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RESEARCH ARTICLE

The Relation between Pre-planning, Commissioning and Enhanced Project Performance

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Abstract

Pre-planning of construction projects is important for the performance of cost, time, and quality. However, recent research finds that quality related to final testing, adjustment, and balancing of HVAC systems are often overlooked due to deadline pressure. Consequently, this results in poor energy performance and dissatisfied end-users. The purpose of this study is to investigate the relationship between pre-planning, commissioning, and project performance. A publicly funded project with a compressed construction period was followed as a case study. During the case study, passive observation, semi-constructed interviews, and questionnaires were applied. This study showed that by implementing commissioning, project pre-planning and organizational support is increased. Moreover, the commissioning process creates awareness and fosters proactivity between the project participants, thus complications are discovered and handled earlier. By improved pre-planning and organizational support, and increasing proactivity, the project's cost, time and quality performance is improved. This underlines the importance of prioritizing pre-planning. Moreover, increased energy and technical demands increase project complexity which makes project success even more dependent on the quality of the plans.

Keywords

Construction management, pre-planning, commissioning, project performance.

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Introduction

Planning is crucial. Although a good plan does not necessarily result in a successful outcome (Zwikael and Globerson, 2004), having no plan at all will guarantee failure (Dvir, Raz and Shenhar, 2003). Planning is thus a management tool that, by carefully considering the project, its obstacles and processes, increases the likelihood of success. By being prepared, project managers can be proactive instead of troubleshooting problems reactively as they arise in the project (Hanna and Skiffington, 2010). The quality of planning is of course important; unrealistic plans have a negative impact on productivity and quality (Park et al., 2010). Moreover, having a competent and experienced construction manager to handle complications is vital to secure productivity, project quality, and project success (Ahadzie, Proverbs and Olomolaiye, 2008; Sun and Meng, 2009).

Research focus is emphasized on pre-planning which is the initial planning that takes place before the contracting begins. Several studies have demonstrated that project success is dependent on the planning level and effort invested at the start up and the design phases (Chang, Shen and Ibbs, 2010; Yang and Wei, 2010). Furthermore, Gibson Jr. et al. (2006) find that a linear relationship between the level of project performance and pre-planning exists. Zwikael et al. (2014) find that pre-planning efforts should be adjusted to a project's specific risks where high-risk projects needs more pre-planning.

In technical projects commissioning is used to ensure that the building fulfils the owner's requirements. The commissioning process focusses on securing technical requirements through all project phases, instead of the traditional method of only focussing on performance related perspectives such as scheduling and budgeting (Elzarka, 2009). Therefore, by having a focus on commissioning, the likelihood of the project fulfilling contractual expectations, increases (Dasher, Potter and Stum (2004). Because the technical requirements for buildings increase, the importance of a successful commissioning increases (Kibert (2012); Pulaski, Horman and Riley (2006). Reference to the literature indicates there is an untapped potential in studying how commissioning affects pre-planning and the time, cost and quality performance. This study considers this gap in the literature.

Literature Review

PRE-PLANNING

Zwikael and Globerson (2004) refined the academic debate by the development of a project management planning quality model (PMPQ). The PMPQ model is divided into two main categories: Pre-planning and Organizational support. The pre-planning category contains nine subcategories such as integration, scope, time, cost, quality, human resources, communication, risk and procurement. The organizational support category contains four supporting areas such as organizational systems, organization culture and styles, organizational structure, and project office. Johansen and Wilson (2006) did find that the largest obstacle for successful pre-planning is the diverse approach between those planning the first plans and those finally executing it.

Gibson Jr. et al. (2006) define project pre-planning as "the process encompassing all tasks between project initiation and the beginning of detailed design". In a case study of a complex industrial construction they find that there is a significant relationship between the effort invested in project pre-planning and final project outcome by improved user satisfaction, cost and time performance.

Hanna and Skiffington (2010) studied mechanical and HVAC enterprises. They find that contractors applying pre-planning have a mean profit margin at 23%, where poorly planned projects were found to have mean "profit" margins at-3%.

