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Abstract

Predicting the outcome of a construction project largely relies on estimated targets of time and cost. Still, hitting the targets does not mean that the project is a success on all performance levels. Here, a retrospective case study was undertaken on a construction project identified as a successful project by the partners involved. The purpose of the study was to validate conceptual design indicators of a high-performance construction project as reported in the literature, by answering the following research questions: "What characterizes the dialogue between the different disciplines; (2) What is the dialogue about; and (3) When in the process do questions arise?" Findings indicate that the interprofessional dialogue within the project team was well established. The paper introduces a discussion that the dialogue benefited from the collaborative project environment as well as the early design intent. Further, the study also suggests that the interprofessional dialogue supported a sound project team development.

Keywords: Structural Design, Buildability, Constructability, Pre-construction indicators, conceptual design

1 Introduction

Predicting the outcome of a construction project largely involves relying on the estimates of time and cost calculations. Still, hitting the target does not necessarily mean that the project is perceived as a success on all levels. In the pursuit of a high-performing construction industry, the focus is often on early involvement of the contractor in the project and numerous studies have investigated the organizational and inter-organizational management tools, [1]. Instead, with a team performance perspective, [2] identifies three main areas of improvement regarding project team development in bridge construction projects and also shows a need for investigating the execution of projects and the underlying mechanisms of collaboration; *Project Culture*, *Organizational Structure*, and *Project Competence*. Demonstrated by the performance-indicators, the inter-professional dialogue act as a linchpin in supporting project-team development. In this paper, we report on a retrospective case study undertaken on a construction project identified as a successful project by the partners involved. Unlike the stated conditions given in the literature regarding projects in collaboration, this project was not specifically procured in collaboration; it was initially procured as a Design-Bid-Build contract (D-B-B) with completed construction documents provided to the contractor by the client. Importantly, it was the experience from similar projects and previous successful collaboration between contractor and engineer that prompted the collaborative design. The purpose of this study was to further evaluate reported pre-construction performance indicators of a high-performance construction project leading to the research questions of this research: (1) What characterizes the dialogue between the different disciplines; (2) What is the dialogue about; and (3) When in the process do questions arise?

2 Inter-disciplinary relations in construction

Inter-disciplinary methods in construction are best exemplified by multi-party contracting practices such as project alliancing, project partnering, and integrated project delivery (IPD). These contracting methods, referred to as 'relational', are based upon a relationship of trust between parties with fair division of responsibilities and benefits [3]. The American Institute of Architects defined IPD as a "method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction" [4]. The relational aspect thus helps enrich inter-organizational relationships to deal with unforeseen events difficult to capture within the dictates of the contract definitions. Thus, it encourages a flexible and speedy response to deal with the challenges usually associated with a risk event that has not been explicitly addressed in the contract.

However, contractual arrangements are only a part of the transition towards a more efficient and sustainable construction process and can only create the prerequisites for a project to be successful. The degree of success still lies in the hands of the project participants, i.e. the individuals involved in the daily work of engineering and construction activities. To reap success in a construction project, the project team should strive for an integrated project process, with a focus on the end-product, and formulate clear project goals and specify priorities regarding quality, cost, and time.

For contractors to operate construction activities both efficiently and competitively, they are directly dependent by the design concept and the detailing. Consequently, it is important to understand the critical aspects which could cause problems on the construction site. The optimization of a structural member, for example to make a beam or a column as slender as possible will result in maximum economy of material but will certainly not minimize cost of the finished product. Simplicity and repetition are usually the keys to success and core conditions for efficient production. It is crucial for a structural engineer to understand governing site activities, and when designing to also have a distinct idea of how construction will be performed, and what equipment is available to the contractor. Further, a structural engineer needs key knowledge of construction operations [5] and an understanding of the advantages and disadvantages of a proposed solution. However, buildability considerations are normally based only on the structural engineers´ knowledge or experience from previous construction projects and without the input from the appointed contractor.

Construction projects increases in complexity and makes it more and more difficult for designers to be fully aware of all the implications of their designs. This complexity underlines the importance for the structural engineer to receive feedback from, and to have a dialogue with, the contractors who are experienced in construction engineering and meet the problems daily.

3 Method

The chosen approach for this study was a retrospective document analysis [6], to explore the interprofessional dialogue within the structural design team and how industry professionals use their abilities to collaborate and share information and knowledge, both within their own organization and to other interorganizational team members.

