION FLOW

Construction is an information intensive undertaking. Each participant entity requires substantial amounts of information to perform their job.

Regarding information flow, researchers have studied, primarily, how to create flow on the job site and only isolated efforts have been undertaken related to the design process, even among those promoting lean construction. For instance, out of 387 papers in the Proceedings of the International Group for Lean Construction (IGLC) Group for the 1993–2004 period, only eight directly address information flow in the design process.

According to Dos Santos et al. (1998), when construction is viewed as a flow many factors that before were considered unimportant come to the surface and become very important to the effectiveness of production. However, the flow must be easy to understand, otherwise managers and workers would prefer to go back to the traditional conversion model as soon as they face the enormous amount of information related to the flow model. Therefore, the production activities have to be transparent in order to make information flow models viable (Dos Santos et al. 1998).

Ballard and Howell (1996) said that practical knowledge builds projects. But to be practical, information must be reliable and accessible. Information that is not practical is waste. Moreover, we need to keep in mind that information flow is the complementary component to work flow. Furthermore, reliable detailed information is necessary for the elimination of waste (Ballard and Howell 1996).

Conceptualizing the design process as a flow of information lends itself to reducing waste by minimizing time information spends waiting to be used, time spent inspecting information for conformance to requirements, time spent reworking information to achieve conformance, and time spent moving information from one design contributor to the next. Further, and even more important than reducing the cost and time of design, conceptualizing the design process as a flow of information allows coordination of interdependent flows and the integration of design with supply and site construction (Ballard and Koskela 1998).

The scarce literature evidences that information flow in construction, and particularly information flow in construction design, has been barely studied, despite that this topic seems very promising in terms of its potential to improve AEC industry's performance. Evidence of successful applications of lean design is documented by Emmitt *et al*. (2004).

DELIVERY OF AFFORDABLE HOUSING

The existing legal framework in Mexico allows financing agencies to deal directly with single entities (i.e. developers, promoters and constructors) to be responsible for the overall construction process, from feasibility studies up to the delivery of the product. According to several studies (Koskela, 2000, and Riley and Horman 2001), having all responsibilities of the overall construction process under a sole entity facilitates teamwork, practice that promotes a better integration of the several stages in the total life cycle of a project.

However, stakeholders in the construction sector addressing the demand of affordable housing in Mexico appear to operate both fragmented

and disintegrated (González *et al*. 2001). Some symptoms of such practice are excessive regulation (SEDESOL), that 90% of the dwelling units are inadequate in terms of comfort (Gómez 2000), 5.7% of materials, in terms of weight, is wasted (Marín 2000) and waste represents at least 5% of the direct cost of the unit (Marín 2000).

Several studies point out that the origins of such inefficiencies arise through decisions or actions during the design phase, and that the most frequent causes for severe deviations for design were deficient planning, deficient or missing information, and changes. In Latin American countries it is estimated that between 20 to 25% of the total construction period is lost as a result of design deficiencies (Loría 2002a).

The authors consider that understanding the design process in the context of affordable housing can ameliorate the problems mentioned above. To achieve that, a research project was developed to identify the flow of information during the design process of large housing developments in Southeastern Mexico.

RESEARCH METHODOLOGY

Response to the research question was sought in the following sources: documentation, archival records, and interviews, as shown in Table 1.

Documentation included administrative documents (projects proposals, design proposals, design layouts, and technical specifications), and written reports of design related events. Archival records consisted of interim records such as organizational charts; to identify formal and informal communication flows. Direct observation was used to gather supplementary information to the interviews, including: layout of working spaces, working conditions, and design team meetings. Finally, in-depth, open-ended, interviews allowed direct data collection from members of the design team.

RESEARCH RESULTS

Tradition in the design and construction process has yielded a great number of drawings and documents that are addressed by names that usually reflect their contents, such as preliminary design, bill of materials, etc. These documents and drawings can contain far more information than strictly required by the user. This extra information is often necessary to make the correct interpretation possible.

