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Accepted manuscript

Abstract

Purpose – Cost and time are two of the primary benchmarks, in which construction projects are measured. A variety of factors, however, affect cost and time on construction projects, as identified in previous research. This has led to a need for better understanding how factors affecting cost and time overruns on public construction projects can be managed more efficiently.

Design/methodology/approach – In this study 26 factors affecting cost and time overruns on construction projects were identified, through qualitative interviews with project managers from Danish governmental agencies and through a literature review. Through principal component analyses the 26 factors were subsequently narrowed down to 4 primary latent factors.

Findings – The identified four latent factors affecting cost and time overruns on public construction projects were, lack of quality management, lack of project pre- planning, lack of user management and lack of project management.

Originality/value – Previous research has focused on increasing knowledge by identifying and ranking factors affecting time and cost performance. This has led to the identification of an overwhelming number of factors to use for managing construction projects. The present research reduced the number of factors by clustering them into key latent factors responsible for most of the deviation in performance, narrowing the scope of construction cost and time management into a few tangible key focus areas. This supports and improves fast decisions making which is necessary in a changeable environment such as construction.

Keywords Principal Component Analysis (PCA), Latent Factors, Public Construction, Cost, Time, Management, Quality Control, Project Preparation, User Management, Project Management.

Paper type Research paper

1. Introduction

Time and cost issues are commonly experienced in the construction industry. Average cost overruns of 27.6 % on publicly funded construction projects, were documented by Flyvbjerg *et al.* (2003), whilst Assaf and Al-Hejji (2006) identified time overruns on similar projects, of between 10 and 30 %. Why such overruns occur can be hard to identify, one reason is the nature of construction projects, which is often complex, and involves a high degree of process uncertainty and constraints (Williams, 2005). Additionally, construction projects tend to be one of a kind projects (Molwus *et al*. 2017), which means a new organisation has to be formed and new collaborations between actors have to be established on every new construction project, which might lead to time and cost overruns.

In previous research, factors affecting construction time and cost were ranked by applying a relative importance index to reduce overruns of time and cost (Kazaz *et al.*, 2012; Olawale and Sun, 2010; Larsen *et al.* 2016). However, a relative importance index does, according to Doloi *et al.* (2012), not allow for correlation between factors. This means that factor analysis is necessary, to identify the factors in construction schedules, with the greatest impact in order to better understand where to focus on improvement. Schedule and budget are, in addition, interrelated and central elements in all construction projects, independent of geographical region.

Focus on pre-project planning is described by Larsen *et al.* (2018) as a means for reducing time and cost overruns, which according to Gibson Jr. *et al.* (2006) can lead to significantly improved project outcomes, improved end user satisfaction as well as a reduction in project time and cost. In a study of cost performance of pre-planned projects, Hanna and Skiffington (2010) found that pre-planned projects have an average profit margin of 23 %, compared to profit margins of minus 3 % for projects taking a more reactive approach to planning. Hwang and Ho (2011), additionally, found that proactively planned projects demonstrates a 10 % quality improvement, a 15 % reduction of project cost and time, as well as a 5 % reduction of project risk. Finally, Thomas and Ellis Jr. (2007) were able to reduce construction project duration by up to 30 %, through improved pre-project planning. Argumentation for why pre-planning is a necessity, for managing time and cost issues on constructions, is thus well established.

Previous research has a strong focus on identifying the different factors affecting time- and cost performance. These studies often identify more than 20 factors, which are all important to project management and project performance improvement. The factors are most often ranked with the top five highlighted as most important. There is, however, no evidence supporting that picking and managing the top five factors will ensure high project performance, as the top five factors themselves, does not necessarily explain the issues arising on construction projects. Issues which are often based on more than one factor in combination with others. This is confirmed by Durdyev (2021), who through a literature review of research mapping factors affecting cost overrun found that myriads of causative factors have been identified through numerous studies looking at the cost problem from different stakeholders, project types or countries. An example could be Lindhard *et al*. (2022), who from the contractor's perspective ranked key factors causing time-overruns in on site construction in Denmark.

By only focusing on a few important factors it is a risk that some other important aspects are overlooked or ignored due to lack of attention towards causal relationships between factors, resulting in sub-optimisation on projects. On the other hand, it is improbable to manage multiple factors at once. Therefore, there is a need for reducing the number of factors, whilst maintaining focus on the entire project. This can be achieved through studying the interrelationships between the factors, using statistical factor reduction, clustering multiple factors into key aspects, which are defined as latent factors, in this study.

In the present study, principal component analysis (PCA) is utilised to identify latent factors in pre-planning of public agency projects in Denmark. A few previous studies have applied factor reduction, mostly focusing on cost factors. Creedy *et al*. (2010), studied risk factors leading to cost overruns at highway projects. Pham *et al*. (2020), studied the impact of cost overrun causes on Transmission Line projects in Vietnam, and a few studies applied factor reduction to time factors, whilst Yap *et al*. (2021) studied critical delay factors in Malaysian construction projects. Only two studies were identified which focussed on public construction projects, utilising factor reduction on cost factors. Those studies were, Sinesilassie *et al*. (2018), who focused on Ethiopian public construction projects and Asiedu and Adaku (2020), who focused on public construction projects in Ghana.

