ABSTRACT: Constructability review is frequently mentioned as solutions to industry-wide problems of improving design efficiency and reducing construction errors. Despite numerous attempts to conduct constructability review, few practical implementations can be found in construction industry today. Inspired by the efforts of industrial researchers in investigating the collaborative aspects of integrated industrial design, the collaboration aspects in constructability review process (CRP) should be well addressed in order to fulfill the promises of constructability review. The study presented in this paper attempts to gain a better understanding of the collaborative process among parties from different disciplines in CRP. Insights and knowledge learned from highly integrated industrial design are transferred to constructability review domain to gain better understanding of the collaborative interfaces, and the barriers and enablers that influence the creation of shared understanding among different parties. This paper also formulates a method for empirical study of the collaborative aspects in CRP. Future work is to conduct case studies on industrial CRP with the developed method.

KEYWORDS: collaboration, enablers, barriers, interface, constructability review process, empirical study.

1 INTRODUCTION

Constructability review is frequently mentioned as solutions to industry-wide problems of improving design efficiency and reducing construction errors. Despite numerous attempts to conduct constructability review, few practical implementations of CRP can be found in construction industry today. Nowadays, both industrial practitioners and researchers have investigated the organizational and collaborative aspects of integrated industrial design. Constructability review demands effective multidisciplinary collaboration and shares common features with integrated industrial design. The promises of constructability review remain unfulfilled, and both researchers and practitioners have not yet put much effort into the collaborative aspects of constructability review process (CRP). This makes that the involved parties are not able to create shared understanding about the design they are reviewing. Shared understanding about designs is important because it influences the quality of the end result of the design process (Valkenburg, 2000). The aim of this study is to gain a better understanding of collaborative aspects of parties from different disciplines involved in CRP. The purpose is to facilitate the knowledge transfer from industrial collaborative design into CRP for improvement.

In order to show what kind of collaborative processes this paper compares, Section 2 discussed the main characteristics of CRP and Section 3 presented the collaborative aspects of industrial design process (e.g., the way different parties are involved in the different stages of the industrial design process). Section 4 focused on the factors (enablers and barriers) that influence the creation of shared understanding among parties from different disciplines in CRP, and examined the collaborative interfaces between parties in CRP. Section 5 formulated a method of empirical study to create knowledge on the factors that influence the creation of shared understanding.

2 CONSTRUCTABILITY REVIEW PROCESS

Constructability is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives (“Constructability” 1986). Constructability review process (CRP) formally review projects and address constructability issues which usually occur at the design stage. Such multidisciplinary reviews intend to improve the constructability of projects as well as the design. CRP typically involves various parties such as planners, designers, engineers, constructors, suppliers, subcontractors, etc.

Previous research has addressed various aspects of constructability and primarily sought to understand the elements in a CRP, and the optimal way to implement a
CRP. For example, Fischer and Tatum (1997) developed models to classify constructability knowledge. Navon et al. (2000) developed methods to automat the process of constructability reviews. Surveys were conducted to better understand the CRP, and to quantify the advantages obtained from constructability reviews (Anderson et al. 1999; Uhlik and Lores 1998). O'Connor and Miller (1994) identified four major types of barriers involved in CRP: cultural, procedural, awareness, and incentive barriers. Cultural barriers are caused by company tradition, inflexible attitudes, frozen mind-sets, or other ingrained paradigms within the organization. Procedural barriers result from established methods or practices considered "set in stone," or by a lack of interest in trying new ideas or suggestions that might force revision or changes to standard operating procedures. Awareness barriers include those arising from a lack of understanding of the goals, concepts, methods, and benefits of constructability, or a lack of comprehension of the application of these items to organizational practices. Incentive barriers are caused because no motivation or inducement for constructability implementation is present (O'Connor and Miller 1994). The focus of the study presented in this paper is on the collaborative aspects between parties from different disciplines involved in CRP.

