http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000391 This is the Pre-Published Version.

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Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects

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Abstract

Due to the loss of financial resources and the need to optimize projects, academics, politicians and the construction industry have become increasingly aware of the challenges presented by the frequent time and cost overruns and reduced quality level of construction projects. The purpose of this study is to analyse the factors that project managers experience as having the greatest effect on time, cost and quality, and to discover whether the factors' effects are significantly different from each other. A questionnaire with 26 factors identified from interviews was sent to the full population of publicly employed project managers. Factors were ranked by using the relative importance index and tested for significant differences by applying the Friedman´s test with the Wilcoxon´s test as post-hoc analysis. From the analysis, the most affecting factor associated with time was found to be unsettled or lack of project funding. For the cost related factor, errors or omissions in the consultant material, was the most important. Finally, the quality related factor was errors or omissions in construction work. The main conclusion of this research showed that the project schedule, budget and quality level are significantly different affected. The project manager therefore cannot handle such critical issues by only focusing at schedule or budget related complication, either can the project manager assume that time, cost and quality are equally affected.

Keywords: Construction Management, Cost Overrun, Denmark, Quality Level, and Schedule Delay.

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Introduction

Delay in construction projects, cost overrun and quality level have long been common problems in the construction and engineering sector. In particular, time and cost increases in large public construction projects seem to be a global phenomenon affecting five continents, with no reduction in the last 70 years and an average cost overrun of 28 % (Flyvbjerg et al. 2002; Flyvbjerg et al. 2003). Optimistic expectations to time and budget planning has as an consequence been found to decrease the level of quality and productivity during the construction stage and in the final end-product (Park et al. 2010).

To reduce such overrun the existing body-of-knowledge tends to focus on critical success factors associated to time and cost as individual concepts of different project types and geographical regions with little frame of reference. Aibinu and Odeyinka (2006); Al-Kharashi and Skitmore (2009); Kazaz et al. (2012) all study causes of schedule delays and effects to the time concept. Iyer and Jha (2005); Shane et al. (2009) study cost escalation factors in construction projects as the cost related concept. And finally Kaliba et al. (2009); Koushki et al. (2005); Olawale and Sun (2010) study the cost and time concepts as interrelated, which fits Hancher and Rowings (1981) definition of a successful project as the ability to meet both budget and deadline according to the contract. However, in addition to previous conducted studies we need to include quality into the debate of time and cost as interrelated concepts since all three concepts have been central in the construction literature, also known as the “iron triangle”. Comprehensive studies focusing on time, cost and quality as interrelated concepts are therefore essential to be able to demonstrate significant differences between the three concepts in the “iron triangle” and to extend the existing body-of-knowledge.

A potential solution to the critical success factors effect on construction projects is increased pre-project planning effort (Yang et al. 2012). The benefits of using pre-project planning is find to be increased profit, a reduction of risk and an increased quality (Barker et al. 2004; González et al. 2008; Hanna and Skiffington 2010; Hwang and Ho 2011). The effort spent in this early project stage therefore affects the level of success during the start-up, detailed design and construction stage (Chang et al. 2010; Yang and Wei 2010). These results are further supported by Thomas and Ellis Jr (2007) who used simple pre-project planning methods to reduce the preliminary construction duration by up to 30 %. Hanna and Skiffington (2010) argue for an increased construction planning level allow the contractor to be more proactive to critical factors which affect the project compared to a reactive approach. The positive effects of realistic planning of cost and time before design, as well as its success during the construction stage is according to Gibson Jr et al. (2006) improved project outcome, user satisfaction and reduced project cost and duration. Identifying and test for significant differences of the impacts at time, cost and quality from the critical success factors are therefore vital to deal with the factors in the pre-project planning process to secure the project outcome.

The aim of this paper is thus:

- To present the factors that have the most negative effect on time, cost and quality

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- To test if a factor affects time, cost and quality significantly different from each other
- If its affects significant different - to identify which of the elements in the "iron triangle" which affect significantly different

The tested H_0 hypothesis is thus based on the definition of a successful project: time, cost and quality should be affected similar by any factor. H_A hypothesis is that there is a significantly different impact. The geographic context and empirical basis of the study is focusing at the Danish publicly funded construction sector.

Literature review

Despite several studies related to cost overrun since Arditi et al. (1985), the definition of cost escalation is not always clearly defined. Flyvbjerg et al. (2002) define cost escalation as the gap between the actual cost and the estimated cost. Actual cost is the actual accounted project cost after completion, and estimated cost is the budgeted or forecasted project cost at the time of decision to start the project.

Contrary to cost overrun, the definition of time overrun is clearly articulated in literature. However, two different definitions have been used. The most commonly used definition is presented by O'Brien (1976) as the delay in time either beyond the agreed contract deadline or beyond the date the parties have agreed upon for the delivery of a project. Among others, the studies conducted by Lo et al. (2006) and Assaf and Al-Hejji (2006) use this definition. The second definition was proposed by Stumpf (2000), and states that a time overrun is an act or event that extends the time to perform the task beyond the agreed contract deadline. Sweis et al. (2008) use this definition.

Looking into how the literature defines quality provides answers that are less clear. According to Flynn et al. (1994), quality is a distinction between input (the quality of management) and output (the quality of performance). Fujimoto (1989) and Voss and Blackmon (1994) describe internal performance as the ability to conform to required specifications, where Fynes and De Burca (2005) express external performance as the level of quality-in-use of the end-product.

However, these definitions are debated in the construction sector due to difficulties in defining quality to construction projects, based on lack of standardisation, size of projects and involved parties (Hoonakker et al. 2010). Loushine et al. (2006) reviewed 26 research papers associated to applied construction quality definitions. The study provided five different definitions for quality: "meeting expectations of the customer", "reduced rework or defects", "repeat business", "conformance to ISO 9000 criteria" and finally "completion on-time and within budget". The definition of quality management is thus not a "controlling the construction process", but should be defined by the level of fulfilment of the project, according to the owner or end-user expectations (Loushine et al. 2006).

