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Methodology for selection of production method in an early stage - improved conceptual design process.

Mats Karlsson

Swedish Transport Administration, Borlänge, Sweden

Chalmers University of Technology, Gothenburg, Sweden

Rasmus Rempling

Chalmers University of Technology, Gothenburg, Sweden

NCC AB, Solna, Sweden

Kent Gylltoft, Mario Plos

Chalmers University of Technology, Gothenburg, Sweden

Contact: mats.d.karlsson@trafikverket.se

Abstract

The design of buildings and load carrying structures in early stages is a challenging task for a number of reasons; scant information generally exists and several different requirements involving building structures should be managed, including technical, environmental and financial requirements. However, this phase of the design process is important and will fundamentally influence the following construction phase, as well as the entire life of building structures. It is particularly important that the construction phase be properly considered already in the design phase and that the production method selected be suitable for the design of building structures. The purpose of this research has been to improve the design process in the conceptual phase. The findings will highlight the benefits of design for production in bridge engineering. The aim has been to identify examples of practices and work methodologies that are of good caliber in the Swedish bridge construction sector. Early findings show that there exists a divergence between research findings and current practices. The research community has presented several participatory methodologies for the design process, such as Early Contractor Involvement (ECI) and Integrated Project Delivery (IPD) for the potential of improving effectiveness in bridge engineering. However, studies of current practices in industry show that these methodologies are difficult to implement and that there are hidden consequences. The processes developed should manage several requirements simultaneously, including technical, environmental, health and safety, and financial. Competencies involved include Structural Engineering, Architecture and Production Management, in addition to expertise in health and safety, materials science, environmental impact and procurement. Further, the intention is for the processes to deal with verification methods for the proposed conceptual solutions and risk analyses based on quality assurance. Both new and existing building structures should be considered.

Keywords: Early Contractor Involvement, Integrated Design Process, Integrated Project Delivery, Form of Remuneration, Public Infrastructure Projects, Bridge Design

1 Introduction

The effect of integrated working methodologies has been widely explored [1]. The researcher Tatum [2] highlights the importance of technical support activities that involve all actors in order to ensure an effective construction process. However, to expand the traditional concept of construction engineering, the activities need to include integration and innovation, as well as making pre-construction activities more prominent. Although his research early pointed out the benefits of automating design and building activities, this goal has not yet been reached [3].

The information that is communicated among actors and the possibility of integration depend on the level on which the integration is made. The researcher Moum [4] defines three hierarchical project levels in order to represent different types of social construction: macro-, meso- and micro-levels. The macro-level incorporates all participants of a construction project, Architects, Engineers, Contractors and Users. This conglomerate of stakeholders with separate interests and expectations is boiled down to a design team with the mandate to uncover the mutually beneficial expectations of stakeholders (meso-level). Finally, Moum defines the micro-level as the collaborative space between the architect and the engineer. This framework has then been applied to a number of projects in order to study their level of integration, the impact of information and communication technology (ICT) on the progress of these projects, as well as highlighting the non-technical parameters influencing integration. Moum's study focused on the micro-level and concluded that if the understanding of aims and intentions were shared within the team and the capabilities of the ICT software were substantial, the collaboration and integration of architects and engineers would make considerable progress. In addition, her results highlighted the fact that soft non-technical parameters, such as the sources of inspiration of an architect, are easily punctuated by the introduction of ICT and that these parameters must be better understood in order to attain successful implementation and use of ICT [5].

The introduction and adoption of new technologies have been proven difficult and time-consuming. According to], strategies for the adoption of new technologies are considered necessary and depend on four drivers: competitive advantage, process problems, technology opportunity and external requirements.

In conclusion, these research results highlight the fact that if routine design activities were to a higher degree automated, together with innovative tools and processes, the innovative stage might become increasingly decisive. This conclusion is important in order to reach an optimal solution to create a larger solution space, as well as narrowing the problem space early during the process (Figure 1).