3 CHARACTERISTICS OF INDUSTRIAL DESIGN PROCESS (IDP)

Industrial design projects are nowadays performed in multidisciplinary design teams. This means that, all disciplines involved in the IDP, are ideally involved from the beginning until the end. Figure 1 shows the IDP. The different tones of the team members around the table represent their discipline. The three different tables represent different phases of the design process. (Different disciplines, such as, Market research, Sales and Quality Control can also be involved in the team.)

Figure 1 also shows that Marketing, R&D and Production are involved from the ‘definition of the market need’ (or ‘definition of new technology’) until the final product has been developed. This is important since most decisions concerning the design of the new product are taken in the first phases of the design process. If production for example is not taken into account in the early phases, the problems that occur in the final product that are related to production issues can only be solved cosmetically.

In order to facilitate IDP, companies use Stage Gate Models that describe the activities that need to be performed in order to develop the new product (Cooper 1988). However, these prescriptive Stage Gate models implicate an undisturbed flow of activities during IDP, which differs greatly from practice. This is because (in addition to cooperative aspects), collaborative aspects play an important role in IDP.

Collaboration between disciplines in an IDP process is difficult and delicate since the actors have different knowledge bases and they represent the design they are making differently (Buciarelli, 1996). Additionally, they communicate in different jargon about the product to be designed. The different team members also represent a different department within the company. Therefore, they have different responsibilities that result in different interests. The mutual interests of the different team members are often in conflict.

All the aspects mentioned cause team members difficulties to create shared understanding about the design they are making. Valkenburg (2000) showed that the creation of shared understanding influences the quality of the end result, which shows the importance of the collaborative aspects of the IDP. Furthermore, interviews with several managers of IDP have revealed that multidisciplinary design teams have to deal with collaboration problems on a daily base.

Kleinsmann (2006) defined the collaborative design process as:

Collaborative design is the process in which actors from different disciplines share their knowledge about both the design process and the design content. They do that in order to create shared understanding on both aspects, to be able to integrate and explore their knowledge and to achieve the larger common objective: the new product to be designed.

This definition of collaborative design shows that the main aspects in the collaboration process are:

- knowledge creation and integration between actors from different disciplines
- communication between the actors about both the design content and the design process
- the creation of shared understanding about the subjects communicated

Knowledge creation and integration are the goal of the collaborative design process. If actors are not able to create and integrate knowledge, then they will not be able to design a new product. The actors involved in the design project share and create knowledge through design communication. The actors communicate orally and through the use of textual documents. Additionally, drawings and prototypes play an important role in supporting content related design communication. The quality of the design communication depends on the process of creating shared understanding. Therefore, it is necessary to create insight into the process of creating shared understanding between actors involved in a collaborative design project. There is not much literature on collaborative design as it is defined here. However there is research done on the three main aspects of collaborative design. For a complete literature review on these aspects of collaborative design see: Kleinsmann, 2006 pp. 29-71.
4 COLLABORATIVE ASPECTS IN CONSTRUCTABILITY REVIEW PROCESSES

Since the process of creating shared understanding influences the quality of the end product, it is important to know what factors influence the creation of shared understanding. Kleinmann (2006; 2007) investigated these factors and their mutual relationship. This section shows how the factors found in the research of Kleinmann can be applied to the CRP process. O’ Connor and Miller (1994) also found some additional factors that are also applied to the CRP process.

4.1 Enablers and barriers in CRP

This section discussed the influence of the factors on the creation of shared understanding in CRP. Knowing these factors is the first step towards implications towards improving CRP. These factors will either support or hamper the creation of shared understanding. Factors that support the creation of shared understanding are called enablers and factors that hamper the creation of shared understanding are barriers. The construction industry needs to be aware of these common barriers and work to mitigate their effects. The work presented in this section allows corporate and project level constructability review program managers to determine which of the common barriers they should expect to encounter.