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This result is supported by Hoonakker et al. (2010) which state that a precise definition of quality associated to the construction sector is difficult to define, and further point out that limited solid empirical data on quality due to lack of an exact definition is to be found.

The level of success after project completion is thus not only based on time and cost based empirical criteria, but is an individual weighing of time, cost and quality. Liu and Walker (1998) divide project success definition into three categories: "project goals", "satisfaction of the claimant(s)" and finally "perception and awareness of different claimant(s)". Project goals represent those regarding the contract agreed time, cost and quality also known as the "iron triangle". Long et al. (2004) define a successful project as one that is completed within agreed contract budget and deadline, in accordance with required specifications, and to the satisfaction of stakeholders. Similar related definition are also used by Avots (1969); Gaddis (1959); Handa and Adas (1996); Kerzner (1998); Morris and Hough (1987); Olsen (1971); Trauner (1993); Tuman (1983); Tuman (1986); Williams (1993).

However, the definition of project success is similar to quality challenging to define due to varying opinions and requirements (Liu and Walker 1998).

Research method

Quantitative surveys are designed to acquire information from individuals about themselves or about a social unit to which they belong or with which they are involved (Rossi et al. 1983). In such processes, the sampling method used, determines the level of information about the population, and its accuracy (Rea and Parker 2012). To develop operational factors from the semi-structured interviews, each factor was objectively evaluated into understanding, retention and application as suggested by Sekaran (1992). Previously tested and used factor expressions from earlier published studies were also used to ensure clear and comprehensible factor definitions (Forza 2002). To measure the impact of each factor on time, cost and quality, all three elements were measured on an ordinal five point Likert scale (where 1 very low, 2 low, 3 medium, 4 high, 5 very high impact), similar to what is used by Doloi (2012), and a 'don't know' option was included to prevent respondent bias.

Data was collected using SurveyXact and sent by email in accordance with the ethical research standards of the Danish Social Science Research Council (S.S.R.C. 2002). The data collection was based on the full population of project managers employed by Danish public construction agencies, totalling four agencies. Their educational backgrounds include architects, engineers and building surveyors. The chosen population has both pros and cons, but was chosen since publicly funded construction projects represent some of the most complex construction projects in Denmark which implies that a further generalization to less complex public funded construction projects is possible. Further, the publicly employed project managers are the only trade group which follow a public construction project from the beginning to the end.

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The analysis was conducted using Statistical Package for the Social Sciences (SPSS), where a data review was made to recode "don't know" responses as "missing". To check the reliability of the dataset, the Cronbach alpha test was conducted. To be acceptable, values had to have a level of at least .7 (Kline 2013). The Relative Importance Index (RII) was used to rank factors with an index range of 0.0 - 1.0 (see equation 1), the same method has been used by Aibinu and Odeyinka (2006) and Doloi et al. (2012).

(1) Relative Importance Index (RII) = $\frac{\sum_{i=1}^{5} W_i}{A*N}$

W_i Total sum of each factor where 1 very low, 2 low, 3 medium, 4 high, 5 very high

A Highest weight in this study 5 very high

N Total number of respondents at each variable

To test for difference between time, cost and quality, a non-parametric approach was used. The strength of such methods, is that they work by ranking data and then conducting the analysis on the ranks instead of the actual data (Field 2009). Friedman´s test is applicable when ordinal scaled data contains more than two related samples, as here where the same respondents have been used (Sekaran 1992). To follow up on significant factors, a Wilcoxon signed-rank test was applied. To limit the number of follow-up tests and Type I errors, the Bonferroni correction was used, where something was accepted as significant if its significance level was less than α/the number of comparisons (Field 2009). To test the correlation between factors, the Kendall tau test was used. This test is useful when small data sets with large numbers of tied ranks are processed (Field 2009). According to Howell (1997), the Kendall tau test performs more accurate correlation estimates than the Spearman test in these situations.

Identification of questionnaire factors

To identify the applied factors that affect construction time, cost and quality a qualitative research approach was initially adopted. An explorative semi-structured interview study was first conducted with in total eight public agency employed project and property managers, where 20 factors were identified. However, examination of an investigation of public construction projects overruns, carried out by the National Audit Office of Denmark in 2009, led to the identification of six additional factors. A total of 26 factors were thus identified.

To support the 26 factors with existing research, a literature review was conducted to evaluate if previous studies have used similar factor descriptions. The conducted review leads, to identification of 20 studies which used similar factors as identified in the interview study (see Table 1). As great geographical differences were expected regarding construction processes and complications we did not include further factors from the literature. Furthermore the focus of the study was on the Danish public construction projects.

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Why we did not consider factors from other geographical areas which are not represented in the Danish construction industry.

Questionnaire categories

External complications are conditions or circumstances that are beyond the control of the project organization, such as delays or long process times by other public authorities, unpredictable soil conditions, state of the market conditions, unpredictable project conditions and finally unpredictable weather conditions.

Complications related to contract are circumstances or inconsistencies in documentation shared by partners. They include the use of selection and assignment criteria, errors or inconsistencies in project documents, lack of requirement specifications in tender documents, lack of project structure or material and unforeseeable authority requirements or restrictions.

Project management-related complications are human-related factors that the management manage to secure a stable organization and process. Problems can include miscommunication between partners, conflicts and disputes between partners, slow user decision making, change of partners in the project organization, inexperienced or newly qualified construction supervisors, and inexperienced or newly qualified consultants.

Project change-related complications are conditions or circumstances that derive from changing requirements. They include errors or omissions in construction work, errors or omissions in the consultant material, failure to identify needs, lack of preliminary examination before design or tendering, and late user changes affecting the project or function.