3.1 Case study

The case for this study was chosen with the preconception to be a generally considered successful project, including the perspective of the client, contractor, as well as the structural design engineer. The construction project was a train-depot for regional trains, located in Stockholm, Sweden. The studied part of the project included an approximately 320 m long concrete tunnel and was executed in 2014, initially procured as a D-B-B-contract, i.e. complete construction documents were delivered by the client.

During construction planning, the contractor identified many time-consuming activities and other difficulties to improve. Together with the structural engineering company, the contractor had just completed the structural design of another project, including some long tunnels similar to this, and saw an opportunity to benefit from the experience of a previously successful collaboration and presented an alternative calculation to the client including a re-design. The date for construction start was fixed so there was time pressure to deliver the first construction documents. Within the original design there were several areas identified to improve and with the new design the intention was to optimize buildability and minimize risk during construction. The following areas were the most significant:

- construction method, including sequence, production rate etc.
- repeatability, simplicity, similarity in details
- minimizing shear reinforcement, and choice of bar type

3.2 Analyzed documents

The documents are notes of meetings and have therefore been reviewed and edited in accordance with common meeting documentation procedure. The meeting notes have been documented by the engineering office with the purpose of recording decisions and responsibilities as a project management tool. Consequently, a series of design meetings was arranged parallel to the original plan. Each meeting was documented including information concerning date; place; participants and affiliation; task and associated responsibility. All known protocols concerning the re-design were gathered and stored in a case study database [6]. The targeted audience is the project members as well as the mother organizations of the client, contractor, and engineering office.

3.3 Thematic analysis

The analysis of the project meeting documentation was made as a qualitative content analysis [7]. Qualitative content analysis is a method to stepwise analyze written or verbal communication while focusing on differences and similarities. The interpretation process results in one or several themes. A theme acts as a common thread which runs through each meaning-unit, code and category [8].

The qualitative data consisted of 17 documents. Initial codes were generated deductively based on our prior research, the conceptual framework of integrated design, and our field expertise. Codes were first fit into a pre-existing coding framework of the main theme as meaning units. The coding was then revised interpreting the meaning units and condensed into condensed meaning units to provide a detailed analysis of aspects of the data. Codes with similar content were then grouped into sub-themes [8]. The following step in the process required researcher triangulation [9]. The triangulation included separate coding by a group of researchers. First, a group of two researchers made a preliminary coding of the documents by first theoretical and reflective thoughts were recorded as well as potential codes and themes. Finally, a third researcher coded the content identified as interesting in the coding structure of the themes. After the research triangulation, a review of the generated coding and themes were done, and the coded material was checked for referential adequacy by returning to the meaning unit. The theme naming was discussed as well as the sub-theme structure. Following this coding methodology [10] we strove for trustworthiness and credibility in approach and interpretation.

4 Results

When analyzing the project execution, the holistic parts of the project, such as presence of the client, engineer, and contractor at meetings; type of tasks and who was responsible for the task; and the task's category of what, how and realize were mapped and documented. Only those tasks clearly including the interprofessional dialogue were further evaluated and presented. In total, 20 tasks were identified, and from the thematic coding the tasks could be categorized into 7 themes representing the content of the interprofessional dialogue: Prototyping (1); Structural Design (6); Logistics (1); Rebar layout (5); Accessibility (5); and Staging (4), see Figure 1.