In order to create more insight into the nature of the barriers and enablers in CRP, these factors are categorized into three levels: party-level, project-level, and corporate-level. Barriers on the party level deals with the active collaboration of the constructor and the architect. The constructor is not able to properly fulfill his own task because he does not have the information he needs. An example of an enabler on the party level is that the architect is capable of explaining the application of the shore to the constructor. A list of party-level factors involved in CRP is identified in Table 1. The second level is the project level. Barriers on the project level deal with project-specific factors, such as planning, monitoring, budget, and project organization. An example of barriers on the project level is the low efficiency of information processing (e.g., it is unclear what information is needed). An example of enablers on the project level is the active use of the Minutes of Meeting. A list of project-level factors involved in CRP is identified in Table 2. The third level is the corporate-level. Barriers on the corporate level deal with how the involved parties organize their CRP and how they apply its resources. An example of a barrier on the corporate level is that in the middle of CRP, problems are not solved adequately because certain mechanical engineers are removed to new projects and no longer dedicated to the CRP. This indirectly hampered the achievement of shared understanding. An example of an enabler on the corporate level is that at the beginning of the CRP, relevant parties from different disciplines are put together in a team. This multidisciplinary team takes all requirements from the different departments into account early on in the project. A list of corporate-level factors involved in CRP is identified in Table 3.

Table 1. Identification of Party-Level Factors in CRP

<table>
<thead>
<tr>
<th>Factors</th>
<th>Discussions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ability to identify constructability issues</td>
<td>The parties involved might be strong in identifying constructability issues, or might fail in searching our problems.</td>
</tr>
<tr>
<td>The experience of parties</td>
<td>The enablers within this factor deal with the experience that parties have with the other parties’ regular tasks. The barriers are lack of experience of other parties (e.g., lack of construction experience in designers).</td>
</tr>
<tr>
<td>The applicable knowledge of a party</td>
<td>e.g., the designer’s partial understanding of construction requirements</td>
</tr>
<tr>
<td>The ability of parties to make a transformation of knowledge</td>
<td>It concerns the knowledge exchange between different disciplines. Since parties of different disciplines use different knowledge, a transformation of knowledge is always needed. The parties need to transform both the content of the knowledge and the representation of the knowledge. In both cases, the barriers within this party deal with the translation of design or construction specification into knowledge that other relevant parties (architects/engineers/constructors) can use during their own respective tasks.</td>
</tr>
</tbody>
</table>

Table 2. Identification of Project-Level Factors in CRP

<table>
<thead>
<tr>
<th>Factors</th>
<th>Discussions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The view of a party on the CRP</td>
<td>• The view on CRP benefits (e.g., the resistance of the owners to formal constructability approaches because of the highly visible extra cost to projects) • The view of a party on the process to follow (e.g., perception of increased liability and reluctance of genuine commitment) • The view of a party on the knowledge to be shared (e.g., reluctance of field personnel to offer preconstruction advice)</td>
</tr>
<tr>
<td>The empathy of the party about the interest of a task</td>
<td>This factor deals with the understanding of the content and interest of one’s task. In addition, it is about to what extend a party is able to interrelate its tasks to other (interrelated) tasks. The barriers within this factor deal with: parties do not fulfill a task that is required because they are not aware of the interest of the task or they underestimate a task or, parties perform a task and do not inform other parties, since they do not know that the information is important for the other party. An enabler might be that if a party knows the context of his task, he has more empathy for other tasks just outside the direct scope of his own task.</td>
</tr>
<tr>
<td>The view on teambuilding</td>
<td>Lack of mutual respect between designers and constructors, e.g., unreceptive to contractor innovation.</td>
</tr>
<tr>
<td>The ability of parties to make use of different communication methods</td>
<td>Poor communication skills</td>
</tr>
<tr>
<td>The equality of the language used between the parties</td>
<td>It concerns the different jargon that the parties use (both in words as well as in drawings)</td>
</tr>
<tr>
<td>Personality and corporate cultural</td>
<td>e.g., diverging goals between designers and constructors</td>
</tr>
</tbody>
</table>
4.2 Interfaces: the relationship between the barriers and enablers