Finance and scheduling complications are problems within project finance and scheduling. They include optimistic expectations regarding time, cost, and quality, political focus on reduced project costs or time, unsettled or lack of project funding, unsettled or lack of project planning, and the complexity or volume of the project.

Results

The questionnaire was sent to 111 potential respondents (see

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Table 2), of whom 56 replied. This gives a response rate of 50.5 %. This is an acceptable response rate according to Flynn et al. (1990), who argue for a minimum response rate of 50 % . The respondents' mean age was 51 (SD 11 years), where the oldest was 70 and the youngest 28 years old. Due to the high mean age, the respondents' experience is expected to be on a sufficiently high level to answer the questionnaire.

The general response frequency of such questionnaire studies in this research area is varying. For example the response rate in Iyer and Jha (2005) study was 25 %; Al-Kharashi and Skitmore (2009); Kaliba et al. (2009) both experienced a response rate of 43 %; Olawale and Sun (2010) reported a response rate of 44 %; Kazaz et al. (2012) 47.7 % and Aibinu and Odeyinka (2006) 51 %. The response frequency of our research (50.5 %) compared to previous studies presented above, is thus considered sufficient.

To validate the consistency of the questionnaire, each category was tested in relation to time, cost and quality (

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Table 3). External cost was found to have a Cronbach alpha (α) less than .7, indicating questionable data consistency and should then be cautiously considered. Four of the 15 tests were found to be acceptable (α between .7 and .8) , and 10 of the 15 tests demonstrated a good level of consistency (α between .8 and .9) (Kline 2013).

Ranking of factors

Of the top five factors that affect time, FS3 (*unsettled or lack of project funding*) was found to be the highest ranking (RII = .774). It was followed by EX1 (*delayed or long process times by other authorities)*, FS4 (*unsettled or lack of project planning)*, PC1 (*errors or omissions in construction work)* and PC3 (*lack of identification of needs)* indicated by their decreasing RII values (

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Table 4 and Figure 1).

When it comes to factors that affect cost, PC2 (*errors or omissions in the consultant material)* is found to be the highest ranking (RII of .766). It is followed by CR2 (*errors or inconsistencies in project documents)*, PC5 (*late user changes affecting the project or function)*, PC4 (*lack of preliminary examination before design or tendering)* and PM6 (*inexperienced or newly qualified consultants)* indicated by their decreasing RII values (

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Table 4 and Figure 1).

Of the factors affecting quality, PC1 (*errors or omissions in construction work*) was the highest ranked (RII of .688), followed by PM6 (*inexperienced or newly qualified consultants)*, FS2 (*political focus on reduced project costs or time)* FS4 (*unsettled or lack of project planning)* and CR2 (*errors or inconsistencies in project documents* (

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Table 4 and Figure 1).

Friedman´s test

To test if the factors affect time, cost and quality to a significantly different degree, Friedman´s test was conducted. Due to the definition of a successful project according to Long et al. (2004), we did not expect to find a significant difference in the impact of the various factors. To secure Friedman´s minimum sample size, 23 datasets with an α of .01 were required (Fahoome 2002), the smallest dataset in the test was 44 (see

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Table 5). Out of 26 tests, 17 rejected the null hypothesis, and nine tests confirmed it (see

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Table 5).

An examination of the survey categories reveals that the category "Project Management - PM" in five out of six tests confirms the null hypothesis. The factors within this category thus affect time, cost and quality differently from the other categories, as the factors within this category affect non-significantly different, whereas the other categories factors affect to a significantly different extent, except factor CR1, CR4 and FS2 which confirmed the null hypothesis.

Post-hoc analysis

Following up on the factors rejecting the null hypothesis, a post-hoc analysis was conducted to find patterns and connections within these factors that would otherwise remain undetected. The smallest data set in the tests was 44, why both the minimum requirement for the Wilcoxon test and the Kendall's tau were obtained (20 and 15 α of .01 respectively) (see

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Table 6) (Fahoome 2002; Sprent 1989).

33 of 51 tests found a significant difference and 18 tests found a non-significant difference. The effect size of all tests was positively correlated in the range from small to large effect size (.226 to .808). Ten of the 18 non-significant factor combinations in

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Table 6 involve the combination time and cost, where factors EX2, EX4, EX5, CR5, PC3, PC4, PC5, FS1, FS4 and FS5 demonstrate a non-significant difference of the impact on time and cost. These impacts were further supported by the effect size (.569 to .808) for all of the ten combinations and thus represented a large positive effect.

The second factor combination was between quality and time and was found in five out of the 18 non-significant combinations EX3, CR2, CR3, PC2 and FS1. They had a medium to large positive effect (.407 to .588), thus a smaller degree of association than for time and cost.

The combination between quality and cost had the smallest degree of association found in the analyses. It was only non-significant in three out of the 18 tests. The equal impact of quality and cost was found for factors PM3, FS3 and FS4 with a large positive effect (.536 to .575).

Discussion

Comparing these results with previous studies done byKaliba et al. (2009); Koushki et al. (2005); Olawale and Sun (2010), time, cost and quality, which were not found related in any previous studies, have been found of particular importance when a factor affects a construction project. As previously mentioned several previous studies in the area of critical factors have mainly focused on factors affecting either project time or cost by ranking them against one another by using the relative importance index. Their findings are thus not associated with a successful project outcome according to for example the definition of project success by Long et al. (2004).

To secure project success by using the results from the relative importance index is it in our research demonstrated that all three elements (cost, time and quality) from the “iron triangle” should be considered due to its significantly different impact on cost, time and quality. Measuring just one or two of the three “iron triangle” elements will therefore not secure either project success, or success of the measured element due to the demonstrated positive correlation between the three “iron triangle” elements. This result supports the need for adequate pre-project planning activities to improve and secure project cost, time and quality before the detailed design stage and construction stage starts (Gibson Jr et al. 2006).