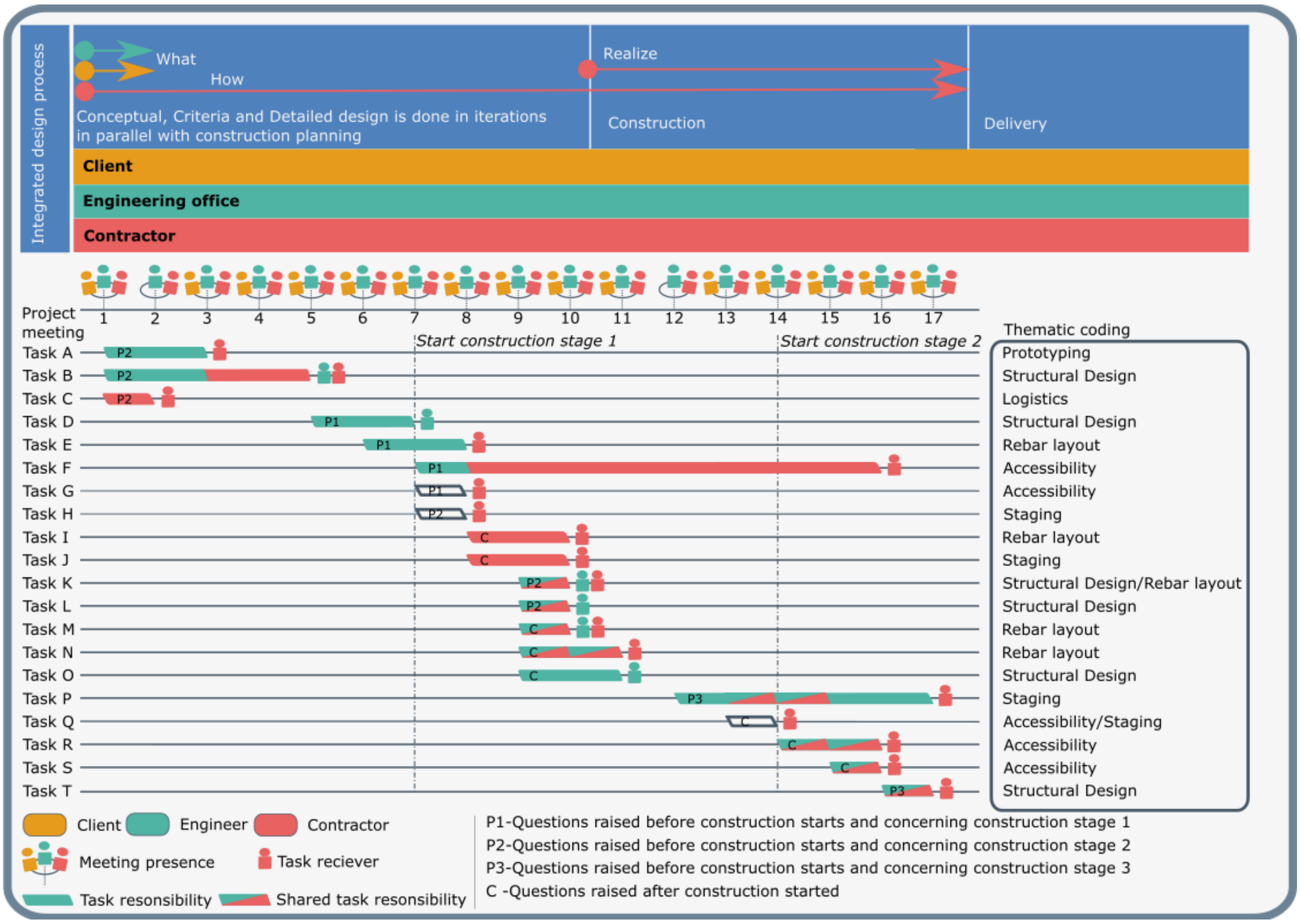

Figure 1: Final theme structure and corresponding definitions.

In the first delivery from the structural engineer, there was a design based on clear guidelines on improvements due to the initial agreement of buildability improvements. So, unlike the traditional process of D-B-B, this already contained much of the contractor's wishes regarding a design related to structural engineering constraints, which is reflected in the documents since few questions appear before start of construction stage 1, and questions that do arise mainly concerns construction stage 2. Following the dialogue, it is possible to identify questions concerning three phases to be included; construction planning, construction works, and experience from construction. Getting an efficient construction procedure is largely dependent of site conditions and what requirements have been set for the structural design. Dialogues that appear are both directly and indirectly linked to construction work. Examples of directly linked dialogues include accessibility at the construction site, or feasible and available construction methods/equipment. Examples of more indirect related dialogues are further clarification of details or adjustments in reinforcement specifications. Interestingly, the dialogue indirectly related to construction works, such as Structural Design, 5 tasks out of 6 appears ahead of construction start, contrary to dialogues directly related such as: Rebar layout; Accessibility; and Staging, in which 8 out of 14 tasks appear after start of construction.

5 Discussion

The results of this study are examined from three perspectives governed by the previously raised questions; (1) What characterizes the dialogue between the different disciplines; (2) What is the dialogue about; and (3) When in the process do questions arise? However, due to space restriction, this discussion will only deal with the first question. Figure 1 illustrates the researchers' interpretation of the documents on how the interprofessional dialogues evolved during the project. The figure clarifies some main topics that are affected during the dialogues and at what stage these topics appear. Further, it also describes the dialogues to appear in three loops originating from: (1) Initial structural design, (2) Construction -Planning/-Works/ and – Experience, (3) Updated structural design.