In general, no previous studies have used factor reduction to identify latent factors to cost and time in public construction projects. Only limited research has studied the latent cost factors of public construction projects and most of such studies have been much different and from a non-comparable construction context to the Danish construction industry, which is the focal industry of the present study. The novelty of this research is hence the study of latent factors of both cost and time at public construction projects which is achieved through answering the following research question: "*Which latent project success factors can be identified through analysing project success factors cost and* *time factors and their synergies, in order to improve pre-planning and management of public construction projects*".

Answering this question provides a novel perspective to the well-established body of scientific literature of identifying factors, in the construction industry, through reducing multiple factors into four categories, whilst maintaining a holistic project scope. This will allow construction managers to better concentrate their scope, as the factors affecting or explaining most of the deviation in performance on construction projects have been identified, in order to guide actions when planning and making decisions on construction projects, providing a holistic management scope, with a priorities list of factors to consider, to reduce cost and time overruns, as well as an explanation of the causal effects of making changes to such factors. This knowledge of factors affecting time and cost, can additionally be applied when making decisions in both pre-planning of construction and during the construction phases.

The study was conducted through identifying factors affecting time and cost in the construction industry, through semi-structured interviews with respondents from governmental agencies in Denmark. The data was then analysed using PCA to reveal key factors, consisting of clustering highly correlating latent factors. This is described in the research methods section of the paper. The results from the analysis are then described, leading to a discussion of similarities and discrepancies between the results from this research and existing scientific literature. The last section, finally, presents a summary of the study and the answering of the research question.

2. Related work

Multiple articles have studied project success, and different definitions exist. The definitions have developed through time: From in the 1960s-1980s to focus on cost, time and quality, to in the 1980-2000 also include benefits to stakeholders and client satisfaction, from the 2000 and forward aspects such as environmental, social and sustainability impacts have been added (Ika and Pinto 2022). Based on this progression of understanding, project success can be understood as the ability to achieve project goals (e.g. cost-, time-, quality requirements), satisfy client and key stakeholders, while generating high social and societal impact and having low environmental impact (Liu and Walker 1998; Molwus *et al.* 2017)

A project's success criteria might vary and the goals and requirements expected when the project is delivered differ from the ones defined in the pre-planning phases (Browning 2019). Dvir and Lechler (2004) highlights, that the consultant's ability of identifying the correct end user requirements in the initial project phases, is significant when it comes to reducing changes mandated by the end user, miscommunication and conflict between project partners.

In this context, Wyke et al. (2021), furthermore, highlight a need for both design intent and design rationale, to be documented and stored throughout the pre-planning phases. This, according to their research, is necessary in order to encapsulate design knowledge and facilitate an informed decision-making process throughout the design-build process, as design reasoning is often lost on design and building projects, due to organisational changes and lack of structured documentation and exchange processes.

2.1 Client Quality control

Quality can be defined in multiple ways. Oxford learner's dictionaries define quality as "*the standard of something when it is compared to other things like it*" or "*how good or bad something is*" (Oxford learner's dictionary, 2021). Similarly, the International organisation for standardisation (ISO) define quality as "*the totality of features and characteristics of a product or service that bare its ability to* *satisfy stated or implied needs*" or "*the degree to which a commodity meets the requirements of the customer at the start of its life*" (ISO 9000, 2015). From a client perspective, a key task in quality control is to define how quality on a project is assured in the pre-planning phases, as well as define the arrangement of such activities.

Habibi and Kermanshachi (2018), emphasises the importance for an early focus on quality, because the performance of the construction phases heavily rely on the quality of the decisions made in the project's pre-phases. Thus, an improved quality control in the early design stage has the potential to reduce failures and their associated costs and delays. Khatatbeh (2022), additionally, found the implementation of the ISO 9000 paradigm had a significant positive effect on both project quality and performance, exemplifying why the focus on quality control is essential. Research, additionally, indicates that the cost of errors due to lack of quality control varies a lot between projects. Forcada et al. (2014) found the cost of error amounting to 16.5 % of the contract value, whilst Liu et al. (2020) found the cost of error to amount to between 2.1 and 10.3 % with an average at 5.0 %

Even though projects are typically evaluated based on the trade-off between time, cost and quality, Dvir *et al.* (2004) argues that such evaluation is not enough to assess project success or failure, whilst Radujković *et al.* (2021) argue that project success is a composite of various success criteria, tailored in alignment with the internal and external circumstances and features of each project to the stakeholders' needs and arrangements.

2.2 Project preparation

Throughout past decades, focus on project preparation has increased, as an effective way to ensure a successful project and a method for reducing risk, time and cost. Dvir *et al.* (2003), however, argue that project preparation and pre-planning will not guarantee project success. Lack of preparation and pre-planning will, however, lead to project failures and resulting in reduced quality, cost, and time performance (Kazar et al. 2022). According to Larsen et al. (2018), accurate project preparation combined with the quality of management during construction and those in combination are the most significant ingredients for ensuring that a project is completed successfully in terms of cost and duration.

