Integrated project teams in early design stages - Key variables influencing cost effectiveness in bridge building

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Abstract

The construction industry is usually regarded as a complex, multidisciplinary and project focused environment. It is also regularly identified as a one-of-a-kind nature, hence focus is on the uniqueness of projects rather than in similarities. The results presented in this article are based on questionnaire addressed to clients, contractors, and designers, mainly active within the Swedish infrastructure sector. The purpose is to highlight key-variables influencing cost effectiveness for the organization of integrated project teams, designing of projects, and construction at site. The results indicate that more attention needs to be paid to the actual project setting if to fully gain the benefits from integrated project teams. Further, the results indicates that it is mainly project culture; collaboration and social relationships, and project competence, the ability to solve mutual issues, that needs to be developed.

Keywords: IPT, bridge design, project performance, integrated design.

1 Introduction

The lack of productivity in the construction industry comes out off several different areas/factors. E.g. owners have not been focusing on productivity and quality when procuring, more focus has been on standard compliance [1], contractors most often miss the important step of experience feedback, resulting in making the same mistakes in many repeating projects, also within the industry focus is on projects rather than processes, making the inefficiencies of design and construction left un challenged [2]. Moreover, owners have come to accept industry pricing, which responds to market place forces, and hence, further cements the low productivity. Contradictory, manufacturing activities becomes cheaper and cheaper over time [1].

Long term relationship within project teams including experience feedback over time is scarce today. In the project setting there are several interfaces where experience feedback and knowledge transformation is possible and a very important step in order to create cost-effectiveness over time. Nevertheless, this is seldom or never utilized systematically, e.g. [3]. How to benefit from an increased collaboration between companies during long term relationships has been a discussion in literature for long e.g. [4].Despite the

vast amount of research findings indicating the potential benefits of a high degree of multidisciplinary involvement in early stages of design very little has been adopted within projects in the Swedish construction industry so far. The intention of early stage involvement, by adopting an integrated design approach and establishing integrated project teams (IPT), is to facilitate the configuration of an end-product by a design based on well substantiated and reasoned decisions. By including clients, contractors, designers and material suppliers, these teams could support improved cost effectiveness and productivity improvements.

The objective of this study was to identify areas of improvement in terms of generating effectiveness within Swedish bridge design teams. Assessing the construction sector and generating a general view regarding collaboration and communication in the prevailing way of work, and giving an indication of where to address the main efforts. To do so, the following research questions were initially formulated.

- What are the organizational hindrances and facilitators for the support of IPT within project-settings?
- Which aspects of collaboration on project-team level enables IPT?
- How are the personal traits and values important for the individual support of the IPT?

Based on these questions a framework was developed from previous research in order to formulate a questionnaire. In the section below follows a review of the underlying literature.

2 Literature

2.1 Integrated design and construction

Most often integration is used to narrate construction methods, working practices and behaviours that make up the culture of efficient and effective teamwork by organisations and individuals in construction [5].

The construction industry is by tradition exposed to extreme fragmentation within its stages and a relational short-term perspective. The process of construction can be viewed as an arena for collaboration between numerous of suppliers all from early design stages up until completion of construction. This is a process not owned by anyone, progress is achieved by involved participant by continuous negotiations: These negotiations are predominantly done with each individual product at focus, not project success. The process itself looks more incidental, but none the less, this is the process which determine the key outcome [6].

Waste in construction is mainly identified to occur in the interaction between different trades. This is also in general related to the self-interest of different parties which makes them put themselves first [1]. Due to this fact, the integration of different trades in the construction industry has been in focus within research for several years in order to generate a more effective process [6,7] and also a prioritised area within a productivity program launched by Trafikverket, the Swedish Transportation Administration. In any organization, whether it is a client organization, a design company, contractor, materials manufacturer, or any other organization, in order to reduce waste, it is crucial to gradually change attitudes and behaviours in their organization. Only then the customer requirements may be fully met [8].

2.2 Teams in construction

When discussing integrated projects, it is generally the contract or the way of procurement that is at the primary focus, e.g. Partnering or Integrated Project Delivery, but this is usually not enough. While contracts act as a stabilizer and formalizing the patterns between client and its suppliers, findings in [9] indicates that there also is a need to change the relational patterns in order to move from fragmented to integrated design. Problems with project performance of integrated design teams are in general related to the context and not the process itself, i.e. they are not technical but socio-cognitive [9]–[11].

Activities on a construction site are performed by persons with different skills belonging to different companies in temporary organisations. These actors need to share information and knowledge

for optimum decisions. Management of these activities performed by the individuals and groups of individuals within the organisation are coordinated to ensure a value flow, hence an organised flow in the work schedule. Baiden [5] asserts that teamwork is not an option but a prerequisite for a successful delivery of a construction project. Efficiency for effectiveness within the team in a construction project is consequently necessary and needs to always improve.