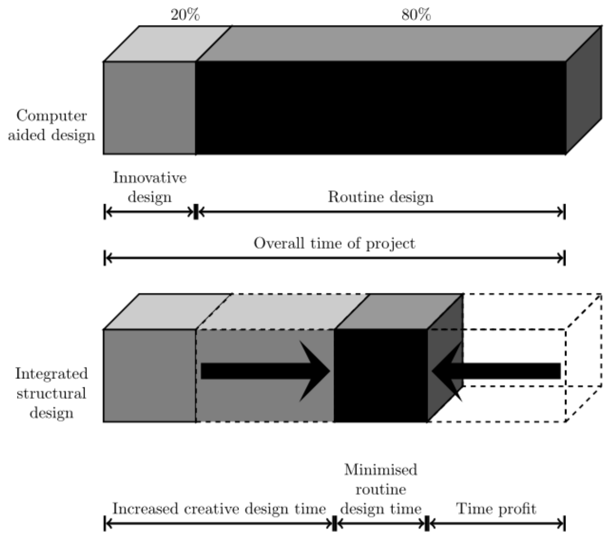

Figure 1: To gain time, all disciplines should strive for an integrated industrialized process, redrawn from [8].

The purpose of this project has been to propose a future design practice with the intent of evaluating the choice of production method at an early stage. The proposed design practice was partly based on Swedish Transport Administration experience, as well as the experience of the construction industry in general. The principal aim has been to identify the position and need for a form of remuneration in the state-of-art collaborative methodologies in current practice.

2 Participatory methodologies

Early Contractor Involvement (ECI) first emerged in England in 2001 [9]. Currently, ECI is used in several countries as a delivery system for large, complex projects with a high risk profile [10]. Research has been focusing on the procurement side of ECI and its pros and cons. It was found that if contractors can contribute their experience at an earlier stage, the constructability would be improved and more reliable cost estimates achieved [11]. In addition, the end-product would most likely result in a better solution, with innovations, greater commitment and shortened project duration becoming more achievable. The major drawback identified is the relationship between client and contractor. In the contract form, the client becomes more dependent on the contractor, with trust and transparency becoming crucial within the project organization. According to [10], this is the greatest challenge for ECI projects. Other research has been focusing on the procurement criteria, i.e. selection of contractor. At the moment, there are a number of selection criteria other than price that are key to awarding an ECI contract, including: technical knowledge, leadership, internal organization and collaboration culture [9].

Integrated Project Delivery (IPD) has been gaining increased use in the building industry, especially for large complex building projects. According to [12], IPD is defined as:

"a project delivery 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"

However, this has been difficult to achieve in practice [13] and therefore, a list of minimum requirements has been developed:

Continuous involvement of owner, key designers and builders from early design through project completion

Business interests aligned through a shared risk-reward arrangement, including financial gain at risk that is dependent upon project outcomes

Joint project control by owner, key designers and builders

A multi-party agreement or equal interlocking agreements

Limited liability among owner, key designers and builders

To further distinguish IPD from other types of project delivery schemes, four additional statements with explanations could be made:

The Integrated Project Delivery is a project method that is different from Design-Bid-Build, Design-Build, Construction Management at Risk and Multiple Prime. The purpose is that the benefits in terms of innovation and efficiency arising from cooperation in the team are brought back to the project in the first place. As a secondary effect, it gives advantages to the individual companies and organizations that are a part of the project team. All parties agree to share the financial savings for optimizing the business case of the owner in accordance with the business terms. Compared to other project delivery methods, IPD has many similarities to building alliances and partnering. In an alliance or partnership for project delivery, owner and contracted parties become jointly responsible for the main tasks of design, construction, etc. The definition of IPD provided suggests such an approach with early and continued involvement of owner, key designers and builders; business interests are aligned through risk-reward sharing and joint project control.

The Integrated Project Delivery method integrates people, systems, business structures and practices. The foundation for IPD is the development of a virtual project organization. The organization includes the individual team members of owner, designer(s), consultants and builder(s). The mission and responsibilities of the project organization are committed to "best project practise" decision-making and this commitment is supported by aligning the business interests of the firm through shared risks and rewards.