Gibson Jr. *et al.* (2006) defines pre-project planning as "*the process encompassing all the tasks between project initiation and the beginning of detailed design*", and can be divided into four categories. Firstly, "*organise for pre-project planning*". Secondly, "*selection of project alternatives*". Thirdly, "*development of project definition package*", and fourthly, "*deciding whether to proceed with the project*".

Meredith *et al.* (1995), describes how project planning must involve a formalised plan to fulfil a project's goal. Hegazy and Menesi (2010), however, found that project planning is often too general, whilst Mpofu *et al.* (2017), found that poor design management and delay in producing design documents are a major cause of project delays in the United Arab Emirates. This argues for investment in project preparation efforts, as a means of reducing the effects of latent factors influencing project success. A detailed plan for how a building must be built and what components it consists of can, however, be hard to develop, as information regarding the building design is often developed and documented based on a poor modelling strategy (Alducin-Quintero *et al.*, 2012), and is fragmented and is not stored in any reliable format (Wyke *et al.*, 2021), which limits the retaining of knowledge gained from a project. (Bryde *et al.*, 2013). Knowledge, which not only benefits the project it is acquired from, with respect to better decision making and process understanding, but also following projects in terms of experience knowledge, which can aid the project preparation processes.

The pre-construction phase is, according to Hanna and Skiffington (2010), of vital importance compared to other project phases, for handling risk before issues affect the construction process, which is in accordance with research by Yang and Wei (2010), and Chang *et al.* (2010). In the Indian, American and Jordanian construction industries, research by Doloi (2012), Yi and Chan (2014), and Bekr (2017) furthermore, identified improper planning as the main causes for delays. Additionally, Lindhard et al. (2022), found improper or incomplete construction design as being the most common reason for delays. In their research, Zwikael *et al.* (2014), found that pre-project planning significantly improves the project performance with respect to time, cost, requirements and end user satisfaction on complex and high-risk construction projects. Larsen et al. (2017) studied public construction in Denmark, and confirms that poor pre-planning often leads to a poor definition of requirements and to optimistic budgets and schedules, thus making it impossible for project managers to achieve project success. Moreover, they add that the experience of the consultants used in the design phase are of vital importance for the pre-planning quality.

2.3 User Management

A central participant in all construction projects is the construction client, who is a central the actor with the ability to majorly influence project success factors. Lindahl and Ryd (2007), define construction clients as either individuals or organisations who commission a construction project on their own behalf or for someone else and the entity that takes care of the project economy, legislation, and regulation, ensuring the fulfilment of end user needs.

In their study, Kazaz *et al.* (2012), described how "owner-based" factors, consisting of bureaucracy and management faults, were found to be the most important reason for time delays across 16 countries. In addition to this, Doloi *et al.* (2012), found that lack of clarity in project scope was the fifth most important factor affecting construction projects time performance. A study by Lopez and Love (2011), looked into the costs of design errors and project changes and found the average direct cost amounted to 6.85 % and the indirect costs amounted to 7.36 % of the contract value, moreover they identified a huge fluctuation in associated cost.. The high associated costs also explain why the "agreed contract documents" used in the Danish construction industry demand that tender material must be unambiguous (Department of Transportation and Housing, 2018, 2019).

Project scope control is according to Nahod (2012), of crucial importance for project success and can only be achieved by managing project changes. Dvir and Lechler (2004) divide project scope changes into two categories. Firstly, "*plan changes*" and secondly, "*goal changes*", whereas the "*goal changes*" encompasses changes to the original project scope or project requirements, which are typically stipulated by the end users.

2.4 Project management

The client management process on construction projects is a balance between the client's various needs and requirements on one hand and the construction project management on the other hand, which according to Ahiaga-Dagbui et al. (2020), sometimes calls for a facilitator to bridge the gap between the client and the project manager and to increase collaboration and keep focus on best-for-the-project decisions. The primary task for the project manager is to fill the requirements set by the client, and ensure the construction project is conducted, so it meets the deadline, holds the budget, upholds legislation and specifications as well as expectations from the stakeholders. In the construction industry, an independent project manager, representing the stakeholders, makes the overall concept and pre-plans, whilst the responsibility of the more detailed plans depends on contract type. In general, a project manager's work is centred on planning the project activities and processes, in an order that increases activity effectiveness and value added, whilst a construction manager or master builder handles the execution of the planned plans and activities. However, experienced construction project managers only have limited time available to plan construction projects, which challenges the quality of both the pre, and post-planning as well as execution (Kelsey et al. 2001). Managers therefore need to identify which factors or activities are most decisive in relation to project or schedule performance, and thus should be given the most attention and be most decisive in the decision making (Salhab et al. 2022). According to Larsen et al. (2017), the ability to know what to focus on comes with experience, but to ensure an efficient project management a simplified decision-making approach is needed.