2.3 Framework

To examine how the collaboration between different disciplines work during the development of construction documents for new bridges in Sweden, a framework was established, Figure 1. The framework was based on previous research, see following sections, and designed in order to evaluate prevailing attitudes and identify possible opportunities and obstacles for more integrated cooperation between different disciplines.

The framework was developed by combining a vertical and a horizontal dimension to form a matrix-analysis. The matrix then enables to identify 9 different areas of measurement in the crossings between the vertical and horizontal dimension.

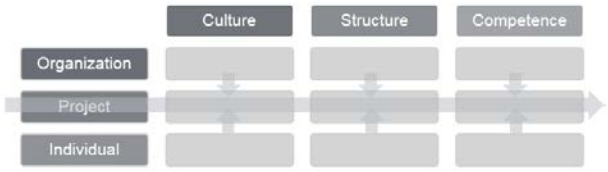

Figure 1: Survey evaluation matrix

2.3.1 Horizontal dimension– driving forces to customer value

In [8], Josephson & Björkman suggested that a holistic view is needed in order to minimize waste and generate high customer value. This recommendation is derived from a study conducted in the Swedish construction industry. In the study the authors formed several discussion groups consisting of a number of experienced people in order to list root causes of waste. The results showed that waste is a complex system of several causes, ultimately categorised by the authors under five main groups of factors that are characteristic for effective operations: holistic view, culture, structure, competence and leadership. To visualise this, the holistic view is organized as the top of a pyramid supported by four cornerstones consisting culture, structure, competence and leadership. The four corners are regarded of equal importance. If any of the corners, acting as the driving forces in minimising waste, are neglected the pyramid will be skewed and the full potential not obtained.

2.3.2 Vertical dimension – organizational hierarchy

Many different authors have clearly indicated the importance of an information flow through the organizational hierarchy, e.g. [8], [12], [13].

In a study of the interaction between the architect and engineer [13] a framework is presented consisting of three hierarchical project levels: macro-, meso- and micro-level in order to represent different social constructions in construction. The intention of the framework is to study the level of integration, the impact of information and communication technology (ICT) within project settings, as well as highlighting the non-technical parameters influencing the integration. The framework gives an indication of the complex relations between project participants even within a minor project and how a design team is influenced by many outer parameters outside the team's control and on many different organisational levels.

A similar concept is presented in [12] which they call organisational shells. The model is presented from a leadership perspective and describes the dependency between the team and its surroundings in different layers of circles with the team at work as the core. The team is in critical need for information and input from the surroundings to perform. For a team to work effectively, information regarding four variables needs to be in place, such as task, norms, boundaries and authority. The content of these variables are common to the four driving forces described by [8] for reducing waste.

2.3.3 Team characteristics

There are multiple authors and theories in the field of team formation and its performance [14]–[16].

For this study, questions were developed based on a self-assessment questionnaires [14]. This type of questionnaires are commonly used in team literature as indicators to provide aid to identify how to become high performance teams (HPT). In several models, categories similar to those identified in [8] could be found. Questions are organised into the three different levels of concepts: organisation, project and individual and to the corresponding variable: culture, structure and competence.

At this stage in the research, the variable of leadership was deliberately left out. The importance of the leadership for the success of a team cannot be stressed enough, which is also reflected in the vast amount of research done in that particular area. This importance is also recently highlighted in a Swedish study [17]. For that reason, this aspect was left out of this study.

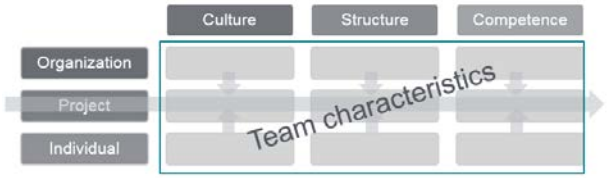

Figure 2: Questionnaire based on team characteristics.

3 Method

A survey was conducted where respondents were presented to several statements. The survey consisted in total of 3 parts, each part given 15 statements about the respondents work. The respondents were asked to answer to what extent the statement agreed with their way of working and to what extent this was important for the level of project success. At each statement the respondent were given the opportunity to add additional text to support their answers.

The respondents were also given a short, text based introductory to the aim and scope of the survey and in order to get coherency amongst the respondents they were presented to a target case which they were asked to relate their responses to.

3.1 Target case

As a result from one of their productivity initiatives, Trafikverket, the Swedish Transport Administration has identified several product categories that are considered particularly suitable for industrial and serial construction [18]. One of these product categories consist of bridges that are considered particularly suitable for industrial and serial construction. These bridges are generally characterized by smaller bridges with a span length less than 20 m, low geometrical complexity, and that they have a limited skewness. This category of bridges is the most commonly built in Sweden and the scope for this survey is therefore limited to that product category.