The factors in the category “Project Management” indicate that when particular human project management related factors affect time, cost and quality, they impact all three elements in the “iron triangle” non-significantly different. This difference should be seen as the three elements time, cost and quality not necessarily are independent of each other when they impact, but are conversely a cause for equal negative impact (Haimes 2005). A similar result was made by Hwang and Lim (2013) who demonstrate that project outcome is a result of owner activity in the project management and delivery. To reduce such project management related impact Dvir et al. (2003) are arguing for the need to capitalise time in project procedures due to the significant relationship between defining “project goals”, “functional requirements”, “technical specifications” and the following project success defined by to the end-user.

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Our study evaluated the effect of 26 factors on the time, cost and quality of public construction projects, seen from the publicly employed project manager's perspective. We found the five main causes of delay were identified as unsettled or lack of project funding, delay or long process times caused by other authorities, unsettled or lack of project planning, errors or omissions in construction work and lack of identification of needs. Furthermore, the factors with the greatest effect on budget were identified as errors or omissions in the consultant material, errors or inconsistencies in project documents, late user changes affecting the project or function, lack of preliminary examination before design or tendering and inexperienced or newly qualified consultants. In addition the quality related factors were errors or omissions in construction work, inexperienced or newly qualified consultants, political focus on reduced project costs or time, unsettled or lack of project planning and errors or inconsistencies in project documents. Comparing these results with existing studies are mostly all identified factors found related to either the owner, end-users and consulting task which should have been completed in either the initiation or planning phase of a project. Dvir et al. (2003) suggestion by invest more time in project goals, functional and technical requirements seems thus also highly relevant in the Danish construction industry to reduce the most affecting factors. Further Kazaz et al. (2012) find that owner based project complication rank as some of the most affecting reasons for delays in 16 different countries. The consultant's ability to identify and fulfil owner and end-users requirements during a construction projects seems thus vital to secure a successful project outcome.

When the Friedman´s test was applied, 17 of the 26 factors rejected the null hypothesis by demonstrating significantly different impacts on time, cost and quality, and nine factors accepted the null hypothesis. In the following post-hoc analysis 33 of 51 tests were further found significantly different in the combinations between time, cost and quality, where 10 out of 18 the non-significant tests were between time and cost, five test between quality and time and three between quality and cost. All 51 conducted post-hoc tests were found positively correlated, meaning an effect in for example time also will increase the impact on cost and quality. Linking these result with studies which have studied time and cost related factors, are Kaliba et al. (2009) state that no straightforward solutions to these overruns and delays seems available. By looking at our results is there clearly a too complex factor structure between time, cost and quality for a project manager to comprehend. However, we do instead suggest that future construction project should focus at monitoring the five identified critical time, cost and quality related courses, combined with an increased pre-planning effort during the initiation and planning phase of a project to reduce and handle these critical project complications.

Conclusion

The conclusion from our findings of this research showed that the project schedule, budget and quality level are affected significantly different. The project manager therefore cannot handle such critical issues by only focusing at schedule or budget related complication, either can the project manager assume that time, cost and quality are affected equally. In addition, the project organization must manage the factors as early as possible, since top five factors affecting time, cost and quality mainly were found to be consultant tasks, which should have been completed in the design stage before either tendering or construction. The project manager must therefore consider and adjust the handling of each factor impact individually.

By adding the quality perspective and test it for significant difference to the existing body-of-knowledge the factor complexity is revealed, but demonstrates at the same time the need for increased pre-planning effort within the project organizations respond to the factors. A project organization can for that reason define a project success outcome, but cannot manage critical issues according to its defined project success.

Potential implication and outcome of this study is relevant to the challenges facing public funded construction projects regarding time, cost and quality. Using these results, it is now possible to counter the impact of a factor on time, cost and quality before it affects a project. Moreover, the results indicate how a given factor will affect time, cost and quality. It is therefore our hope that these significant new results will be used by public construction agencies to understand the challenges that their project managers are facing and that the factors with the greatest effect thereby can be reduced.

Even though a significant effort has been invested in limiting bias and study limitations these results still have some. Firstly, the study focuses on a limited small population and is thus more sensitive to bias due to a low response rate. Secondly, the limitation of applying questionnaire research is that it reduces the ability for extension and generalization of the results to other populations or areas due to findings are restricted to the studied population (public funded construction projects).

Future research into the effect of factors on time, cost and quality of public funded construction projects could be continued by conducting similar studies in other regions of the world. Further, it could be beneficial if studies like this were followed up by for example factor analysis, regression analysis or case studies to explain and demonstrate the effect of these factors at a higher level.

Acknowledgement

Thanks to Associate Professor Derek Drew and M.Sc. Siff Dea Hjort Stöckel for review and comment during the writing process, and a special thanks to the respondents for their involvement and honesty throughout the research project. The Department of Mechanical and Manufacturing Engineering, Aalborg University provided financial support for this article. The authors would like to thank the reviewers of this paper for their constrictive comments.

References

Abd El-Razek, M., Bassioni, H., and Mobarak, A. (2008). "Causes of delay in building construction projects in Egypt." *Journal of Construction Engineering and Management*, 134(11), 831-841.

Aibinu, A. A., and Odeyinka, H. A. (2006). "Construction delays and their causative factors in Nigeria." *Journal of Construction Engineering and Management*, 132(7), 667-677.

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Al-Kharashi, A., and Skitmore, M. (2009). "Causes of delays in Saudi Arabian public sector construction projects." *Construction Management and Economics*, 27(1), 3-23.

Arditi, D., Akan, G. T., and Gurdamar, S. (1985). "Cost overruns in public projects." *International Journal of Project Management*, 3(4), 218-224.

Assaf, S. A., and Al-Hejji, S. (2006). "Causes of delay in large construction projects." *International Journal of Project Management*, 24(4), 349-357.

Avots, I. (1969). "Why does project management fail?(Project management systems failure analysis, discussing cost, products quality and project objectives)." *California management review*, 12, 77-82.