3. Research Methods

The present research was carried out as a two-step data collection. In step one, qualitative data was collected through semi-structured interviews, in which the research focussed on identifying factors affecting projects cost- and time performance. The identified factors were then used in step two, in which quantitative data was collected through applying a questionnaire approach.

3.1 Qualitative data collection

Interviews were conducted to identify factors affecting public construction project's cost and time performance.

The interviews were conducted following the guidelines of Kvale and Brinkmann (2009) Thus, the interviews were planned using four steps.

Step 1: Thematising. In this step the overall scope is defined. The interviews focused on identifying factors affecting time and cost performance of construction projects.

Step 2: Designing. In this step interviewees, number of interviews and overall design is identified. Interviewees were selected with outset in the largest public agency in Denmark, employing in total 80 project and property managers. The agency focuses on construction and facility management of courthouses, police stations and university buildings. Interviewees were selected by applying stratified sampling where it was ensured that all construction- and facility management departments were represented. In total 10 % of the managers were selected resulting in six project managers and two property managers. The job experience of the interviewees varied from 7 to 36 years with an average experience at 16 years.

Step 3: Interviewing. In this step the interviews were conducted. All interviews were carried out as face-to-face interviews whilst recording the conversation for further analysis. Moreover, the interviews were carried out in the native language of the respondents to avoid miscommunication.

Step 4: Analysing, identifying and categorising factors. The interviews led to the identification of twenty factors affecting cost and time performance in public construction projects. Finally, a cross-comparison with findings from the literature review expanded the factors to 26.

The identified factors were then used as the basis for designing the questionnaire. The 26 factors can be viewed in Table I.

3.2 Quantitative data collection

The questionnaire was sent to 111 project managers at four governmental agencies in Denmark, by email using the SurveyXact survey program. The project managers from the four agencies work with construction and maintenance of various types of public and governmental facilities. The focal facility types for each of the participating agencies is as follows.

Table I Variable descriptions with category classification applied in the questionnaire. Derived from the conducted interview study and the report from the National Audit Office of Denmark compared with existing research studies

			Studies using comparable variable descriptions																			
Category	**Id.**	**Variable 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 financing	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●		●	
	FS4	Unsettled or lack of project planning	●		●	●	●	●	●		●					●	●	●	●	●		
	FS5	Complexity or volume of the project				●					●		●					●		●		●

- Agency one: courthouses, police stations and university buildings.
- Agency two: military structures and buildings
- Agency three: maintenance of cultural and heritage structures.
- Agency four: prison facilities.

To ensure unambiguous questions, which were easy to understand for respondents, the questionnaire was reviewed with respect to “understanding”, “retention”, and “application”, as recommended by Sekaran (1992).

In the questionnaire, an ordinal five-point Likert scale was applied (going from 1 = very low to 5 = very high impact, with a “don’t know option”), measuring time and cost effects of each of the 26 factors individually.

In total 56 respondents replied, which amounts to a response rate of 50.5 %, which according to Flynn *et al.* (1990), satisfies the minimum acceptable response rate threshold of 50 %.

3.3 Parametric assumptions

To detect outliers, boxplots and Z-values for each factor were assessed as recommended by Field (2009). The Little’s Missing Completely at Random (MCAR) test were furthermore utilised to evaluate if missing values from the “don’t know” answers in the questionnaire, were randomly missing. The Little’s MCAR found no pattern between missing values ($\chi^2(572)=563.93$, $p\geq.0.5$ for cost related factors and $\chi^2(601)=593.10$, $p\geq.0.5$ for time factors), missing values were replaced with the factor mean as suggested by Field (2009).

The findings from a PCA can be generalised if the factors are found roughly to be normally distributed (Field 2009). Normality was proven by looking into the skewness and kurtosis of the data, where all values were in the range from -1.5 to 1.5 as required c.f. Byrne and Campbell (1999). Finally, approximately equal variance between factors was demonstrated by performing a Levenes’ test ($p\geq0.05$).

3.4 Data analysis

The present research aims to reduce the multiple factors, which affect time- and cost performance into a few tangible key focus areas, to ensure good performance. Having only a few factors to consider will provide hands-on guidance and support fast decision-making, which is often required by construction professionals in on-site construction.

The aim of dimension reduction methods is to identify a lower dimensional space explaining the higher dimensional space with as little loss in information as possible. Different approaches to dimension reduction exist including unsupervised methods such as singular value decomposition, and PCA, which only demand inputs, clustering and supervised methods such as sliced inverse regression which also requires a response variable. Since the data does not include a response variable, a supervised approach cannot be applied, hence, the PCA approach was preferred to use in this research.

PCA is a well-established and commonly used approach for dimension reduction (Koc et al. 2021; Guo and Lu 2022). In PCA, the input factors are through a linear transformation mapped into a lower dimensional space while the variance of the input factors explained by the latent factors in the lower dimensional space is maximised. These latent and linearly uncorrelated variables are the principal components.