COMMISSIONING

Commissioning was first applied in the construction industry in the 1980s and was prior to that applied by industrial engineers in the US navy to fine-tune processes and to test new equipment and vessels (McFarlane, 2013b). The concept of commissioning has however received an increased relevance due to governments requiring improved energy performance of buildings. The commissioning process applied in the construction industry is defined by ASHRAE (2005) as "a quality orientated process for achieving, verifying, and documenting that the performance of a buildings facilities, systems, and assemblies meets defined objectives and criteria". Tseng (2005) state, commissioning firstly is a process-oriented concept, secondly, a process with a focus on quality, and thirdly, a process with focus on performance. Wolpert and Bowman (2006) investigated the effects of commissioning and found that it reduces utility costs, maintenance costs, reparations and replacements, and that it improves the productivity of the staff facilitating the HVAC system, and user satisfaction.

McFarlane (2014a), argues that commissioning should be an integrated part of all project phases such as planning, design, construction, and the post-occupancy stage, to increase the level of project success. This argumentation is based on the premise that buildings requiring advanced HVAC mechanical systems to increase energy efficiency are more complex than the planned architecture (McFarlane, 2014a). Enck (2010), finds that the longer the partners postpone defining goals and owner requirements (OPR), the costlier the project becomes. The predesign phase of a commissioned project is thus vital since the owners' ability to influence a project is largest and least expensive in the project beginning (Pulaski, Horman and Riley, 2006). Therefore, the owners have a central role and responsibility in preparing the OPR document and in being a key player within the process (McFarlane, 2013a). However, the final testing, adjusting, and balancing (TAB) process of HVAC and mechanical systems is mostly overlooked because of time limitations (McFarlane, 2013b). To implement commissioning, two industry accepted approaches are applied: process commissioning and technical commissioning (McFarlane, 2013b).

Process commissioning applies observations, review, inspection, and testing processes to secure the quality. The project affiliate designer, engineer, and contractor are operating as technical experts and are required to undertake several tests pointed out by the commissioning authority (CxA). This approach is criticized by McFarlane (2014b) since HVAC and mechanical systems are unique and need to fit the specific systems.

PROJECT SUCCESS

The concept of project success seems at first quite simple since a successful project is a project executed according to requirements and with owner satisfaction. Long et al. (2004) propose a performance-oriented definition of successful projects: Where success is a project completed within contract agreed deadline, budget, fulfilled requirement, and with customer satisfaction. Murphy, Baker and Fisher (1974) found by applying multiple regression analysis, that the concept of project success was dependent on seven elements: (1) coordination and relations, (2) adequacy of project structure and control, (3) project uniqueness, importance and public exposure, (4) success criteria clarity and consensus, (5) competitive and budgetary pressure, (6)

initial over-optimism and conceptual difficulty and finally (7) internal capabilities build-up. Ashley, Lurie and Jaselskis (1987) later found six elements as vital for establishing the final level of project success in the construction sector: (1) level of planning effort, (2) level of project team motivation, (3) construction project manager goal commitment, (4) project scope and work definition, (5) control systems and finally (6) construction project manager technical capabilities.

Freeman and Beale (1992) conducted a literature review and found across 14 international research papers seven performance measures which defined project success such as (1) technical performance, (2) efficiency of project execution, (3) managerial and organizational expectations, (4) personal growth, (5) project termination, (6) technical innovativeness and finally (7) manufacturability and business performance. Nevertheless Griffith et al. (1999) note that a successful project for one stakeholder can be a failure for another. Liu and Walker (1998) argue project success is like quality, and for that reason, complex to define due to diverse views and project requirements.

Research Method

Case study research is, according to Fellows and Liu (2009), an in-depth investigation of a studied phenomenon. The purpose of a case study as a single case is that it leads the researcher to see new theoretical relationships and testing old ones (Dyer and Wilkins, 1991). This is further supported by Flyvbjerg (2006), who argued that findings conducted from a single case study can be generalized if the study is carefully selected. Yin (1993) states, case studies following a well-planned research procedure are of higher quality than case studies using a flexible research approach. Therefore, an explanatory single case study is applied for this research.

The studied construction project is a two-story office building with a budget-sum of US$16,400,000 and a construction duration of 275 days. The project is organized as a turnkey contract with a subcontractor whose responsibilities are heat, ventilation, air conditioning, plumbing, power and data installation. The complexity of the architecture and structural design is low, but the complexity of the technical systems is high. To ensure contract requirements are fulfilled, a final test of all the functional systems is required. The turnkey contractor has therefore applied commissioning to the comfort systems and has planned a two-month period up to the final deadline to test the performance of the technical systems. The owner is the Danish public construction agency, one of the largest developers and property owners within the Danish sector. The selected case is particularly interesting because it is the first time the agency requires a functional performance test due to a high level of complexity. The findings from this high complexity case can, according to Smith and Stupak (1994), be generalized to less complex projects.