Barker, R., Childerhouse, P., Naim, M., Masat, J., and Wilson, D. (2004). "Potential of total cycle time compression in construction: Focus on program development and design." *Journal of Construction Engineering and Management*, 130(2), 177-187.

Chang, A. S., Shen, F.-Y., and Ibbs, W. (2010). "Design and construction coordination problems and planning for design-build project new users." *Canadian Journal of Civil Engineering*, 37(12), 1525-1534.

Doloi, H. (2012). "Cost overruns and failure in project management: understanding the roles of key stakeholders in construction projects." *Journal of Construction Engineering and Management*, 139(3), 267-279.

Doloi, H., Sawhney, A., Iyer, K., and Rentala, S. (2012). "Analysing factors affecting delays in Indian construction projects." *International Journal of Project Management*, 30(4), 479-489.

Dvir, D., Raz, T., and Shenhar, A. J. (2003). "An empirical analysis of the relationship between project planning and project success." *International Journal of Project Management*, 21(2), 89-95.

Fahoome, G. F. (2002). "Twenty nonparametric statistics and their large sample approximations." *Journal of Modern Applied Statistical Methods*, 1(2), 35.

Faridi, A. S., and El-Sayegh, S. M. (2006). "Significant factors causing delay in the UAE construction industry." *Construction Management and Economics*, 24(11), 1167-1176.

Field, A. (2009). *Discovering statistics using SPSS*, Sage publications.

Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., and Flynn, E. J. (1990). "Empirical research methods in operations management." *Journal of Operations Management*, 9(2), 250-284.

Flynn, B. B., Schroeder, R. G., and Sakakibara, S. (1994). "A framework for quality management research and an associated measurement instrument." *Journal of Operations Management*, 11(4), 339-366.

Flyvbjerg, B., Holm, M. S., and Buhl, S. (2002). "Underestimating costs in public works projects: Error or lie?" *Journal of the American Planning Association*, 68(3), 279-295.

Flyvbjerg, B., Holm, M. S., and Buhl, S. (2003). "How common and how large are cost overruns in transport infrastructure projects?" *Transport Reviews*, 23(1), 71-88.

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Forza, C. (2002). "Survey research in operations management: a process-based perspective." *International Journal of Operations & Production Management*, 22(2), 152-194.

Frimpong, Y., Oluwoye, J., and Crawford, L. (2003). "Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study." *International Journal of Project Management*, 21(5), 321-326.

Fugar, F. D., and Agyakwah-Baah, A. B. (2010). "Delays in building construction projects in Ghana." *Australasian Journal of Construction Economics and Building*, 10(1/2), 103-116.

Fujimoto, T. (1989). *Organizations for effective product development: The case of the global automobile industry*, Harvard University.

Fynes, B., and De Burca, S. (2005). "The effects of design quality on quality performance." *International Journal of Production Economics*, 96(1), 1-14.

Gaddis, P. O. (1959). *The project manager*, Harvard University.

Gibson Jr, G. E., Wang, Y.-R., Cho, C.-S., and Pappas, M. P. (2006). "What is preproject planning, anyway?" *Journal of Management in Engineering*, 22(1), 35-42.

González, V., Alarcón, L., and Mundaca, F. (2008). "Investigating the relationship between planning reliability and project performance." *Production Planning and Control*, 19(5), 461-474.

Haimes, Y. Y. (2005). *Risk modeling, assessment, and management*, John Wiley & Sons.

Hancher, D. E., and Rowings, J. E. (1981). "Setting highway construction contract duration." *Journal of the Construction Division*, 107(2).

Handa, V., and Adas, A. (1996). "Predicting the level of organizational effectiveness: a methodology for the construction firm." *Construction Management & Economics*, 14(4), 341-352.

Hanna, A. S., and Skiffington, M. A. (2010). "Effect of preconstruction planning effort on sheet metal project performance." *Journal of Construction Engineering and Management*, 136(2), 235-241.

Hoonakker, P., Carayon, P., and Loushine, T. (2010). "Barriers and benefits of quality management in the construction industry: An empirical study." *Total Quality Management*, 21(9), 953-969.

Howell, D. (1997). "Statistical methods for psychology." *Wadsworth, Belmont, CA.*

Hwang, B.-G., and Ho, J. W. (2011). "Front-end planning implementation in Singapore: Status, importance, and impact." *Journal of Construction Engineering and Management*, 138(4), 567-573.

Hwang, B.-G., and Lim, E. S. J. (2013). "Critical success factors for key project players and objectives: Case study of Singapore." *Journal of Construction Engineering and Management*, 139(2), 204 - 215.

Iyer, K., and Jha, K. (2005). "Factors affecting cost performance: evidence from Indian construction projects." *International Journal of Project Management*, 23(4), 283-295.

Kaliba, C., Muya, M., and Mumba, K. (2009). "Cost escalation and schedule delays in road construction projects in Zambia." *International Journal of Project Management*, 27(5), 522-531.

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Kazaz, A., Ulubeyli, S., and Tuncbilekli, N. A. (2012). "Causes of delays in construction projects in Turkey." *Journal of Civil Engineering and Management*, 18(3), 426-435.

Kerzner, H. (1998). *In search of excellence in project management*, Van Nostrand Reinhold.

Kline, P. (2013). *Handbook of psychological testing*, Routledge.

Koushki, P., Al-Rashid, K., and Kartam, N. (2005). "Delays and cost increases in the construction of private residential projects in Kuwait." *Construction Management and Economics*, 23(3), 285-294.

Liu, A. M. M., and Walker, A. (1998). "Evaluation of project outcomes." *Construction Management and Economics*, 16(2), 209 - 219.

Lo, T. Y., Fung, I. W., and Tung, K. C. (2006). "Construction delays in Hong Kong civil engineering projects." *Journal of Construction Engineering and Management*, 132(6), 636-649.