In the present study, a PCA was applied in the data analysis, to explore the structure of the 26 factors by dividing them into underlying latent factors, as described by Doloi (2009). Orthogonal factor rotation was utilised as suggested by Doloi *et al.* (2012), to improve the interpretation of the results, as no robust theoretical ground for correlation between underlying factors in construction management has been established in previous research.

The latent factors: lack of quality control, lack of project preparation, lack of user management, and lack of project management, were developed based on a subjective evaluation of the clustering of factors in the PCA analysis, to efficiently summarise the contents of the clustering of factors in a one sentence format.

Before starting the analysis process a preliminary examination of the internal consistency of the data from the questionnaire was evaluated. The evaluation was based on a Cronbach alpha test at category level of the factors. A cut-off point of Cα≥.7 was additionally used, as suggested by Kline (2013), instead of the more generally accepted Cα≥.8, because questionnaire surveys are expected to measure a greater diversity of constructs than other types of tests. The results are shown in Table II below:

Table II Principal component analysis for time, variable loadings over .40 appear in bold

Var. id.	**Variable description**	**Levene´s test**	**Lack of Quality Control**	**Lack of Project Preparation**	**Lack of User Management**	**Lack of Project Management**
CR3	Lack of requirement specifications in tender documents	*F*(4,45)=.14,*ns*	**.862**	.106	.333	-.011
CR4	Lack of project structure or material	*F*(4,46)=.99,*ns*	**.850**	.265	.156	.254
CR2	Errors or inconsistencies in project documents	*F*(4,47)=1.31,*ns*	**.820**	.246	.119	.118
PM6	Inexperienced or newly qualified consultants	*F*(4,42)=.39,*ns*	**.681**	.122	.067	**.443**
FS1	Optimistic expectation to time, cost and quality	*F*(4,40)=.66,*ns*	.198	**.773**	.117	-.036
FS3	Unsettled or lack of project financing	*F*(4,40)=.60,*ns*	.020	**.762**	.308	.307
FS4	Unsettled or lack of project planning	*F*(4,44)=2.60,*ns*	.270	**.645**	.381	.230
PM2	Conflicts and disputes between project partners	*F*(4,44)=.39,*ns*	.173	**.633**	.279	**.447**
PM1	Miscommunication between project partners	*F*(4,44)=.02,*ns*	**.479**	**.632**	.032	.085
PM3	Slow user decision making	*F*(4,46)=1.45,*ns*	.195	.323	**.790**	-.070
PC5	Late user changes in the project or function	*F*(4,46)=.26,*ns*	.186	.353	**.776**	.145
PC3	Lack of identification of needs	*F*(4,44)=.79,*ns*	.128	.001	**.725**	**.485**
PC4	Lack of preliminary examination before design or tendering	*F*(4,42)=2.57,*ns*	.142	.212	.163	**.822**
PC2	Errors or omissions in the consultant material	*F*(4,46)=.46,*ns*	**.548**	.167	.037	**.670**
Eigenvalues			6.62	1.70	1.15	1.06
% variance			47.26	12.13	8.20	7.53
Cronbach alpha			.89	.89	.80	.83

The Cronbach alpha test revealed that the External Category with regards to cost is just below the .7 threshold, with a value at .664, thus these factors have in the following been applied carefully because the data consistency is somewhat questionable. All other categories passed the test both with regards to cost and time.

The analysis process was divided into three parts. Firstly, a preliminary evaluation of the internal consistency of the questionnaire data, of review factors with either too low (r≤.3) or too high (r≥.8) correlation values on the time and cost dataset. Secondly, a main analysis reviewing the R-*matrix'* multicollinearity determinant for the time and cost dataset with a minimum limit of 1E-04, and thirdly, an adequacy and sphericity sampling testing was conducted, by applying the Kaiser Meyer Olkin (KMO) measure with a minimum value of .5 (Kaiser, 1974), and a Bartlett's test with a minimum value of ≤.5 (Field 2009).

Identified latent factors with eigenvalues above 1.0 were retained in accordance with Kaiser (1960) and Field (2009). A Cronbach alpha test was furthermore applied to evaluate the latent factors internal consistency and a cut-off point of Cα≥.7 was again used.

4. Results

The results from the quantitative data acquisition and the PCA are divided into two categories. Firstly, a PCA analysis for time and secondly, a PCA analysis for cost.

4.1 PCA for time

The PCA for time was split in two parts. Firstly, a preliminary analysis, initiated by reviewing factors with correlation values either below .3 or over .8, which led to the exclusion of ten factors (EX1, EX2, EX3, EX5, CR1, CR5, PM4, PM5, PC 1 and FS2). The 16 remaining factors were subsequently tested through orthogonal rotation, where two additional factors (EX4 and FS5) were excluded, due to communality values below .6.