In most D-B-B construction projects, the possibility for any constructive dialogue between contractor and structural engineer is usually limited. For this specific case, finalized construction documents were provided to the contractor by the client due to a tight schedule. Although the construction documents were based on current codes and regulations, and assumed site conditions, the contractor saw great potential for improvements and wanted to re-design and remake the construction documents. While rethinking construction, the contractor established a clear picture of how they wanted to organize construction and could bring this input as new entry values to the new structural engineering company. In some way, there was a fairly completed "design intent" as an entry point for the contractor and the structural engineer dialogue.

The meeting documents distinguished that the interprofessional dialogue from the structural engineer to the contractor is much more difficult to identify than the opposite (Loop 1 and 3). This dialogue may be embedded within the project delivery itself and the structural engineer's dialogue is conducted through the product or service that is provided, in this case the construction documents.

Further, meeting documents revealed a high presence from all actors. All parties had the individuals needed present to be decisive at the meeting and were thus organizationally ready, which simplifies the inter-disciplinary dialogue. It is normally difficult to receive early feedback on construction documents due to staff shifting between design and construction personnel. Such shifting is a problem since late error detection or changes leads to further time-rushed revisions or re-work that further increases the risk of errors. When the structural engineer needs input concerning reinforcement layout and intended construction sequencing, these issues have normally not yet come to light for the contractor. Further, when the contractor starts to think about construction procedures, the structural engineer has moved on to other projects.

The project was initially given very limited work-site area, so discussions about the possibility of utilizing the finished constructions became a clear issue. Questions such as: When and in what order can finished constructions be backfilled to make construction procedure more efficient? How is the access to and within the construction site and availability of cranes during staging? Can cranes be placed on top of finished construction works instead of alongside? The fact that these questions about construction procedures remain, highlights these issues as largely unpredictable. Yet, the project team demonstrated a strive to constantly improve and streamline construction procedures when solving them.

6 Conclusion

This research is still ongoing and conclusions for the parts studied so far are here limited to the following:

An environment for collaborative efforts needs to be established and supported by the client. Here, allowing for a re-evaluation of the structural design and construction planning created that environment despite the short available time and the established interprofessional dialogue enabled a sound project team development.

Further, to support the interprofessional dialogue requires some form of vehicle, it is important of have something to discuss around, otherwise the dialogue tend to fail. Allowing the contractor to establish a "design intent" created that vehicle to carry the dialogue.

7 References

[1] L. E. Gadde and A. Dubois, "Partnering in the construction industry-Problems and opportunities," *J. Purch. Supply Manag.*, vol. 16, no. 4, pp. 254–263, 2010.

[2] D. Ekström, R. Rempling, and M. Plos, "Integrated project team performance in early design stages – performance indicators influencing effectiveness in bridge design," *Archit. Eng. Des. Manag.*, 2019.

[3] P. Lahdenperä, "Making sense of the multi-party

contractual arrangements of project partnering, project alliancing and integrated project delivery," *Constr. Manag. Econ.*, vol. 30, no. 1, pp. 57–79, 2012.

[4] The American Institute of Architects California Council, *Integrated Project Delivery: A Guide*. Chicago: The American Institute of Architects, 2007.

[5] C. B. Tatum, "Core Elements of Construction Engineering Knowledge for Project and Career Success," *J. Constr. Eng. Manag.*, vol. 137, no. 10, pp. 745–750, 2011.

[6] U. Flick, *An introduction to qualitative research.*, 5th ed. London: Sage Publications Ltd., 2014.

[7] S. Kvale and S. Brinkmann, *Den kvalitativa forskningsintervjun.*, 3rd ed. Lund: Studentlitteratur, 2014.

[8] U. H. Graneheim and B. Lundman, "Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness," *Nurse Educ. Today*, vol. 24, no. 2, pp. 105–112, 2004.

[9] V. N. V. Anney, "Ensuring the quality of the findings of qualitative research: looking at Trustworthiness Criteria," *J. Emerg. Trends Educ. Res. Policy Stud.*, vol. 5, no. 2, pp. 272–281, 2014.

[10] L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, "Thematic Analysis," *Int. J. Qual. Methods*, vol. 16, no. 1, pp. 1–13, Dec. 2017.