A phenomenon that is very special for the AEC industry is that the group of participants changes with every new project. This implies that agreements about communication and information only last as long as a project lasts. Furthermore, the design process of affordable housing is not understood only as house conception activities, but it also includes transactional and organizational activities (planning activities, partnership negotiations, management integrated to external agents, land acquisition, enterprise regulation, legalization, etc.). It is important to emphasize that these activities are not design process components, but have interfaces with one. According to Koskela (1992), such activities are the origin of waste in engineering processes.

Following, elements related to the flow of information in the design process of large affordable housing developments in Southeastern Mexico are described.

INFORMATION AND MEDIA

During the construction phase, information is shared and disseminated through multiple bi-directional communication channels (O'Brien and Al-Soufi 1993). Diverse and complex information flows between participants. This information is mainly conveyed using documents. In common language the word document usually means an information carrier (most likely on paper) containing written or drawn information

Table 1: Case Study Design: The Design Process

Question	Objectives	Units of Analysis	Sources of Evidence	Data Types
How does the information flow during the design process of affordable housing developments in Mexico?	Establish a reference framework upon how the information flows, as the design team currently carries it out. Thus, it requires to identify: 1- Types of information needed 2- Who it is coming from 3- Quality of the information 4- Sequence of the information 5- Participant in the process 6- Ways of keeping them informed	• The selected case study firm • Embedded subunits: • The design team	• Interviews • Documentation • Archival records • Direct observation	• Open-ended interviews • Design related communiqués from agencies • Organizational charts • Service records • Drawings and specifications • Casual data collection of design activities

for a particular purpose. Central to the idea of a document is usually that it can be easily transferred, stored and handled as a unit (Löwnertz 1998). A large part of the documents handled in today's business world are stored as individual computer files and are treated as units. Hardly any documents today are produced by hand, but a lot are still transferred by printing them out and sending them to the other parties. A slightly more sophisticated method is that documents are both produced digitally and transferred electronically. Such method speeds up the document transfer, but in terms of document management, this hardly offers any improvement over the current situation since finding a document in another person's personal computer may be even more difficult than in his shelves. Retrieving a document may often as a last resort require asking a person to deliver it.

Based on interviews, and confirmed by observations, the authors detected that there are many operations that are carried out informally, primarily *orally*. Therefore, historical records are limited. This has a significant impact upon the corporate knowledge; it exists but implicitly and in multiple forms. Actually, it is not even recognized as such. Furthermore, the informal information handled by the design team was found to be of the following data types: *unstructured text data files* (i.e. specifications, field reports, catalogs, contracts, change orders); *unstructured graphic files*, stored in binary format (i.e. 2D and 3D drawings); *unstructured multimedia files* (i.e. pictures, video); *semi-structured data files* (i.e. spreadsheets); and *structured data files*, stored in specific applications of database management systems (i.e. cost estimating, scheduling, resource planning, accounting).

INFORMATION REQUIRED

The data collected and analyzed from the in-depth interviews with the design team allowed the authors to identify 38 key pieces of information, or steps, that are required to prepare, evaluate, and approve a housing development.

The steps were also grouped in several ways to identify patterns. The first grouping was by the person and/or party responsible for the step, resulting in four categories, namely: the developer, the notary, the bank, and the household.

SEQUENCE OF THE INFORMATION

A sequence represents the steps by which work is done, the triggers that kick off a set of steps, and the plans that are being accomplished. A sequence supplies the low-level, step-by-step information on how work is actually done that designers need to make detailed design decisions. A sequence is most similar to flow diagrams or task analysis, but is unique in stating the intent and trigger for the sequence.