Long, N. D., Ogunlana, S., Quang, T., and Lam, K. C. (2004). "Large construction projects in developing countries: a case study from Vietnam." *International Journal of Project Management*, 22(7), 553-561.

Loushine, T. W., Hoonakker, P. L., Carayon, P., and Smith, M. J. (2006). "Quality and safety management in construction." *Total Quality Management and Business Excellence*, 17(9), 1171-1212.

Morris, P. W., and Hough, G. H. (1987). "The anatomy of major projects: A study of the reality of project management."

O'Brien, J. J. (1976). "Construction Delay: Responsibilities, Risks, and Litigation." *Boston: Cahners*.

Odeh, A. M., and Battaineh, H. T. (2002). "Causes of construction delay: traditional contracts." *International Journal of Project Management*, 20(1), 67-73.

Olawale, Y. A., and Sun, M. (2010). "Cost and time control of construction projects: inhibiting factors and mitigating measures in practice." *Construction Management and Economics*, 28(5), 509-526.

Olsen, R. P. (1971). *Can project management be defined?*

Park, M., Kim, W., Yoon, Y., and Nepal, M. P. (2010). "Scheduling decisions and their dynamic consequences on construction performance." *KSCE Journal of Civil Engineering*, 14(3), 251-259.

Rea, L. M., and Parker, R. A. (2012). *Designing and conducting survey research: A comprehensive guide*, John Wiley & Sons.

Rossi, P. H., Wright, J. D., and Anderson, A. B. (1983). *Handbook of survey research*, Academic Press New York.

S.S.R.C., D. (2002). "Vejledende retningslinier for forskningsetik i samfundsvidenskaberne." *Danish Social Science Research Council*.

Sambasivan, M., and Soon, Y. W. (2007). "Causes and effects of delays in Malaysian construction industry." *International Journal of Project Management*, 25(5), 517-526.

Sekaran, U. (1992). "Business Research Methods." McGraw-Hill.

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Shane, J. S., Molenaar, K. R., Anderson, S., and Schexnayder, C. (2009). "Construction project cost escalation factors." *Journal of Management in Engineering*, 25(4), 221-229.

Sprent, P. (1989). "Applied Nonparametric Statistical Methods." Chapman and Hall, London.

Stumpf, G. R. (2000). "Schedule delay analysis." *Cost Engineering-Ann Arbor Then Morgantown*, 42(7), 32-32.

Sweis, G., Sweis, R., Abu Hammad, A., and Shboul, A. (2008). "Delays in construction projects: The case of Jordan." *International Journal of Project Management*, 26(6), 665-674.

Thomas, H. R., and Ellis Jr, R. D. (2007). "Contractor prebid planning principles." *Journal of Construction Engineering and Management*, 133(8), 542-552.

Toor, S. U. R., and Ogunlana, S. O. (2008). "Problems causing delays in major construction projects in Thailand." *Construction Management and Economics*, 26(4), 395-408.

Trauner, T. J. (1993). *Managing the construction project: a practical guide for the project manager*, Wiley New York, NY.

Tuman, G. (1983). "Development and implementation of effective project management information and control systems." *Cleland, DI & King, WR Project management handbook. New York, Van Nostrand Reinhold Co*, 495-529.

Tuman, J. "Success modeling: A technique for building a winning project team." *Proc., Proceedings of Project Management Institute*, 29-34.

Voss, C., and Blackmon, K. (1994). "Total quality management and ISO 9000: A European study." *Centre for Operations Management, London Business School, London*.

Wambeke, B. W., Hsiang, S. M., and Liu, M. (2011). "Causes of variation in construction project task starting times and duration." *Journal of Construction Engineering and Management*, 137(9), 663-677.

Williams, T. (1993). "Risk-management infrastructures." *International Journal of Project Management*, 11(1), 5-10.

Yang, J.-B., and Wei, P.-R. (2010). "Causes of delay in the planning and design phases for construction projects." *Journal of Architectural Engineering*, 16(2), 80-83.

Yang, L.-R., Chen, J.-H., and Huang, C.-F. (2012). "Requirements definition and management practice to improve project outcomes." *Journal of Civil Engineering and Management*, 18(1), 114-124.

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Table 1: Category and factor description for the factors used in the questionnaire

			Studies using comparable factors																			
Category	**Id.**	**Factor description**	Aibinu and Odeyinka (2006)	Abd El-Razek et al. (2008)	Al-Kharashi and Skitmore (2009)	Assaf and Al-Hejji (2006)	Doloi et al. (2012)	Faridi and El-Sayegh (2006)	Frimpong et al. (2003)	Fugar and Agyakwah-Baah (2010)	Iyer and Jha (2005)	Kaliba et al. (2009)	Kazaz et al. (2012)	Koushki et al. (2005)	Lo et al. (2006)	Long et al. (2004)	Odeh and Battaineh (2002)	Olawale and Sun (2010)	Sambasivan and Soon (2007)	Shane et al. (2009)	Toor and Ogunlana (2008)	Wambeke et al. (2011)
External	EX1	Delays or long process times by other authorities	●	●	●	●	●			●												
	EX2	Soil conditions		●		●	●	●	●	●			●		●	●	●		●	●	●	
	EX3	State of market conditions			●		●		●	●		●	●			●		●		●	●	
	EX4	Project conditions	●												●			●		●	●	
	EX5	Weather conditions	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Contractual Relationship	CR1	Selection and assignment criteria			●	●			●		●				●					●		
	CR2	Errors or inconsistencies in project documents			●	●		●		●		●	●		●	●	●	●	●	●	●	
	CR3	Lack of requirement specifications in tender documents	●								●				●	●			●	●	●	
	CR4	Lack of project structure or material	●	●	●	●	●	●	●						●	●	●		●		●	
	CR5	Unforeseeable authority requirements or restrictions	●			●	●								●		●		●		●	
Project Management	PM1	Miscommunication between project partners	●	●	●	●	●			●	●		●		●	●	●		●		●	●
	PM2	Conflicts and disputes between project partners		●	●	●	●				●		●		●	●	●	●	●		●	
	PM3	Slow user decision making	●	●	●	●	●	●	●		●					●	●		●			
	PM4	Change of partners in the project organization		●	●		●	●			●						●		●			
	PM5	Inexperienced or newly qualified construction supervisors			●	●	●	●	●		●		●		●	●	●		●		●	●
	PM6	Inexperienced or newly qualified consultants			●	●					●					●					●	
Project Changes	PC1	Errors or omissions in construction work		●	●	●	●	●	●			●					●		●	●		
	PC2	Errors or omissions in the consultant material	●	●		●	●	●		●											●	●
	PC3	Lack of identification of needs	●		●	●				●	●					●			●		●	●
	PC4	Lack of preliminary examination before design or tendering			●	●							●			●					●	
	PC5	Late user changes affecting the project or function	●	●	●	●	●	●		●					●	●	●	●	●	●	●	●