After the preliminary analysis, 14 factors remained, to be scrutinised in the main analysis, using orthogonal rotation. The Kaiser Meyer Olkin (KMO) test was performed with KMO=.87, to confirm sampling adequacy, which confirmed that all KMO values related to the 14 factors were a minimum of ≤.79, which is above the acceptable .5 limit. Bartlett's test furthermore demonstrated that the variables correlation were adequately large, to support the use of PCA (sphericity of $\chi^2(91)=316.11$, $p<.001$). For this, Kaisers' eigenvalue criterion of 1.0 was used as the cut-off point, which led to the identification of four latent factors, as shown in table III. First of all, the identified latent factors all had values above 0.7 and passed the Cronbach alpha test of the internal consistency.

Factors clustering at latent factor one explained 47.3 % of the total variance and indicated quality control in terms of six factors (CR3, CR4, CR2, PM6, PM1 and PC2). The second latent factor, lack of project preparation, explained 12.1 % of the total variance in terms of five factors (FS1, FS3, FS4, PM2 and PM1). Lack of user management, was identified as latent factor three, which was identified by three factors (PM3, PC5 and PC3) explaining 8.2 % of the total variance. Finally, factors clustering around latent factor four, identified as lack of project management explained that 7.5 % of the total variance indicated by five factors (PM6, PM2, PC3, PC4 and PC2).

4.2 PCA for cost

Similarly, to the PCA time analysis, the cost analysis was conducted in two parts. Firstly, a preliminary analysis and secondly a main analysis. In the preliminary analysis, ten factors were removed (EX1, EX2, EX3, EX4, EX5, CR1, PM3, PM4, PM5 and PC1) based on a correlation review. The 16 remaining factors were subsequently used in an initial analysis applying orthogonal rotation. Four factors (PM1, PC4, FS1 and FS5) were, based on this analysis, also excluded, due to communality values below .6, as shown in table IV. First of all, the identified latent factors all had values above 0.7 and passed the Cronbach alpha test of the internal consistency.

Table III Principal component analysis for cost, variable loadings over .40 appear in bold

Var. id.	Variable description	Levene´s test	Lack of Quality Control	Lack of Project Management	Lack of Project Preparation
CR3	Lack of requirement specifications in tender documents	$F(4,45)=2.20, ns$	**.833**	.222	.085
CR2	Errors or inconsistencies in project documents	$F(4,47)=.50, ns$	**.707**	**.550**	.166
CR4	Lack of project structure or material	$F(4,46)=.71, ns$	**.678**	**.415**	.302
CR5	Unforeseeable authority requirements or restrictions	$F(4,46)=1.07, ns$	**.674**	-.263	**.474**
PM6	Inexperienced or newly qualified consultants	$F(4,41)=1.01, ns$	-.027	**.775**	.281
PM2	Conflicts and disputes between project partners	$F(4,43)=.82, ns$	.248	**.770**	.310
PC2	Errors or omissions in the consultant material	$F(4,46)=1.02, ns$	**.501**	**.708**	.109
FS4	Unsettled or lack of project planning	$F(4,44)=1.31, ns$	.377	**.528**	**.499**
FS2	Political focus on reduced project costs or time	$F(4,44)=.24, ns$	-.068	.313	**.812**
FS3	Unsettled or lack of project financing	$F(4,38)=.34, ns$	.367	.254	**.754**
PC5	Late user changes affecting the project or function	$F(4,46)=.66, ns$	**.511**	.148	**.650**
PC3	Lack of identification of needs	$F(4,44)=.64, ns$	.331	**.443**	**.618**
Eigenvalues			6.42	1.31	1.11
% variance			53.49	10.94	9.25
Cronbach alpha			.88	.91	.87

12 factors were then used in the main analysis applying orthogonal rotation once more. The KMO test was performed with KMO=.87, to confirm sampling adequacy. All KMO values were at a minimum of ≤.79 with respect to the 12 factors used in the analysis, which is above the acceptable threshold limit of .5. Bartlett's test additionally showed that the variable correlation of the factors were large enough to grant use of PCA (sphericity of $\chi^2(66)=277.22$, $p<.001$). Kaiser's eigenvalue criterion of 1.0 was again used as the cut-off point, revealing three latent factors.

Factors clustering at latent factor one explained 53.3 % of the total variance. A lack of quality control was indicated as a latent factor in terms of six factors in the analysis (CR3, CR2, CR4, CR5, PC2 and PC5). The second latent factor explained 10.9 % of the total variance in terms of seven factors (CR2, CR4, PM6, PM2, PC2, FS4 and PC3), and indicated lack of project management as another latent factor with respect to construction project costs. Finally, factors clustered around latent factor three, explaining 9.3 % of the total variance, and lack of project preparation was indicated in terms of six factors (CR5, FS4, FS2, FS3, PC5 and PC3).

Table IV, inserted here.

5. Discussion

In this section the identified four primary underlying latent factors affecting time and cost are discussed. This is done through comparison of similarities and discrepancies between the results presented in this paper and the existing literature presented in the related work section.