3.2 Respondents

The survey was administrated to clients, contractors, designers and (material suppliers) in the Swedish construction industry. The survey was distributed electronically and in total, 139 people fully completed the survey. Besides the major client, Trafikverket, the respondents represented some of the largest construction and consultancy firms in Sweden. Of the 139 survey respondents there were 20 representing the client, 53 a contractor and 63 a consultant. The majority of the respondents were working in either detailed design (52) or in the construction stage (51) and the work is in general performed in relation to a design-bid-build contract (66) or a design-build contract (49). Approximately 50 % of the respondents (69) had an experience in the industry for 16 years or more. 85 of the respondent answered that they had some sort of leading position whereas 32 had the responsibility for 16 people or more.

3.3 Survey analysis

The survey responses are analysed by using Likert scaling [19]. The survey is made in order to capture people's opinion of several statements and by adopting a Likert scale to the responses it is possible to generate a numerical value to something actually being a subjective opinion. The questions are ranged from 1 to 5, whereas 5 represents a high degree of conformity. Scoring high in the evaluation is indicating a highly mature

group setting, a so called high performance team [14].

Five questions (items) are asked within every area leaving the range of score in each block (indicator) between 5-25, and the total score for each level (concept) in the range of 15-75. In the analysis it is then possible to generate a mean value for each indicator leaving the final total score for each concept in a range of 5-15. By using this kind of multiple-item scale it is more likely that the generated response gives a broader view of the concept measured, makes it possible to draw finer distinctions between the different indicators and also minimize the error from questions being misunderstood [19].

For this article the framework has been utilised to identify where the largest gaps between the perceived *potential benefits* of working in integrated project teams and the advantages that normally are realized in practice in the Swedish bridge construction today A similar approach is adopted in [20] in order to evaluate the effectiveness of applying constructability principles in the Canadian construction industry.

4 Results

The scientific framework applied generated three units of analysis: organization, project and individual, with three corresponding attributes: culture, structure and competence as described previously in 2.3. The results was treated and analysed within each of the 3 levels and its 3 attributes which corresponds to the 9 cells of the evaluation matrix in Figure 1. From the individual responses, the mean values and standard deviation around the means were calculated for each of the 9 blocks, and is presented in Table 1. The gaps between the potential and realised benefits from utilising a team approach in project settings are also calculated.

Table 1: Overall summary of survey results (mean values)

	Culture	Std	Structure	Std	Competence	Std	TOTAL
Organisation							
- Realized benefit	3,82	0,601	3,69	0,630	3,64	0,730	**11,14**
-Potential benefit	4,32	0,467	4,29	0,524	4,12	0,693	**12,73**
-Gap	0,50		0,60		0,48		
Project team							
-Realized benefit	3,38	0,717	3,75	0,597	3,53	0,611	**10,65**
-Potential benefit	4,08	0,619	4,25	0,614	4,13	0,614	**12,46**
-Gap	0,70		0,50		0,61		
Individual							
-Realized benefit	3,91	0,535	3,68	0,702	4,16	0,556	**11,75**
-Potential benefit	4,15	0,604	4,19	0,595	4,31	0,576	**12,65**
-Gap	0,24		0,50		0,16		

Std = Standard deviation

5 Discussion

In the following sections analysis for each of the *potential benefit*, *realized benefit* and corresponding *gaps* is made.

5.1 Analysis of areas of importance *(potential benefit)*

On the overall level, in Table 1, there is a very small difference between the total scores for the different levels which indicates that the three levels: organisation, project team and individual, are valued equally important by the respondents. The score ranged from 83%-85% of the total where

the organizational level was the level with the highest score for *potential benefit*, 12,73 out of 15.

Looking at the different *areas of measurement,* the mean values, as can be seen in Table 1, for the *potential benefit* varies within a fairly high range from 4,08 -. 4, 32. The areas which is indicated by the survey respondent to be the 3 most important for project success are the following:

- *Organizational culture*
- *Individual competence*
- *Organizational structure*

5.2 Analysis of prevailing way of work (realised benefit)

For the realised benefits, in contrast to the *potential benefits*, there is a larger spread in the total score ranging from a low of 71% to a high of 78%. Here the organisational level generated the highest total score with 12,73 out of 15, whereas project team level was marked with the lowest "level of satisfaction" amongst the respondents leaving the individual contribution in the middle. The *realised benefits* generated on an overall level lower values and also with a wider range compared to the *potential benefits*. In Table 1 the mean values for *realized benefit* varies within a range from 3,38 -. 4.16. The 3 areas here indicated to be working best today are:

- *Individual competence*
- *Individual culture*
- *Organizational culture*

5.3 Gap analysis (potential of improvement)

The most interesting analysis at this stage, and maybe the analysis exposed to the minimum amount errors, is the gap analysis. The calculated gap between the perceived level of how we are performing today and the importance of that same action can be interpreted as a measurement of the potential of improvement. To be able to look at the different areas of measurement and also compare them, the relative importance of each attribute needs to be accounted for. The calculated gap in Table 1 was therefore weighted with the level of importance for each attribute to generate the weighted results seen in Table 2.