Searching for more evident patterns, the sequence of the steps (another sort of grouping) was explored, and identified from the analysis, arising the following four categories: land-related, construction-related, proprietorship-related, and municipalization-related. This grouping resulted in 28 steps in charge of the developer, a function that is primarily performed by managers, 11 steps in charge of the notary, and one step each in charge of the bank and the household (Figure 2). These steps, or pieces of information, add to more than the 38 steps shown in Figure 2 because two parties carry three of them out

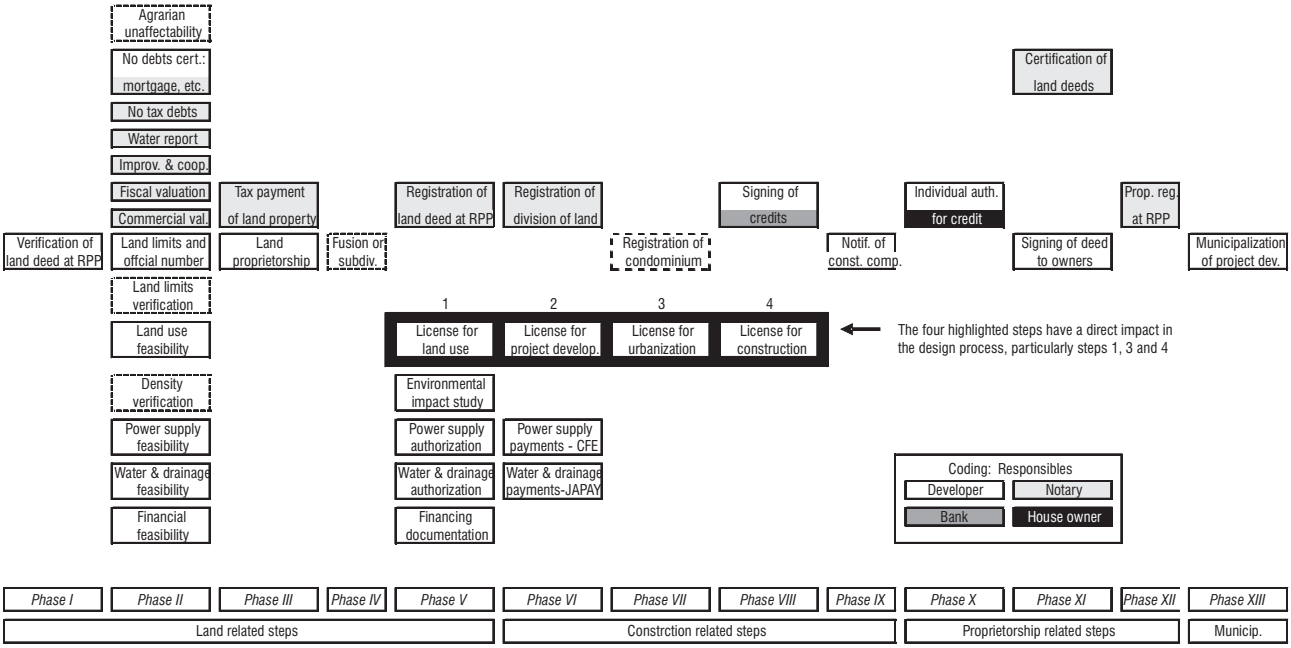

Figure 2: Steps Affecting Affordable Housing Designs

jointly. The content of the pieces of information reveals the following issues:

Most steps reflect transactional and/or organizational activities, important to the process but not directly related to design as it is traditionally practiced or known.

In quantitative terms, participation of households in the design process is extremely limited, almost nonexistent. One out of thirty eight steps accounts for only 2.5% of the overall process. In qualitative terms households' participation is even more limited.

The fact that most activities identified by the design team are transactional and/or organizational is congruent with other studies. For instance, Freire and Alarcón (2001) found that "the share of conversion (or transformation) flow from the total flow time is very little." Regarding the limited participation by households, the results obtained are similar to those obtained in other countries worldwide, for instance Spain and the UK in Europe, and Chile and Brazil in Latin America (Loría 2002a).

Members of the design team tend not to think about the customer (either the client or the household) but more about the next user in the chain. Moreover, affordable housing developers do little systematic research on what the end user actually wants.

DESIGN-RELATED STEPS

After reviewing the description, the grouping and the sequence of the 38 steps, the design team determined that only four steps do have direct impact upon design (Figure 2). This agreement was only possible after revising, first individually and then collectively, the chart resulting from the interviews.