Data was gathered by observing and interviewing stakeholders within the case as well as collecting documentary material (Walker and Shen, 2002; Yin, 1994). Interviews were conducted as semi-structured (see Table 1) with open questions, supported with sub-questions (Dexter, 2006; Ritchie, Burns and Palmer, 2005). To secure the quality of the interviews and to reduce the task of transcription, the interviews were planned as 45-minute sessions (Bryman, 2004). Interviews were documented by audio recording or jotted notes (Have, 2004). To capture social cues or differences within interviewee body language or voice, all interviews were conducted face-to-face. Opdenakker (2006) argues that face-to-face interviews have the advantage that the interviewee has reduced time for reflection and is stimulated to answer instantly. This approach gives the interviewer the challenge to conduct the interview in a good ambience to maximize data outcome (Wengraf, 2001). To create trust and confidence between

researcher and interviewee prior to the interview session, the researcher was communicating with interviewee and participated in meetings (Oakley, 2003). The interviewees all had an educational background within civil engineering.

Table 1 Interviews conducted within the commissioning team

Project function in the commissioning team	Duration
Client consultant	45min.
Commissioning agent	37min.
Owner representative	39min.
Prime contractor for electrical fittings and information systems	35min.
Prime contractor for ventilation and plumbing systems	55min.
Turnkey contractor	32min.
User representative for project construction management	37min.
User representative for technical systems and services	39min.
Mean duration	40min. *sd.* 7

During the planning and construction process, passive observation and participation within the commissioning team was applied (see Table 2). During the meetings the researcher took jotted notes as recommended by Have (2004) and observed the meeting and relations between partners. Fellows and Liu (2009) note that participant observation is a common data source, which can support interviews. To supply the authors' own observation notes, minutes were used as supporting material (Walker and Shen, 2002; Yin, 1994). All three data sources were mixed into smaller themes. Conceptual abstracts of each segment were subsequently written. The written conceptual abstracts were applied in the inductive qualitative data analysis where the final arguments were constructed (Guba, 1981; Krefting, 1991).

Results

COMMISSIONING

The commissioning process was implemented on suggestion of the turnkey contractor and included as a part of the tendering process. This suggestion was encouraged by the assignment criteria where the most economically advantageous tender was applied. The owner representative from the public construction agency explains: "we asked the bidders to offer a process which involved the owner and users of the project, and which fulfilled the requirements we set". The focus on the project requirement fulfilment from the agency was based on previous experiences with poor energy performance and end-user dissatisfaction. To ensure the procedures and adjustments were completed before delivery, the agency developed a test paradigm in collaboration with the client consultant, commissioning agent, and turnkey contractor to ensure the owner requirements were fulfilled.

Table 2 Meetings with observation during the case study

General meeting context	Date	Duration
Compilation of commissioning project plan	8th January 2015	120min.
Coordination of critical project interfaces	19th January 2015	120min.
Coordination of construction process and IT	5th February 2015	120min.
Mean duration		120min. *sd.* 0

To manage the commissioning process during the overlapping design and construction stage, the turnkey contractor started the process with a workshop for the commissioning team. The purpose of the workshop was to develop a common project vision which all partners could agree on. Furthermore, it was agreed that decisions in the commissioning team should not affect project deadline, economy, and quality. These basic rules helped the commissioning team to focus on the process and requirement fulfilment. If issues regarding time, cost and quality appeared they were handled at construction status meetings.

However, to ensure enough time for final TAB of the HVAC and mechanical systems, the commissioning team was operating with two deadlines. The first deadline was six to eight weeks before the second and final contract deadline. Between the first and second deadline all HVAC and mechanical systems would be inspected and functionally tested to confirm that the completed TAB procedure was according to the received TAB report. The turnkey contractor and commissioning team's approach to these tests and planning was remarkably proactive, constantly focusing on adjusting the project plan to ensure that there was at least six weeks to perform the TAB. The turnkey contractor expresses: "good planning is always good leadership, having planned the project as early as possible is always a good thing".