5.1 Lack of quality control

Lack of quality control on construction projects, was found to be the primary underlying latent factor affecting cost and time, which is in accordance with findings by Habibi and Kermanshachi (2018), who emphasised the importance of early quality control focus, in their research. The importance of quality assurance and control in a Danish context is additionally described by Loll *et al.* (2018). In this study, lack of quality control was indicated in terms of six factors in the analysis, with respect to both time and cost, whereas four of the six factors were similar for both time and cost, however, with different weighing of the factors. The primary factor for both were nonetheless, lack of requirement specification in tender documents, which is in accordance with research by Mpofu et al. (2017), who described incomplete design at the time of tender as one of the top variables for construction delay in the United Arab Emirates. Requirement specification documents are in Denmark typically developed as part of the preliminary project. A phase in the pre-planning process, which occurs well before construction begins (Wyke *et al.*, 2021; Landgren *et al.*, 2019; FRI and Danske ARK, 2012). Hence, development of better-informed tender documents is needed, to improve quality control factors on construction projects.

According to Loushine *et al.* (2006), the largest barriers to implementation of quality systems in the construction industry are "shoddy implementation", "the nature of the construction work", and "the industry itself". Hoonakker *et al.* (2010), additionally observed that the attitude of construction companies to the definition of quality often amounts to appreciating how something "looks" or "feels". They further argue that "the nature of the construction process" itself, is the largest obstacle to improving quality, which is in line with research by Habibi and Kermanshachi (2018), describing how continuous inspection and preventive decision making in the project design stage will reduce failure cost, resulting from lack of quality control. Hence, quality control of a project is closely connected to the planning of a project or designing processes, arguing that a better knowledge exchange is needed between people planning and conducting the pre-planning and the ones managing the quality control. This exchange of knowledge can be aided, through adding a description of how something must be done to ensure quality on a project. However, other information such as the intent behind a design and its prescribed quality as well as the rationale or justification for why a solution is the way it is (Lee and Lai, 1991), for a project's processes and solutions, might also improve the quality control process. Mainly, because it explains both what and why a certain quality must be achieved, and requires project managers to consider this aspect of the project more thoroughly. Kozemjakin da Silva *et al.* (2013), additionally argue how there is a strong potential in knowing more than *what* was done in previous designing, but also in knowing *why* it has been done, emphasising the documentation and exchange of design knowledge, as a means of improving quality on subsequent projects, as well as project preparation.

5.2 Lack of project preparation

In the analysis, lack of project preparation was found to be the second most important latent factor affecting time performance and the latent factor with the third greatest effect on cost performance. Pre-construction planning does according to Hanna and Skiffington (2010), allow the construction manager to troubleshoot project complications before they affect a project. Project planning is therefore, not surprisingly one of the first tasks, which is carried out in the initial project phases (Zwikael and Globerson, 2004).

Lack of project preparation was identified in terms of five factors with respect to time and seven factors with respect to cost. Most factors, which were found to influence the two categories were different, however one factor, "unsettled or lack of project planning" (FS4), was identified as a common factor for both time and cost. This is also in line with research by Gibson Jr. et al. (2006), who describes how lack of project experience, limited time or will to put more effort into project preparation, has been recognised as a problem for a long time, even though many experienced project managers acknowledge the importance of project preparation. It further adds to existing research by Meredith et al. (1995), underlining the importance of a formalised plan to ensure fulfilment of project goals, as well as research by Dvir et al. (2003), describing how lack of project planning will lead to failure. Even though success cannot be guaranteed, if project planning is carried out, it can help reduce both cost, time and risk on a project (Dvir et al., 2003).

Finally, the importance of data-availability during project planning is highlighted by Wyke et al. (2021), explaining that multiple types of design knowledge must be documented and stored as well as be exchangeable throughout pre-planning and construction phases, in order to support decision-making, providing a foundation for better time, price and quality management and the fulfilment of project goals. It seems obvious, in this regard, that the more design knowledge is shared between the people doing the designing of a building, the people doing the pre-planning for construction, and those actually constructing the building, the easier it becomes to do efficient decision-making. However, the reasoning behind a solution taken in early design phases, is not necessarily available during pre-planning, and it might, additionally, not include the arguments for why a given solution must be constructed in a specific way.

According to Bracewell *et al.* (2009), and Wang *et al.* (2011), design knowledge such as design rationale, can be very useful for designers, to know how previous designs evolved and in what context such evolution happened, through its record of the issues addressed, the options considered, and the arguments used when specifying decisions during the design process.

Without such design knowledge project managers, however, might face issues when making decision during the construction phases, as their decisions can affect other parts of the construction project in terms of both cost and time, not obvious from the drawings and descriptions of the design received from the designers. Effects which would be obvious if the project manager were allowed access to the design rationale, allowing the project manager a better foundation for decision making.

5.3 Lack of user management

Lack of user management was found to be the third most time-affecting latent factor for construction projects, however not found as an influential latent factor on project cost. As described, one study identified "owner-based factors" as the most important reason for project delays in some countries (Kazaz *et al.*, 2012), whilst another study identified "goal change" or changes to the original scope or the requirements to a project as a reason for issues arising on construction projects (Dvir and Lechler, 2004). This fits well with the results from the analysis in this study, in which the time performance was affected in terms of three factors. Firstly, "Slow user decision making" (PM3). Secondly, "Late user changes in the project or function" (PC5) and thirdly, "Lack of identification of needs" (PC3).