Table 2: Weighted summary of survey results (mean values)

	Culture	Std	Structure	Std	Competence	Std	TOTAL
Organisation							
- Realized benefit	3,82	0,601	3,69	0,630	3,64	0,730	**11,14**
-Potential benefit	4,32	0,467	4,29	0,524	4,12	0,693	**12,73**
-Gap	0,44		0,51		0,40		
Project team							
-Realized benefit	3,38	0,717	3,75	0,597	3,53	0,611	**10,65**
-Potential benefit	4,08	0,619	4,25	0,614	4,13	0,614	**12,46**
-Gap	0,57		0,43		0,50		
Individual							
-Realized benefit	3,91	0,535	3,68	0,702	4,16	0,556	**11,75**
-Potential benefit	4,15	0,604	4,19	0,595	4,31	0,576	**12,65**
-Gap	0,19		0,42		0,14		

Std = Standard deviation

The weighted gap is calculated through multiplication of the ratio between the mean value from *potential benefit* and the maximum score of 5. For example the calculated gap for project culture is obtained by $0{,}70 * 4{,}08/5 = 0{,}57$

Table 2 shows that for the organisational and project team level the variation in mean values varies between 0,40-0,51 and 0,43-0,57 respectively. For the individual level the variation is much larger and varies between 0,14-0,42.

The largest gaps, and thereby also areas identified with the largest potential for improvement are according to Table 2 are as follows:

- *Project team culture*
- *Organisational structure*
- *Project team competence*

The largest potential for improvement perceived by the respondents is therefore identified to be within the project team settings. Looking on the total score, this perception is mirrored as the concept of project team received the lowest total score of the three levels.

In the project team section of the questionnaire, the statements are targeted at communication, goal statement and goal perception, collaboration, team composition etc. in order to evaluate how well the general project team are developed. The results presented supports, in large, the findings found in the studied literature presented in chapter 2 and indicating that the construction industry still is struggling to get the most out of their project teams.

To develop a well-functioning team is well known to require both time and effort. But to what maturity level are the general Swedish bridge design team allowed to reach with the prevailing conditions? Are we constantly in the initial stages of level 1 or 2 [14]? Do we ever get past the ”storming” part, see [15], in the projects? Regardless, the construction industry is of a multi-disciplinary nature and within the projects the team developing processes will be present. This is completely natural and instead of offering resistance to it, these stages can be embraced to generate clarity of the behaviour of the project teams. When evaluating project performance the team’s performance and the corresponding process is rarely included and therefore “how” things are done are usually left unmeasured. The risk is that lack of performance is mistakenly blamed on the leader, specific individual’s etc. while instead being related to group or team issues. In psychology this is referred to as a “fundamental attributional error” [14]. An analogy used in [12] this would be a doctor who diagnose the symptom of an infection but who then treats the symptom rather than attacking the underlying cause. Using root cause analysis, such as e.g. five whys, is a fundamental technique used in lean practices, see e.g.[1].

When considering construction as an activity, both the inputs and outputs generally are physical entities. In structural design, the input may be knowledge as for team design, the inputs are in general considering human and psychological factors [11], [12], all from the individual to the environmental level. The different levels cannot be overlooked or neglected The literature is repeatedly stating, that getting the “right people” is one of the most critical issues when constituting a project team, e.g. [21]–[23]. Individuals are appointed as a key-factor and that it requires a lot from both the individual team member and the surrounding organisation in order to generate the expected outcome [12]. As an inadequate process still can generate successful outcomes it is important to measure both the process and its outcome, and at all levels. As both culture and competence are attributes which are closely related to an individual’s personal traits and values it strengthens the view that the levels should not be separated and that all needs to be monitored. The root of the problem may very well be already at the inputs.

6 Summary and conclusion

Based on the findings in this study, the authors opinion is that to generate the most significant gains from the application of IPT in the Swedish construction industry efforts need to be appointed to the following areas where the largest gaps exists between potential and realized benefits.

- *Project culture*
- *Organisational structure*
- *Project competence*

Even though the greatest potential for improvement were found at the project team level, as a final remark, the individual contribution and the organisational support to the project team’s performance cannot be overlooked or neglected. Reliable measurements is needed an all levels in order to sufficiently capture the true project performance and in order to fully benefit from the project team.

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