Several of the participants stated that the commissioning meetings have a positive impact on fulfilling project requirements and in avoiding process complications. Moreover, they find that proper testing and adjustment of the mechanical system increase the likelihood of meeting user requirement leading to reduced troubleshooting and end-user dissatisfaction. The major challenge of introducing the commissioning process is being able to finish the project six to eight weeks before deadline and thus have enough time for the final TAB.

PROJECT MANAGEMENT

As the case evolved, the proactive project management approach was very different, because the team was constantly focusing on details relating to both the construction process and to the HVAC procedures. Risk and process complications were continuously debated at the meetings before they potentially emerged. The turnkey contractor stated: "I think many issues surfaced very early in the process, which is an absolute advantage". However, the proactive project management approach was not an intentional choice but an outcome of the process. The proactive management style was developed because of the emphasis on keeping a constructive dialog while simultaneously focussing on fulfilling quality and execution requirements.

When evaluating the process, the project pre-planning period was identified as the most important project phase. Almost all in the commissioning team pointed to either the early project initiation or the design phase as the phases with the highest impact on project

performance. Furthermore, they stated that the most important part of pre-planning is to create a detailed owner and user requirement list and detailed project description and design guidelines, to enable enough resources for testing, adjusting and balancing procedures in the plans, and finally to involve the owner and ensure that they play an active part in the process.

To enable the TAB at the end of the project, solitary construction work such as groundwork, exterior and interior wall panels, and roof systems were accelerated. Accelerating the work requires an even higher level of pre-planning since the individual contractors are increasing their workforce while performing work simultaneously.

To simplify communication and collaboration, the turnkey contractor chose a prime contractor for the HVAC and mechanical systems. Furthermore, to reduce waiting time, there was a focus on communication to owner and end-users to facilitate a fast decision-making process.

PROJECT COMPLICATIONS

The commissioning process did not reduce the number of emerging conflicts. During the case study the following problems were identified: Lack of requirement-description in tender material, too optimistic fire and emergency plan, missing end-user purchases of media and entertainment panels, and insufficient space for HVAC and mechanical systems.

All problems originated from the early pre-planning and design phase. An owner representative clarifies: "The design phase is where you are completing the design and where control and regulation descriptions are detailed. If these tasks are not done well enough there will be complications". Nevertheless, when the initial project was moved into the detailed design and construction stage the listed complications where overlooked, resulting in increased cost. The commissioning agent explains: "There are some areas where the design could have been better, but in a turnkey contract there will always be something you have overlooked."

Due to the compressed construction period, to secure enough time for the final HVAC adjustments, the management team had a constant focus on reducing potential complications. The ability to collaborate, negotiate, and renegotiate compromises within the team was a vital parameter to secure an ongoing process. The process was articulated by the turnkey contractor who was taking the commissioning process very seriously and indirectly forced the prime contractor for HVAC and mechanical systems to participate in both the general construction planning and the design of the HVAC systems. The commissioning process also required that the owner and end-user representatives were actively involved in the project and proactive in the decision-making process. The turnkey contractor explains the planning process as follows: "There is an increased focus on quality control. A lot of the planning concerned requirements, testing and documentation of all systems."

During the interviews the project team were asked if the commissioning, in their experience, was resulting in fewer process complications compared to an ordinary construction process. The quantity of critical complications was not found to be lower, but the complications were handled in a more proactive manner which reduced the costs of the complications. The owner representative explains: "I do not think there are fewer complications but they are handled much earlier and that makes a difference". Thus, it is not the commissioning process itself that reduces complications, but the proactive approach and awareness from the project team which follows from the commissioning process that makes the difference.

FORECASTING PROJECT SUCCESS

To forecast the level of success after completion and evaluate the quality of the project planning, all interviewees were asked to fulfil a questionnaire for their expectations to performance. The budget and time performance were measured in three categories by stating the most optimistic, most likely, and most pessimistic expectations to performance in relation to the contract budget and deadline. The technical performance and customer satisfaction was measured by a ten-point numeric scale. The quality of the project pre-planning was measured by a five-point numeric scale with a don't know option. The data-collection emulated the questionnaire design of Zwikael, Shimizu and Globerson (2005) to enable a comparison between the studies. Response rate for the survey was 50% (four participants). Respondents were all chosen due to their key project involvement, experience with the construction industry, as well having an in-depth understanding of the project. Selecting key players as respondents increases the quality and validity of the data.