It is evident that even though the design team recognizes those four steps (described in Table 2) like the ones that have direct influence upon design, they hardly fall into the framework of design that has been previously presented and discussed in this research work. Those steps can definitively be considered more like managerial activities or perhaps more like milestones within an overall process.

This result confirms that a key competitive strategy for the Mexican speculative affordable housing developers has been to optimize their land holdings and the time of sale of dwelling units to benefit from market demand (Loría 2002b). It becomes evident that land acquisition is

Table 2: Factors Affecting Affordable Housing Design

Activity	Responsible	Agency	Description
License for land use.	Developer.	City's Urban Development Department.	The license for land use is the document issued by the city authorizing the proper use of a land. It is mandatory to obtain it before the construction license when the partial programs, when it is pertinent, have been assigned as conditioned for the zone. • This step establishes particular conditions to: • Avoid higher infrastructure cost • Avoid undercapacity in road, hydraulic, and sewage infrastructure. • Promote positive impacts in the existing infrastructure • Maintain balance between land use and purpose use • Preserve environmental quality • Take care of urban security
Division of land deed.	Notary.	Department of General Cadastre.	It is the step to divide the land according to the lot seed previously authorized in the license for project development. At this step, the name and the lots' cadastre numeration is assigned.
License for urbanization.	Developer.	City's Urban Development Department.	It is the technical proposal before the city authority, regarding the following services: • Public lighting • Pavement • Sewage • Transit signaling • Sidewalks • Nomenclature
Construction permit.	Developer.	City's Urban Development Department.	Authorization by the city to the developer, or to the owner of the land, so he can build new dwelling units, and/or expand, modify, change condominium regime, repair, or demolish existing constructions. All this based on the corresponding City's Building Regulations.

paramount for developers, since 24 steps (63% of the process) are land-related steps. However, many have argued that this approach has been detrimental to technical innovation in the industry and has resulted in a low wage, unskilled workforce (Loría 2002b). That condition is not particular to the Mexican affordable housing sector. Similar findings have been observed in the UK, Spain, Chile, and Brazil (Loría 2002a).

This is also a confirmation that the transformation/conversion view of production, input-transformation-output, still continues as the preferred way of operations for many design professionals in the housing sector of the construction industry, not just in Mexico but in many counties as well.

That situation in Mexico, and the other countries listed, about the emphasis in land holding strategies, stands in stark contrast to that of some other countries, where the structure of housing supply forces house builders to pay more attention to product or process innovation. In Sweden, for example, there has been less scope for developers to make purely profits because of the system of land ownership and development control. In Japan, some house builders have transformed the delivery of new housing by adopting component-based approaches use in manufacturing industry (Loría 2002a).

The condition mentioned should be a concern for those agencies financing affordable housing. However, a more striking finding is that during the overall process households' participation almost does not exist. On the other hand, the developer's influence is quite significant.

FLOW OF INFORMATION BETWEEN PARTICIPANTS

To get the work done, people divide responsibilities among roles and coordinate them between themselves while doing it. The key issue is how people's roles are defined and how they communicate to get the job done.

Searching for more evident patterns, members of the design team were asked to draw charts showing the flow of information during the design process, according to their individual perspective. Three of those charts are shown in Figure 3. Two members of the design team, the Production Manager and the Administrative Manager, did not draw a chart; they delegated that responsibility to the Construction Manager.

In the charts, the flow of information is shown as arrows between individuals. Flow may consist of informal talk and coordination, or it may consist of passing artifacts. Artifacts may be physical, such as a document or message, or may be conceptual, such as a design idea between the team members.

Regarding individual perspectives, it makes sense to expect variations among people, not just upon design but also about any process for that matter. Even simple things, people conceptualize them in different ways. However, the charts drawn by each member in the design team are significantly diverse. The arrows between individuals (information flow) and their respective directions, the sequence of the information, the number of participants, the number of levels (hierarchies), do not suggest any type of agreement about the design process, or at least hint some explicit patterns that could provide some indications about the existence of a standard process.