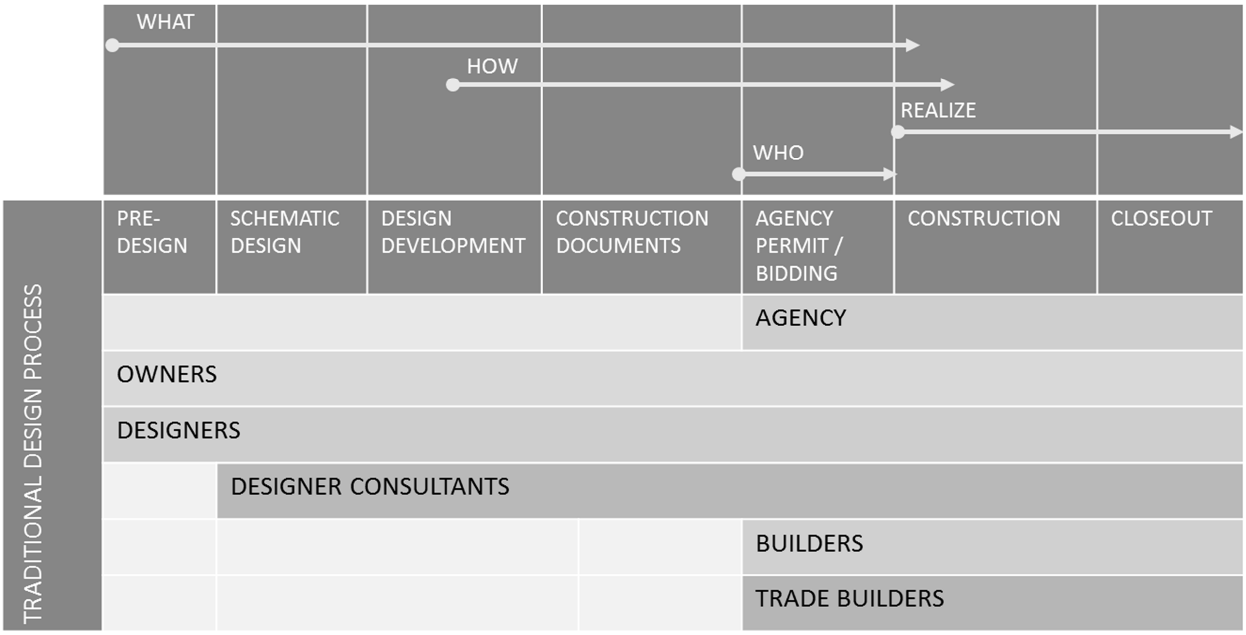

Figure 2: In the traditional design process, construction competence is introduced late in the building process and the potential for steering the design towards easy construction is missed [14].

Collaboration harnesses the talents and insights of all participants. The primary purpose of the virtual organization is collaboration. Project firms and individuals are committed to creating a team culture of joint decision-making. Team members are formally organized into multidisciplinary clusters responsive to project goals. Team members are individually accountable for contributing alternatives to design and construction issues. The input of the builder is typically not made until the construction phase, when it is typically too late to benefit project design.

The Integrated Project Delivery method reduces waste and optimizes efficiency. IPD incentivizes the minimization of waste. In addition to integration and collaboration, the method utilizes formal tools to achieve maximum results. Typical tools include: Building Information Modelling (BIM), prefabrication, manufacturing of larger integrated units, process improvement metrics and LEAN design and construction techniques.

3 Current practice

Even though different collaborative design processes are promoted by researchers and early adopters, current practices in the design of construction and especially infrastructure revolve around the traditional design process. Our definition of this process is presented in Figure 2. In the traditional design process, the initial project team outlines the design concept based on client needs.

Despite some relevant innovations introduced in recent years – as well as the development of BIM, the strengthening of communication tools between players and stakeholders, the dissemination of concurrent design methodologies – gaps and weaknesses still jeopardize the possibility for project teams to be proactive and effective.

In particular, in the initial phases of the design process, gaps and weaknesses depend among others on the following factors [14]:

- a limited availability of tools, information and data for supporting the assessment of the cost efficiency related issues;
- poor and limited cooperation between players due to the fact that technical information and tools are not readily accessible nor consistently provided to the different stakeholders (client, users, professionals and advisors);
- the habit of several players to work on a prematurely detailed design, thereby limiting their cooperation and technical contribution during the conceptual design stage;

- lack of tools and data to evaluate the relationships between the technical/functional/architectural choices and the consequences related to Quality and Cost.

4 Future practice

This proposal for future design practices with the intent of early evaluating the choice of production method is based partly on the experience of the Swedish Transport Administration, but also of the construction industry in general.

This paper describes how further steps can be taken in the application of IPD as a method for achieving more effective project management of Infrastructure projects.

Some focus areas that should be highlighted in particular to achieve this are the following:

- Form of Contract
- Organization
- Staffing
- Conceptual form
- Requirements

This study has not considered any contractual forms where the partners jointly find financial solutions but have assumed that the payment is made by the client in full.