This section shows the individual factors that influenced the creation of shared understanding. This section shows that these factors occur not isolated. Some of them are interrelated to each other. According to Smulders (2006), an interaction pattern between parties is an interface if two (groups of) parties work to a large extent separately, yet share a common boundary. As a result of this common boundary, they must interact with each other. One (group of) party (s) needs to share their knowledge with each other in order to share and create the knowledge necessary. Each interface involved in CRP actually consists of barriers and enablers on more than one level (party, project, and corporate). Therefore, the enablers and barriers within each interface can be identified and analyzed. In addition, the identification of interfaces could allow revealing:

- the knowledge that the parties have to share and create within the interface
- the communication processes between the actors
- the relationship between the barriers and enablers within each interface
The designer explained himself with design intention and design requirements. Although the designer tried to explain his point of view clearly, the constructor did not understand. By using drawings of drainage design, the constructor tried to explain to the designer the impossibility of getting all the functionality into such a small space. The designer did not understand what the constructor was talking about. They ended the discussion with the knowledge that there was a space problem. Yet, they were not able to negotiate with one another in a productive way in order to solve the problem.

A CRP program manager who faces the problem can use the method presented in this paper to recognize the underlying causes of the collaboration problem that occurs on the party level. The main problem here is that the designer and the constructor are both incapable of transferring their knowledge to one another. The major interface lies between the designer and the constructor if this process is regarded as CRP. Looking at the collaborative mechanisms of this interface, a program manager should be aware of the fact that this design issue can lead to construction and maintenance problems. In order to manage this, a program manager should help the designer and constructor transferring their knowledge to one another. He should function as a boundary spanner between the two parties. If the transition of knowledge is made and both parties have learned some of the language of the other, then both the designer and constructor can together solve the design problem. Furthermore, a program manager should be flexible with the planning of this aspect. He should be aware that this design task may influence the critical path of the entire project delivery. In order to control this, a program manager should also monitor his progress and possible problems.

This method can help program manager to recognize and distill the factors (enablers and barriers) and collaborative mechanism within his CRP team. The program manager should actively observe his own team during their regular meetings. He should take notes about the most important issues concerning communication about the design content. During the regular face-to-face meetings (design problems or changes) with the separate parties, he can use his notes as input for discussing the collaborative aspects with the parties. This form of storytelling will provide the program manager with knowledge about the collaborative aspects of this CRP. The program manager should also learn to distill the barriers and enablers from these conversations. Dependent on the kind of barriers and enablers he has found, he can then decide if he needs to intervene to fix some collaborative problems.

6 DISCUSSION

The next example shows how future CRP processes could be improved by the Learning history method in an IDP project. This example was transformed from an example from industrial design engineering into a CRP problem. This section shows the value of the research method proposed in this paper. It would be interesting if we can apply the method proposed in realistic CRP in the future. Imagine the following situation:

“A mechanical constructor got an assignment to build the hydraulic piping for drainage. In the list of specifications, he saw the maximum amount of space he could use for the hydraulic piping. From his experience, he knew that he was not able to put all of the components he needed in that space. The program manager told him that the drainage designer came up with this design and specification. The constructor asked the drainage designer if he could change this design. The designer told him that this was the maximum amount of space the constructor could use.
budget, and project organization. Barriers on the corporate level deal with how the involved parties organize their CRP and how they apply its resources. This paper also formulates a method to implement empirical study of the collaborative aspects involved in a specific constructability review process. This method is based on the identification of factors (enablers and barriers) at each interface (e.g., interface between designers and constructors) that exists in a CRP. Future work will use the findings of this paper and the presented method to implement case studies from existing CRP in construction industry. The results from the case study will be used to reflect the method and conclusion can be made accordingly.

REFERENCES