To forecast project performance at the four perspectives, triangular distributions were applied, where the most optimistic, most likely and most pessimistic values were supported by a Monto Carlo simulation. Simulating the distribution is more reliable and accurate than using mean values, given its three-input variable are simulated with its variance of probability, and for that reason relevant (Nicholas, Steyn 2017). Missing values in the dataset were replaced with mean. All simulations were simulated until a 95% confidence interval for the mean was achieved. For budget and customer satisfaction 1,000 simulations were conducted (see Figure 1 and Figure 3), and 2,563 simulations were needed for the time performance (see Figure 2). Lastly, the technical performance wasn't simulated given all respondents expected nine out of ten.

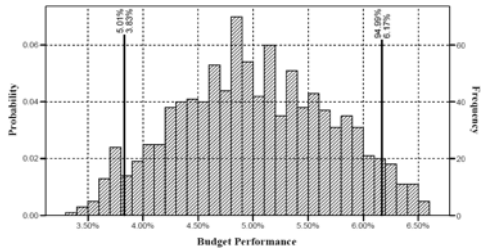

Figure 1 Probability density distribution for budget performance, 1,000 simulated cases scenario

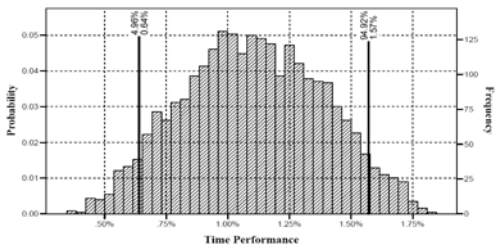

Figure 2 Probability density distribution for time performance, 2,563 simulated cases scenarios

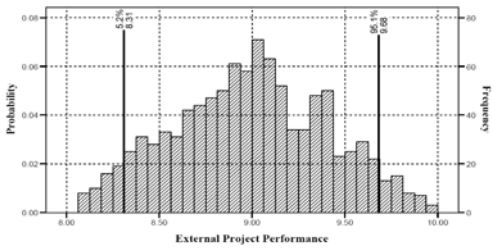

Figure 3 Probability density distribution for customer satisfaction, 1,000 simulated cases scenario

Looking at the forecasted budget performance (see Table 3) the most likely performance is found to be a 5.02% budget overrun. This overrun is within the agency overrun policy of maximum 10% overrun margin. The time performance is found to be 1.11% or three days overrun (see Table 3) and will probably be caught up during the buffer zone in the end of the project during the TAB procedure. The expectations to technical performance and customer satisfaction (see Table 3) were both found to be nine out of ten.

To evaluate the quality level of the project pre-planning, the PMPQ model developed by Zwikael and Globerson (2004) was applied. The results from the study were benchmarked against results from case-studies in Japan and Israel without commissioning, to see if the commissioning increases the quality of the pre-planning. The PMPQ model do, as mentioned in the introduction, measure pre-planning quality on two main perspectives: The pre-planning processes and the organizational support.

Table 3 A summary of the forecasted project performance at the four perspectives, with a 95% confidence interval for mean

Forecasted project perspective	Mean	SD	Min.	Max.	Lower	Upper
Forecasted budget performance	5.02%	.70%	3.39%	6.63%	4.97%	5.06%
Forecasted time performance	1.11%	.29%	.35%	1.90%	1.09%	1.12%
Forecasted technical performance	9.00	.00	9.00	9.00	9.00	9.00
Forecasted customer satisfaction	8.99	.41	8.06	9.96	8.97	9.02

A comparison of the pre-planning processes (see Table 4) reveal that all processes except 'scope definition' are found to be on equal or greater level. This result in an improved mean from 3.5 to 4.1. Thus, the commissioning process is found to increase the general level of the pre-planning process and align with the proactive pre-planning approach identified during the meetings and interviews.

A comparison of the organizational support (see Table 5) once again reveal a greater performance. Only the categories 'Use of standard project management software' and 'Ongoing project management training programs' scored lower than the cases without commissioning. The mean performance by using commissioning was found to be 4.1 which is significantly higher than 3.0 and 3.3 found at the other case studies. Both the pre-planning processes and the organizational support are improved by introducing commissioning.

