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EXPLORING THE ROLE OF TCQ FACTORS IN ECONOMIC PROJECT SUCCESS

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Abstract

This study examines the interrelationships among the Time, Cost, and Quality (TCQ) dimensions of project performance and their combined influence on economic outcomes. Using Multiple Correspondence Analysis (MCA), we identify typical performance patterns and assess whether strong performance in one dimension tends to align with others. The results reveal asymmetric but significant associations among TCQ categories, with quality and time showing a stronger link to profitability than cost. To determine the relative importance of each factor, we apply literature-based statistical indices (QBI′, SDI′, L′), which confirm that quality is the most differentiating dimension, followed by time. These findings offer a data-driven contribution to prioritizing evaluation criteria in project performance assessment.

Keywords: economic project success, Iron Triangle, Multiple Correspondence Analysis, project performance, TCQ

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1. Introduction

One of the basic tenets of project management is that the success of projects is assessed along the three factors of the Iron Triangle - time, cost, and quality (TCQ). These factors affect project performance individually and in interactions with each other and should be considered in their interrelationship. While previous research has pointed to the strength of the relationship between time and cost in many cases, a deeper analysis of the three factors is rarely carried out using statistical methods.

The present study aims to explore the patterns of the TCQ factors and their relationship to each other, as well as which factors and categories are associated. In addition, we seek to answer which of the three basic project evaluation dimensions plays a more decisive role in economic performance. The research will focus on how better performance along a specific factor, such as on-time delivery or sound quality, influences perceptions of other factors and in what combinations they contribute to successful projects.

The research hypothesizes that quality and time play a more critical role than cost in the economic performance of TCQ elements. Moreover, it is hypothesized that better performance in one factor is positively associated with better performance in the other. The multi-correspondence analysis used in this research allows visual and statistical exploration of the relationships between TCQ categories and the relationship of each performance pattern with economic outcomes.

2. Literature review

2.1. Traditional Understanding of Project Success: Time, Cost, Quality (TCQ)

The classical interpretation of project success is based on the fulfillment of time, cost, and quality dimensions, which is confirmed by numerous studies [1], [2], [3]. This research considers achieving TCQ balance a fundamental project management goal, especially in cases where an imbalance in performance indicators can lead to undermining project success. Peng et al. (2010) and Golpîra (2014) have shown with quantitative models that the integrated optimization of the three factors supports

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successful decision-making more effectively [4], [5]. Knoepfel (1989) also affirms that successful project delivery depends on systematic cost–quality integration across the project life cycle, emphasizing structured phase control, functional hierarchies, and the alignment of technical outcomes with financial expectations [6]. However, these analyses are often theoretical in nature and do not examine in detail how different combinations of TCQ performance affect the economic performance of projects.

Our study goes beyond the above models by examining the existence of TCQ factors and analyzing their relationships and their effects on economic performance on an empirical basis.

2.2. Redefining the role of TCQ factors in project evaluation

Recent studies increasingly reconsider the weighting, relationship, and evaluation logic of the TCQ dimensions. Gardiner and Stewart (2000) challenge traditional "on-time, on-budget" success indicators and emphasize NPV as a superior metric, yet they still highlight TCQ's influence on shareholder value [7]. Atkinson (1999) argues for expanding the Iron Triangle with broader stakeholder-oriented criteria [8]. Aubert et al. (2013) and Joseph Abani & Ogedengbe Alaba (2023) show how weak cost control negatively impacts quality and timeliness, highlighting the need to analyze TCQ jointly rather than in isolation [9], [10]. Clements and Si (2011) also advocate for a shift in evaluating project success, arguing that not only TCQ compliance but also the pace and adaptability of execution determine outcomes - elements often shaped by the regulatory environment and project dynamics [11]. Furthermore, Weijermars (2012) introduces a team alignment model that quantifies how internal collaboration, and shared goals influence the probability of project success, ultimately affecting economic value despite TCQ metrics [12].

While the above studies relied primarily on qualitative or limited empirical data, the present research attempts to explore the relationship between TCQ categories and economic performance through quantitative analysis using a novel statistical methodology.

3. Analytical Framework and Methodology

The empirical analysis is based on a dataset collected through an online survey conducted between November 2019 and August 2022. The research specifically targeted projects in which there was disagreement among participants regarding the perceived success of the project. A total of 372 responses were collected, of which 354 were deemed valid for analysis. The survey employed a snowball sampling method, making the sample statistically non-representative but suitable for exploratory purposes. Projects covered a wide range of sectors—from services to manufacturing and healthcare to finance—and varied in size from micro-projects (1–9 participants) to large-scale initiatives involving over 250 team members. Organizations included both public and private actors, and respondents held diverse roles with varying levels of project management experience. Descriptive statistical analysis was performed using Minitab, Statistica, and complementary spreadsheet tools (see the dataset in [13]).