In addition to coinciding with existing literature, the revealing of the third factor (PC3) also argues for the use of better identification processes for project goals and requirements on construction projects, capturing the needs and wishes of the client as well as other end users. However, systems and methods for adequate capturing of end user satisfaction, are according to Lindahl and Ryd (2007), not currently available in the construction industry. As end user satisfaction, according to Lipovetsky *et al.* (1997), are more important than project time, project cost and project required specifications, a gap between user management and project management needs to be closed. However, slow decision making, late changes to a project or function as well as the lack of identification of needs, are all factors, affecting time and cost, and factors which can be managed through better pre-planning and better information and knowledge exchange between all project participants from end user and building owner to the various disciplines participating in the initial designing through on-site planning. This argues, that the effect of the factors in terms of user satisfaction might be the most important aspect on a construction project. However, without managing the factors affecting the satisfaction, it cannot be achieved.

Finally, it is important to recognise that construction projects tend to be one of a kind projects, as also described by Molwus et al. (2017), hence new relationships must be established between the actors involved in the construction project, which can be a challenge. Especially, if the foundation for decision making, such as design drawing, descriptions, schedules and other types of documents holding design and building knowledge is lacking or entirely missing. Again, arguing for a more thorough and structured documentation of design knowledge during the design phases, which can be exchanged with project participants during pre-planning and construction.

5.4 Lack of project management

In our analysis, lack of project management was found to be the latent factor with the fourth greatest effect on construction time performance and the second greatest effect on construction projects. As described by Zwikael and Sadeh (2007), project completion to the satisfaction of stakeholders is the central task for project managers. A task, which can only be achieved if quality is specified, and if the actual and perceived quality is aligned on the project. This is also apparent in the analysis in which, "lack of identification of needs" (PC3) is an affecting factor for both time and cost on construction projects. It is furthermore in accordance with Zwikael (2009), who found that the level of project planning and the level of project success on completion are the highest in the construction and engineering sectors, when comparing sectors.

Zwikael (2009), further argues that because critical planning processes are insufficient in the construction industry, and that construction project managers should invest more effort in planning. Hence, arguing that project management is equivalent to knowledge management in some regards.

Larsen et al. (2015), additionally, found that the importance of pre-planning was acknowledged by the project managers, but time restrictions most often limited the pre-planning and feasibility studies. Better use and re-use of design material from initial design phases, describing wished of the client and end-users, demands for function and building use, as well as the reasoning behind the selected design solutions, could nonetheless provide project managers supplementary information and knowledge allowing additional, improved or better-informed planning on a project.

6. Limitations

- The study has a geographical limitation, as the data was based only on project managers employed in Danish public agencies, limiting the generalisability of the results, when comparing them to construction industries in other countries.
- Generalisation of the results is furthermore only possible if others outside the sample experience similar latent factors.
- The sample size must be taken into consideration with respect to statistical analysis.

7. Conclusion

Through semi-structured interviews and a literature review, 26 latent factors affecting construction project's time and cost performance were identified. A questionnaire survey was afterwards designed to identify the importance of the 26 factors in relation to cost and time performance of public construction projects in Denmark. The results from this data collection was then used in a PCA, utilising orthogonal factor rotation.

The analysis revealed that time and cost performance of most construction projects are affected by the same four latent factors. The four identified factors were: 1) lack of quality control, 2) lack of project preparation, 3) lack of user management, and 4) lack of project management.

Even though this research focuses solely on public construction projects, comparison with previous research on closely related project types, however shows that factor affecting time and cost of a construction project, is largely the same on public and privately funded projects. Future research will be able to confirm that the same relationship exists.

Managing time and cost performance has proven difficult, despite a great effort to improve the industries performance, additional cost and prolonged projects are still very common. Previous research has focused on increasing knowledge by identifying and ranking the factors affecting both time and cost performance. Due to the task's high complexity, this has resulted in an overwhelming number of factors, making management and control difficult. The present research helps in creating a simple approach for handling a complex problem by reducing the number of factors by clustering them into key latent factors responsible for most of the deviation in performance. From a practical perspective, both client consultants and construction contractors can benefit from focusing their attention on the management and improvement of the identified four latent factors. By improving these four latent factors, the general level of cost and time performance can be improved, which would not be the case, if focussing on only one of the factors, or if the causal relationship between factors had not been identified.

The identified four latent factors includes: quality control, project preparation, user management and project management, which all are consultant related tasks, which are largely planned, and often conducted well before a building process begins on a construction project, explaining and arguing why more focus and collaboration should be introduced in the construction industry, in and between design and construction phases.

Future research can focus on developing hands-on tools for managing and controlling the four latent factors and how decision-making and control can be supported by improving how knowledge documented throughout the pre-planning phases is stored and exchanged between project participants.

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