Table 4 Level of applied pre-planning processes between Japan, Israel and the studied case

Project processes	Mean Japan - (Zwikael, Shimizu and Globerson, 2005)	Mean Israel – (Zwikael, Shimizu and Globerson, 2005)	Mean for the case study
Activity definition	3.7	4.1	4.0
Staff acquisition	3.3	3.6	3.7
Project plan development	3.7	4.0	5.0
Resource planning	3.5	3.7	4.5
Activity duration estimating	4.0	4.2	4.8
Scope planning	3.9	4.1	4.5
Procurement planning	2.9	3.0	4.0
Organizational planning	3.7	3.8	4.0
Risk management plan	2.8	2.8	3.5
Quality planning	3.0	2.9	4.5
Activity sequencing	3.6	3.5	3.7
Schedule development	4.1	4.0	5.0
Scope definition	3.8	3.7	3.3
Cost budgeting	3.4	3.2	3.0
Communications planning	2.9	2.4	3.3
Cost estimating	4.1	3.0	4.0
Mean	3.5	3.5	4.1

It is important to underline that the commissioning process itself is not reducing problems nor improving performance. But the commissioning process creates awareness and an increased focus on aspects in the pre-planning process, which together with an increased focus on complications and proactivity from the project participants, improves performance.

Table 5 Level of applied organizational support processes between Japan, Israel and the studied case

Organizational support processes	Mean Japan (Zwikael, Shimizu and Globerson, 2005)	Mean Israel (Zwikael, Shimizu and Globerson, 2005)	Mean case study
Use of standard project management software	2.5	4.2	3.7

Table 5 continued

Organizational support processes	Mean Japan (Zwikael, Shimizu and Globerson, 2005)	Mean Israel (Zwikael, Shimizu and Globerson, 2005)	Mean case study
Communication between the project manager and the organization during the planning phase	2.9	3.9	4.8
Use of new project tools and techniques	2.1	2.8	3.7
Existence of interactive inter-departmental project planning groups	2.7	3.5	4.8
Project manager assignment	3.0	3.6	4.5
Project office involvement	2.4	2.7	4.5
Use of organizational projects data warehouse	2.5	2.8	3.0
Supportive project organizational structure	3.0	3.4	4.5
Organizational projects´ quality management	2.8	3.0	4.0
Existence of projects´ procedures	3.6	3.7	3.8
Involvement of the project manager during the initiation stage	3.8	3.9	4.5
Ongoing project management training programs	2.8	2.7	2.3
Refreshing project procedures	3.2	3.0	3.5
Organizational projects risk management	3.0	2.8	4.3
Organizational projects resource planning	3.3	3.1	4.3
Existence of project success measurement	3.5	3.3	5.0
Project-based organization	4.1	3.6	4.3
Mean	3.0	3.3	4.1

Conclusion

In this case study, the effect of commissioning was studied. The commissioning process was required in a test case by the construction agency, due to problems with technical issues and due to end-user dissatisfaction. The case study revealed that the quality of pre-planning together with the quality of management during construction are the most important parameters to ensure high performance on both time, cost, technical issues, and end-user satisfaction.

The derived effect of the commissioning process was measured by using the PMPQ to compare the performance to cases without commissioning. By comparing the planning to the case study of Zwikael et al (2005), the quality of both the pre-planning process and the organizational support was improved. This finding aligns with observations made during the case study where it was found that the commissioning process itself did not improve

performance, but it increases the focus on pre-planning and on complications during construction.

The turnkey contractor was found to be a key player with responsibility to facilitate a process that fosters collaboration and proactivity in the commissioning team. It is important that the owners and end-user representatives also take an active part in the decision making. The study revealed that the closer relationship between contractor, owner, and end-user stimulated the owner and end-user representatives to take a more active role in the process.

Improved collaboration helped the project team to overcome project shortcomings and to secure a smooth design-build process. Moreover, the increased focus on complications helped the team identify problems earlier and, by reacting proactively, the negative effects on production and end-product were reduced.

To sum up, commissioning can, by improving pre-planning and organizational support, reduce the probability of budget and time overruns, and can secure a higher quality of technical systems resulting in increased end-user satisfaction.

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