4.1 Form of Contract

The contractual forms in this proposal are basically Design-Build contracts with some additions and adjustments; contracts are divided into two phases and the price and form of remuneration are jointly determined at a gate between Phase 1 and 2 (see Figure 3).

Briefly, these additions and adjustments can be described as follows.

- The project starts with Phase 1 in which the partners work out a joint solution based on the objectives to be achieved. These requirements may include structural and production engineering, as well as health and safety and environmental impact. Phase 1 concludes with a calculated price based on a jointly developed technical solution.
- Phase 2 consists of a Client and Contractor agreement in the form of a performance contract to execute the project on the basis of the joint work performed during Phase 1. During this phase, the technical

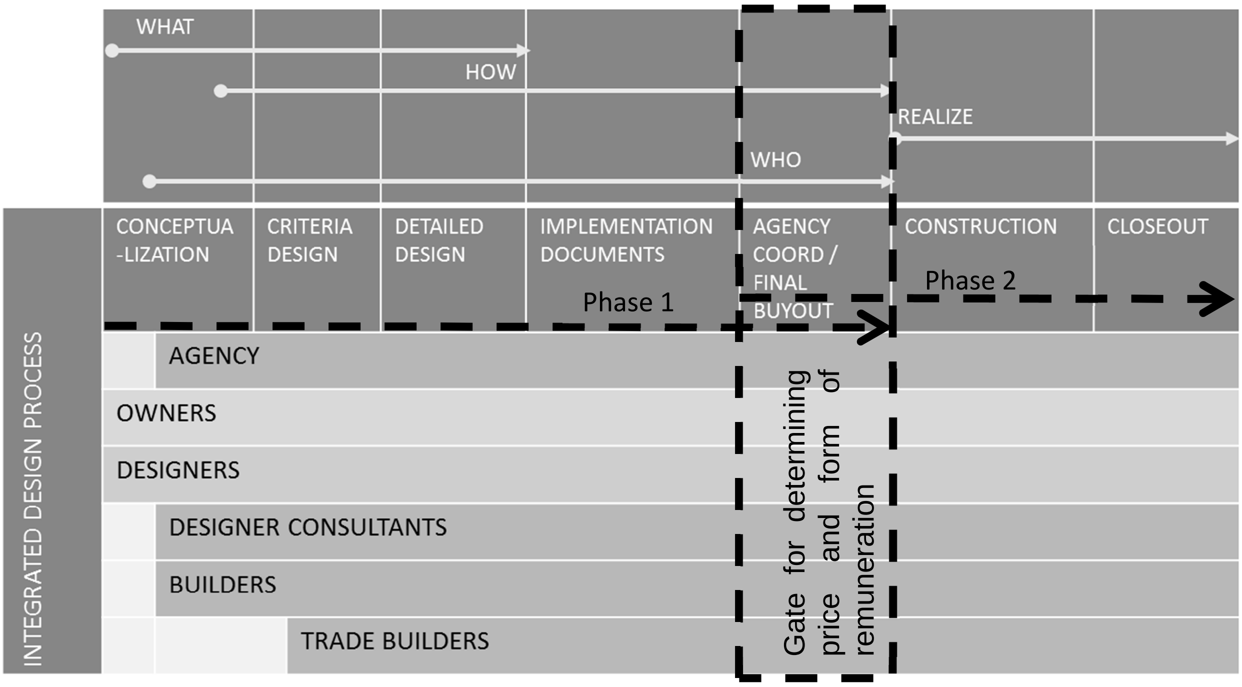

Figure 3: Illustration of Integrated project delivery with price and form of remuneration gate included in the process [14].

solution based on the objective is worked out in a more detailed way. Improvements that emerge during the work leading to lower costs should preferably be divided between partners. A form of remuneration which favors such sharing of cost savings is an advantage.

Compared with a traditional way to manage projects this form of contract means the following difference:

- More work and analysis is put in in the early conceptual phase, where the potential of impact regarding design, performance, cost of the project is the greatest
- Phase 1 is conducted in close cooperation with the three parties placed in a joint project office
- Staffing in phase 1 is done by persons with long and extensive experience and knowledge. See 4.3
- It is possible to cancel the project after phase 1 if the cooperation is not working or the project´s goals will not be met. This without that any contractual problems arises.