To explore which categories of the TCQ dimensions (Time, Cost, and Quality) tend to be mutually associated or mutually exclusive, we employed Multiple Correspondence Analysis (MCA) as a multivariate statistical technique. Based on a smaller sample, an earlier study investigated associative relationships among project success factors, including using standards at both organizational and project levels, with a particular focus on TCQ interactions [14]. That preliminary analysis only revealed a statistically significant moderate association between time and budget adherence. Time demonstrated a weaker-than-moderate correlation with economic outcomes, while quality showed a moderately strong relationship with profitability—but only within the for-profit sector. The most robust correlations with project profitability were observed in cases where project management and public safety standards were explicitly applied. We hypothesized that the use of standards in project execution might reflect more structured operational conditions, increased discipline in execution, heightened attention to quality, and improved adherence to time and cost constraints—factors that, collectively, appear to influence financial outcomes positively.

In the earlier analysis, categories to meet the assumptions of the χ^2 test were aggregated due to sample size limitations, resulting in predominantly 2×2 or 2×3 contingency tables. This aggregation precluded the use of two-dimensional correspondence plots to visualize category-level associations. In contrast, based on a significantly larger dataset, the present study enabled a more refined statistical treatment. Nevertheless, descriptive statistics (see Tables 1 and 2 in [14]) revealed that only a small proportion of projects concluded significantly earlier or with substantial budget underruns. The scarcity of these cases generated low expected cell frequencies in corresponding contingency tables when cross-tabulated with other variables. To address this issue, we grouped the 'Much earlier,' 'Earlier,' and 'On time' categories under a unified label ('On Time') for the time variable. Similarly, 'Much under budget' and 'Under budget' categories were merged into 'Under budget,' while 'Much over budget,' which represented only 5.65% of cases, was combined with 'Over budget.' Quality categories, however, remained disaggregated due to sufficient cell sizes.

Consequently, each TCQ factor was consolidated into three performance levels:

- Time: On Time, Late, Much Late
- Cost: Under Budget, On Budget, Over Budget
- Quality: retained original categories

Pairwise independence tests (χ^2) conducted among the TCQ variables yielded statistically significant results. However, the strength of association (as measured by Cramer's V) ranged from 0.15 to 0.18, indicating weak-to-moderate associations.

Using the first two dimensions, a comprehensive MCA performed on the entire dataset produced a correspondence map (Figure 1) in which two distinct clusters emerged. The first cluster grouped the categories 'On Budget,' 'Exactly' (referring to expected quality), and 'Late,' suggesting a tight association. A second, looser cluster consisted of relatively proximate categories but more dispersed. Based on spatial proximity within the map, the following typologies were inferred:

- Projects delivered close to budget, with acceptable quality, and only minor delays
- Projects characterized by cost overruns, inferior quality, and significant time delays

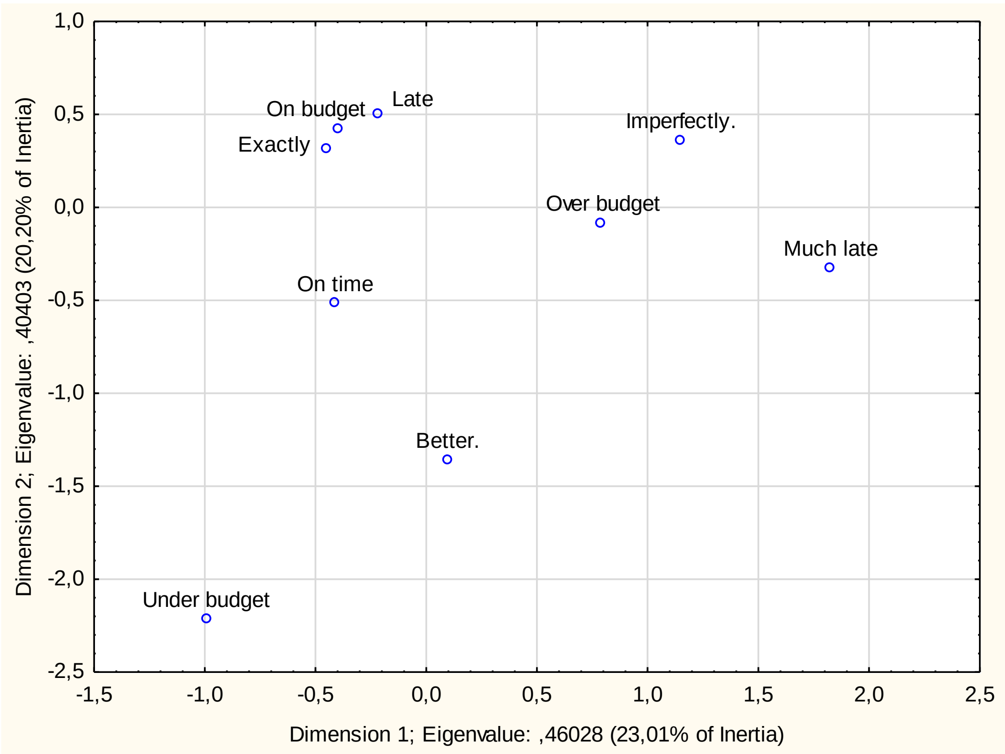

Fig. 1. Two-dimensional correspondence map

Suppose one were to rely solely on these two clusters and their respective PUI (Project Utility Index) scores confirmed by Mann–Whitney tests. In that case, one might infer that the first group represents economically successful projects. In contrast, the second corresponds to economically underperforming ones. However, three additional categories—each representing the highest performance level within a TCQ dimension—appear spatially isolated from both clusters and each other. This spatial detachment complicates any simplistic interpretation of project profitability solely based on TCQ associations.