Finance and Scheduling	FS1	Optimistic expectation regarding time, cost and quality			•	•	•	•		•					•	•	•		•		•	
	FS2	Political focus on reduced project costs or time																				
	FS3	Unsettled or lack of project funding	•	•	•	•	•	•	•	•		•	•	•		•	•	•	•		•	
	FS4	Unsettled or lack of project planning	•		•	•	•	•	•		•					•	•	•	•	•		
	FS5	Complexity or volume of the project				•					•		•					•		•		•

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Table 2: Response rate and agency distribution of the questionnaire

Agency	Potential respondents	Response frequency	Respondent rate
Agency 1	5	2	40.0 %
Agency 2	16	6	37.5 %
Agency 3	52	24	46.2 %
Agency 4	38	24	63.2 %
Total	111	56	50.5 %

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Table 3: Reliability values for each questionnaire category: time, cost and quality

Category	*N*	Time	*N*	Cost	*N*	Quality
External	52	.708	52	.664	52	.725
Contractual Relationship	48	.773	48	.822	46	.845
Project Management	43	.776	43	.825	43	.848
Project Changes	46	.822	45	.849	46	.832
Finance and Scheduling	40	.856	40	.888	40	.856

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Table 4: Relative importance index (RII) and rank (R), ranking is conducted by giving the lowest index value one or A, the next lowest two or B, and so on

	Time			Cost			Quality		
Id.	***N***	**RII**	**R**	***N***	**RII**	**R**	***N***	**RII**	**R**
EX1	56	.739	25	56	.529	4	56	.421	4
EX2	54	.511	4	54	.541	5	54	.344	1
EX3	55	.476	1	54	.570	8	54	.433	5
EX4	55	.629	11	55	.647	14	55	.476	7
EX5	55	.505	2	55	.491	2	55	.360	2
Average		.572	A		.556	A		.407	A
CR1	49	.510	3	49	.469	1	47	.438	6
CR2	54	.630	12	54	.726	25	54	.641	22
CR3	52	.573	6	52	.692	19	52	.631	20
CR4	53	.615	9	53	.645	13	53	.600	18
CR5	53	.589	8	53	.558	6	53	.408	3
Average		.583	B		.618	C		.544	B
PM1	51	.573	7	51	.592	9	51	.573	14
PM2	51	.659	16	50	.612	10	51	.588	16
PM3	53	.683	20	52	.558	7	52	.519	9
PM4	51	.537	5	50	.508	3	50	.556	12
PM5	49	.616	10	49	.624	11	49	.629	19
PM6	49	.645	14	49	.698	22	49	.678	25
Average		.619	C		.599	B		.591	D
PC1	49	.694	23	49	.661	18	48	.688	26
PC2	53	.649	15	53	.766	26	52	.631	21
PC3	51	.690	22	50	.696	20	50	.592	17
PC4	48	.679	19	48	.700	23	49	.567	13
PC5	53	.683	21	53	.717	24	52	.554	11
Average		.679	D		.708	E		.606	E
FS1	48	.671	18	48	.650	15	48	.579	15
FS2	49	.665	17	51	.651	16	50	.644	24
FS3	46	.774	26	44	.636	12	44	.545	10
FS4	50	.712	24	50	.696	21	48	.642	23
FS5	51	.639	13	51	.651	17	51	.506	8
Average		.692	E		.657	D		.583	C

Larsen J.K., Shen G.Q.P., Lindhard S.M. and Brunoe T.D. (2015). Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects. Journal of Management in Engineering, 32(1), DOI 10.1061/(ASCE)ME.1943-5479.0000391, June. (SCI, among the Top Ten Article Download in 2016, 1431 times. Ranked 30/126 in Civil Engineering by JCR in 2015).

Table 5: Friedman´s test of time, cost and quality, * significant at the .01 level, two degrees freedom

Id.	*N*	Chi-Square	Asymp. sig.
EX1	56	64.679	.000*
EX2	54	48.620	.000*
EX3	54	21.938	.000*
EX4	55	35.724	.000*
EX5	55	33.476	.000*
CR1	47	8.719	.013
CR2	54	13.059	.001*
CR3	52	23.138	.000*
CR4	53	2.600	.273
CR5	53	42.471	.000*
PM1	51	1.089	.580
PM2	50	6.258	.044
PM3	52	33.724	.000*
PM4	50	4.541	.103
PM5	49	.338	.845
PM6	49	4.522	.104
PC1	48	1.339	.512
PC2	52	31.829	.000*
PC3	50	17.845	.000*
PC4	48	25.224	.000*
PC5	52	33.787	.000*
FS1	48	17.465	.000*
FS2	49	.261	.878
FS3	44	28.474	.000*
FS4	48	13.291	.001*
FS5	51	31.196	.000*