4.2 Organization

The project organization involves three parties:

The Client has the ultimate responsibility for project completion and for transferring the project to operational management. In addition, the Client is responsible for setting the objectives and adapting the project to existing infrastructure managed by the Client in order to achieve an effective operation and maintenance organization.

- Consultants and designers perform the general design on an overall level and thereby ensure that demands and requirements are met in general.
- The Contractor carries out the developed design and thereby ensures that the demands and requirements will be achieved in detail. Furthermore, the contractor is responsible for the production and execution of the project.

It is beneficial to have a joint project organization consisting of all three parties and that at least the management of the project be placed in a joint project office. This is especially important during phase 1.

4.3 Staffing

The basis for manning a bridge and infrastructure project in the areas of structural and production engineering is the level of expertise. These two competencies are not conclusive. In addition, there is need for expertise in such different areas as environmental impact, health and safety and cost estimation.

In order to get employees with both the right professional profile as well as the right personal qualities to work in a team in this way, it is important that recruitment and selection take place in a precise way.

In order to get employees with both the right professional profile as well as the right personal qualities to work in a team in this way, it is important that recruitment and selection take place in a precise way. Verification of professional skills should therefore be supplemented with interviews or similar to ensure the ability collaborate and work in team.

The team members should be “T-shaped people”. This means that the professional profile should be characterized by “Breadth” and “Depth”. The term “Breadth” means keywords likes interests and understanding and the term “Depth” means keywords likes knowledge and understanding.

The advantage of the approach described in this paper is that the three parties work together in order to carry out a specific task on the basis of who has the best knowledge and experience in the project organization as a whole.

This approach in turn means that the decision about who should carry out a particular task is selected on the basis of competence and therefore the choice might be made later in the process depending on the type of issue.

4.4 Conceptual phase

The conceptual phase is a significant element of the initial part of the contract. It comprises among others the following elements:

- Development of goals and objectives on the basis of the terms of the contract. Goals should relate to both the process and end-product.
- Identification of risks related to the project.
- Conduct a risk analysis with respect to the risks that have been identified.
- Brainstorming to get the best solution in terms of both product and process. This brainstorming session starts from objectives and goals and all three partners contribute their expertise in the best way possible.

4.5 Requirements

Client requirements specification in terms of both technical as well as other aspects is based on project terms. These terms may range from overall functional requirements to detailed criteria depending on the type of project and its restrictions.

In order to achieve a conceptual phase that leads to innovation and efficiency, it is an advantage if the Client´s requirements are based on functional requirements as far as possible.

The above does not affect the applicability of the method. However, it is important that the client requirements are as explicit as possible in the beginning of the conceptual phase.

5 Conclusions

This study was conducted in collaboration with industry, the public sector and academia. The state-of-the-art methodologies for collaborative project delivery have been reviewed. The aim of this study has been to formulate a methodology as a practical guide for implementing the reviewed methodologies.

The benefits of collaborative project delivery in the form of Early Contractor Involvement and Integrated Project Delivery have been identified, assessed and adapted to Swedish public infrastructure requirements. In the literature, the case is made for a more collaborative building process. The argumentation starts with the limitations of the traditional design process – in which the initial project team outlines the concept of the design based on client needs – leading to a cost-inefficient construction process. In addition, it is argued that the information transfer mechanism between design and production lacks some essential components.

The benefits and methodologies have been identified and assessed in the building sector, but is lagging behind in the public infrastructure sector. This slow and deficient development gave the impetus for this study. By assessing the Early Contractor Involvement and Integrated Project Delivery in practice, a two-phase process was developed. Five different aspects of the conceptual design process have been addressed in order to present a framework for a practical collaborative project delivery method in Sweden:

Form of Contract: The proposed form of contract is basically a Design-Build contract with some additions and adjustments.

Organization: The organization should at a minimum include the client, design office and contractor.

Staffing: Expertise in the areas of structural and production engineering, as well as expertise in such areas as environmental impact, health and safety and cost estimation is necessary.

Conceptual Phase: A basis for design should be developed with regard to design for production.

Requirements: Client requirements in terms of both technical as well as other aspects are dependent on project terms and conditions.

6 Acknowledgements

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knowledge dissemination and management, as well as technology development and collaboration for better rules and fewer misunderstandings in the construction industry.

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