Notably, projects completed on time (or earlier) and meeting or exceeding quality expectations were situated equidistant from both clusters, suggesting that high performance in time and quality does not necessarily coincide with either cost category. High-quality outcomes were found to occur under both budget-saving and budget-exceeding conditions. Conversely, low-quality performance typically coincided with budget overruns and substantial delays. At the same time, high quality was more frequently associated with budget adherence and modest delays—patterns consistent with broader project management experience.

4. Relative Importance of TCQ Dimensions

The results so far show that the Iron Triangle factors together show significant differences in the economic performance of projects. We also saw correlations between the categories of factors. A comparison of the means shows that the time and quality factors appear to be the most significant factors in economic performance. The results are not statistically conclusive, while the PUI indicator shows a statistically significant difference. The correspondence analysis confirms the hypothesis from the study of the PUI indicator that better performance of one factor is associated with better performance of another factor and vice versa. However, the result is still not clear. The correspondence map also shows that "Better" quality and timely (or earlier) performance can occur with any budget. Better quality is mainly associated with projects that are completed on time (or earlier), but if the project is late (and this is typical), then it is almost equally distant from the "Late" and "Much late" categories, i.e., there is nearly the same probability that the project product can be of better quality for small and significant delays. The question arises: do each of the TCQ elements have the same weight in evaluating projects, or are some more important than others?

First, the relative ranking of the TCQ factors was examined using the indices presented above. Table 1 summarises the distribution of frequencies and relative frequencies of the three factors between categories, as well as the median and the calculated values of the indices presented above.

Table 1. Frequency distribution, medians for the TCQ categories

Numeric label	Time		Cost		Quality	
	f_k [db]	g_k [%]	f_k [db]	g_k [%]	f_k [db]	g_k [%]
1	51	14,49	20	5,90	77	22,32
2	169	48,01	106	31,27	202	58,55
3	119	33,81	184	54,28	66	19,13
4	12	3,41	27	7,96	---	---
5	1	0,28	2	0,59	---	---
Total	352	100,0	339	100,0	345	100,0
Median	2		3		2	

As a reminder, a score of 1 is the worst performance for all factors (long delays, high overruns, and below-expected quality). In contrast, a score of 5 (or 3 for quality) is the best performance for the client and the owner/project manager. The median is useful for selecting the evaluation, while the Leti and QBI index helps express the consensus level on the chosen assessment [15], [16]. The median is the measure of the scale median value for all factors except time, which suggests that both factors are equally important. In terms of median values, time is an important factor; here, the median deviates from the mid-point of the scale downwards, i.e., projects are typically delayed. This is also shown by the value of the SDI' index, which is closest to 1 for time (SDI'T=0.683). This indicates a shift in the distribution towards the lower end of the scale, an asymmetry similar to the other two factors. The smallest deviation from symmetry is SDI'=0.5 for the Q-factor SDI'Q= 0.516, but the value is also above 0.5. The other two indices show that both the L' and QBI' indices are largest at Q, indicating more significant heterogeneity. For the quality factor, the data are more concentrated in one category, which may be partly due to the different number of categories. Although all the indices are normalized, the Q scale has three levels, while the T and C factors have five, making the comparison somewhat tricky. This may cause some variation in the values of the indices, but the approximately 1.5 times higher QBI' and L' values compared to the others are striking. Based on the L' and QBI' indices, quality comes first in the relative order of the TCQ factors. These elements of the Iron Triangle suggest that quality may be an important factor in addition to time.

5. Conclusions

The results of the multicorrespondence analysis show that certain TCQ categories - such as on-time, on-budget, less delay, and quality as expected - are closely associated, while other combinations - long delay, over-spending, poor quality - are also clustered. However, cost does not always show a clear relationship with the other factors, so the associations are asymmetric.

Of the three factors, quality and time show the strongest relationship with economic performance. Quality is the most differentiating factor (highest QBI' and L' indices) and time is the most asymmetrically distributed factor (highest SDI'), which confirms their dominance.

The results partially support the hypothesis. Better performance in one factor is often associated with better performance in the other, but the relationship between budget performance and quality/time is not always clear. Quality appears to be the most important, time is also important, and cost is less important for economic performance.

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