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Table 6: Wilcoxon´s test of T - time, C - cost and Q - quality, *significant at .003 level, sum of ranks is conducted by giving the lowest value one, the next lowest two and so on **effect size is significant at .01 level

Id.	*N*	Factor combination	Asymp. sig.	Sum of ranks	Effect size
EX1	56	EX1-T – EX1-C	.000*	8.0	.522**
	56	EX1-Q – EX1-T	.000*	31.5	.300**
	56	EX1-Q – EX1-C	.000*	57.0	.440**
EX2	54	EX2-T – EX2-C	.146	54.0	.695**
	54	EX2-Q – EX2-T	.000*	11.0	.614**
	54	EX2-Q – EX2-C	.000*	24.0	.466**
EX3	54	EX3-T – EX3-C	.001*	22.5	.632**
	54	EX3-Q – EX3-T	.146	100.5	.407**
	54	EX3-Q – EX3-C	.000*	6.0	.565**
EX4	55	EX4-T – EX4-C	.307	79.0	.596**
	55	EX4-Q – EX4-T	.000*	52.5	.299**
	55	EX4-Q – EX4-C	.000*	11.0	.407**
EX5	55	EX5-T – EX5-C	.588	156.0	.569**
	55	EX5-Q – EX5-T	.000*	24.0	.420**
	55	EX5-Q – EX5-C	.000*	22.0	.425**
CR2	54	CR2-T – CR2-C	.000*	46.0	.576**
	54	CR2-Q – CR2-T	.624	210.0	.456**
	54	CR2-Q – CR2-C	.003*	57.0	.519**
CR3	52	CR3-T – CR3-C	.000*	22.0	.557**
	52	CR3-Q – CR3-T	.016	108.0	.588**
	52	CR3-Q – CR3-C	.003*	27.0	.675**
CR5	53	CR5-T – CR5-C	.146	104.0	.728**
	53	CR5-Q – CR5-T	.000*	.0	.494**
	53	CR5-Q – CR5-C	.000*	9.5	.561**
PM3	52	PM3-T – PM3-C	.000*	43.5	.490**
	52	PM3-Q – PM3-T	.000*	8.5	.467**
	52	PM3-Q – PM3-C	.074	84.0	.575**
PC2	53	PC2-T – PC2-C	.000*	40.5	.605**
	52	PC2-Q – PC2-T	.425	183.5	.554**
	52	PC2-Q – PC2-C	.000*	12.5	.654**
PC3	50	PC3-T – PC3-C	1.000	85.5	.646**
	50	PC3-Q – PC3-T	.001*	71.5	.462**
	50	PC3-Q – PC3-C	.000*	27.0	.584**
PC4	48	PC4-T – PC4-C	.197	40.0	.808**
	48	PC4-Q – PC4-T	.000*	30.0	.593**
	48	PC4-Q – PC4-C	.000*	30.0	.544**
PC5	53	PC5-T – PC5-C	.097	88.5	.714**
	52	PC5-Q – PC5-T	.000*	46.0	.523**
	52	PC5-Q – PC5-C	.000*	34.5	.432**
FS1	48	FS1-T – FS1-C	.265	54.5	.660**
	48	FS1-Q – FS1-T	.005	56.0	.539**
	48	FS1-Q – FS1-C	.003*	26.0	.705**
FS3	44	FS3-T – FS3-C	.001*	17.5	.527**
	44	FS3-Q – FS3-T	.000*	25.0	.226
	44	FS3-Q – FS3-C	.005	28.0	.591**
FS4	50	FS4-T – FS4-C	.346	45.0	.779**
	48	FS4-Q – FS4-T	.001*	7.0	.632**
	48	FS4-Q – FS4-C	.010	51.0	.536**
FS5	51	FS5-T – FS5-C	.623	45.0	.725**

51	FS5-Q – FS5-T	.000*	52.0	.422**
51	FS5-Q – FS5-C	.000*	9.0	.516**

Figure captions list

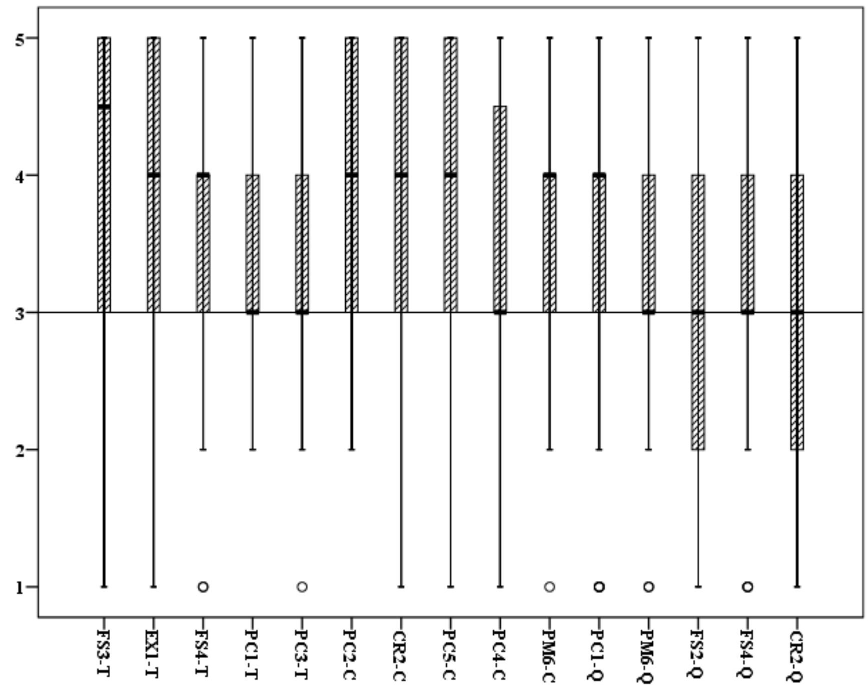

Figure 1: Boxplot for the five highest ranked factors affecting T - time, C - cost and Q - quality