Further analysis of the interviews allowed to identify one important finding: the role of the construction manager appears to be central to the design process. All three charts suggest him playing a sort of gatekeeper role. He is the liaison between top management (the two directors) and other participants in the design team. This became more evident when flow and sequence of information was traced during group sessions.

Figure 3 portrays a simplified representation of the information flow between participants as identified in the selected firm. Verbal exchanges, paper drawings, and reports are frequently used for data transfer between design team members, and often they need to take data from memory or paper and enter it into their own personal agendas.

Figure 3 clearly illustrates the problem of fragmentation in the design process, of affordable housing developments, similar to the one in the overall construction process. But it also suggests the following set of characteristics of the flow of information:

- Feedback is not explicit, rather it is random and unmanaged
- Significant feedback is very late and slow.
- There are no inherent criteria for defining design versions.
- Organizational (lack of) control may lead to unstable designs.
- Errors and omissions may occur in moving data from one discipline to another.

CONCLUSION

One limitation of the existing design process is the dependence of push techniques. Push information systems release information based on manual classification and retrieval methods controlled by humans. One example of the limitations of manual classification and retrieval is the time and effort required in order to access all documents.

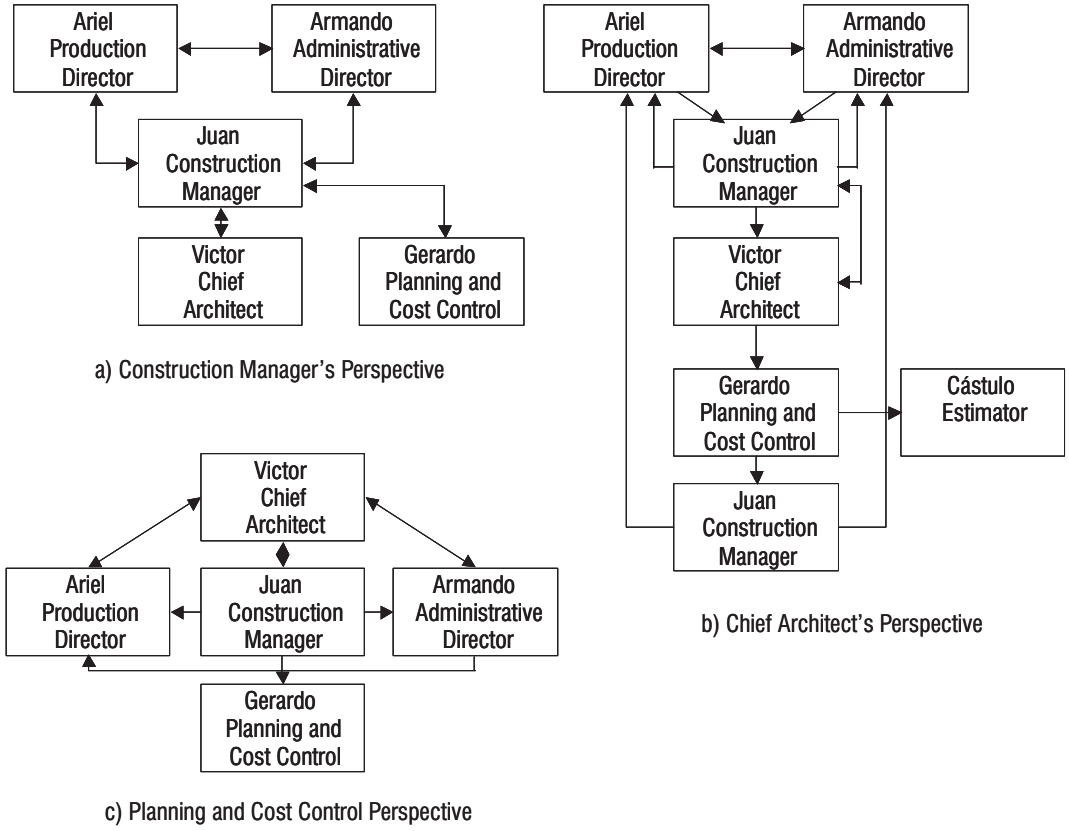

Figure 3: Flow of Information: Individual Perspective

Another limitation is the consideration of documents as single units for the purpose of classification and retrieval. This limitation can be illustrated by the case in which the construction manager wanted to access the information containing the report of a specific project in order to solve an issue. He had to manually search and analyze each document individually in order to obtain the desired information.

A third problem is the lack of support for differences in vocabularies and naming conventions. This problem can be illustrated by the case in which the chief architect gave a name to a particular object in a housing project. Since there is no standard vocabulary among the participants, references to that particular object in project documents were often done using different names.

Furthermore, the design process of affordable housing developments is not understood only as pure design activities, but also includes transactional and organizational activities. Regarding media to store and manage information, current design process also relies on push mechanisms for information management. A great deal of operations is carried informally, primarily orally. Most of the information is unstructured and not integrated. Almost two thirds of the information is land related, with a strong input from the developer. The flow of information is neither direct nor continuous. Feedback is not explicit, occurs randomly, unmanaged, and slowly. Sequence of information revealed four groups of pieces of information, namely: land related, construction related, proprietorships related, and municipalization related. The number, type, and sequence of steps identified to deliver an affordable housing development confirm that a key competitive strategy for the Mexican speculative affordable housing developers has been to optimize their land holdings and the time of sale of dwelling units to benefit from market demand. Moreover, it confirms that households' participation almost does not exist. Rather, the developer's influence is quite significant in the process.

Summarizing, 1) the current process rely on push mechanisms for information management, 2) a large percentage of data is stored on semi structured and unstructured files, 3) it is very hard to find the information needed for decision making, 4) the information is not integrated, and 5) there is no clear association between information and their related project product and process components.

RECOMMENDATIONS

This research has been an exploratory and descriptive investigation into the relatively uncharted field of design of affordable housing. As such, it has served to provide additional insight

into the knowledge embodied in the process of design, as well as knowledge about the process itself. The intent of this research has been to begin to uncover an understanding about the design skills behind the creation of solutions to specific affordable housing developments design problems. As such, three recommendations are made for future research to focus on furthering this understanding and thus eventually providing tools that will provide for integrated solutions to the problem of design in affordable housing developments allowing it to be solved from the bottom up at the same time it is being solved from the top down:

- Developing of National Standards for the Classification of Design Information
- Development of Models for Managing Design in a Collaborative Environment
- Development of Electronic Document Management (EDM) Systems

The construction industry is unique in that it involves parties from a myriad of professions. Different types of information are exchanged between the various parties for the purpose of communicating design, construction and contractual matters. Individual firms have developed their own means of classifying and disseminating information to facilitate this process. However, as there is no standardized system in Mexico of classifying and sharing of such information, much of the data is lost along the way. Developing such type of standards should result in a common ground for all parties involved, the authors suggest to start with an urgently needed Glossary of terms.

Coordination of design information during the detailed design stage is essential for the design team to provide quality construction technical documents that are free of incompatibility errors. Building design represents a collective effort from specialists who belong to various disciplines. These specialists, who are usually geographically separated, make autonomous design decisions, with respect to their own discipline. These decisions, nevertheless, are independent and therefore need to be coordinated so as sustain compatibility among the various systems and components in the building under design. Replication of the Value/Process/Operation (VPO) model by Emmitt et al. (2004) within this context could lead to be very promising results.

Design management is getting a lot of attention in the AEC industry due to its strong implications for the entire project. An Electronic Document Management (EDM) system has the potential to enhance the information management in construction projects, including the design phase, without radical changes to current practice. EDM systems focus on facilitating the management of documents pertinent to particular enterprises, projects and work groups in computer networks. In addition to the basic file management capabilities found in operating systems, EDM systems contain enhanced features related to the life cycle and versioning of particular classes of documents.

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