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Relationship Between Time Inflation and Financial Inflation in Road and Bridge Projects in Iraq: An Empirical Analysis

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ABSTRACT

Time and cost overruns are problems that persist in projects involving transportation infrastructure, especially in developing regions. This research examines the empirical relationship between time inflation (TI), which is defined as the percentage increase in project duration from the original schedule, and financial inflation (FI), which is defined as the percentage increase in project cost from the original budget for road and bridge projects in Iraq. The problem that the research aims to cover is the escalation in project costs associated with time inflation, with the aim of quantifying this relationship to aid in project planning and risk management. Using a quantitative method, data from 18 completed projects were analyzed using descriptive statistics, Spearman's rank correlation (ρ), and simple linear regression. The results show a very strong positive monotonic relationship between TI and FI ($\rho = 0.743$, $p < 0.01$). Regression analysis shows that the TI variable can explain about 32.9% variance in the FI variable ($R^2 = 0.329$), and 1% increase in the TI variable can lead to an average increase of 0.556% in the FI variable. The study concludes that although time inflations are a significant cause of financial inflation in Iraqi road and bridge projects, there are other factors that have a significant influence on financial outcomes. These findings highlight the need for proactive schedule control as a basic cost-control strategy and suggest improved contractual and monitoring structures to reduce the financial consequences of delays.

Keywords: Cost overrun, Financial inflation, Iraq, Road and bridge projects, Time inflation.

1. INTRODUCTION

Time performance is a key measure of performance in transportation infrastructure projects, especially road and bridge construction projects, where time inflations are often matched by substantial cost overruns and loss of socio-economic benefits. Despite the significant improvements in project planning and project control methods, time inflation has remained a major problem in all public infrastructure projects in the world, and more so in developing and transitional economies. Past empirical research with consistent findings

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demonstrates that delays do not just lead to an increase in direct construction expenditures, but also lead to increased indirect and administrative costs, thus lowering the value of the project and delaying the delivery of critical transport services **(Bordat et al., 2004; Bhargava et al., 2010).** The Extension of Time (EOT) is normally allowed to respond to unforeseen circumstances like alteration in design, site constraints, insufficiency of resources, or external interruptions. Although EOT provisions aim to maintain the equity of contracts, prolonged project durations put projects at risk of reduced labor productivity, increased costs of materials, and accruing overhead over time. Accordingly, time inflation and cost overruns are correlated rather than independent phenomena, indicating that schedule performance and financial performance are closely interrelated **(Stoll et al., 2006; Senic et al., 2024).** There is a considerable amount of literature on the causes of delays and cost overruns in road and bridge projects, and it includes inadequate design, poor coordination, financial constraints, and unfavorable environmental conditions as common factors **(Aryal and Dhakal, 2022; Belay et al., 2021).** A large part of this work, however, is devoted to cost increases in aggregated form, and relatively limited studies have quantitatively examined the extent to which schedule extensions translate into financial escalation, particularly using project-level empirical data. Several studies have examined the relationship between delays and cost performance using correlation-based and ranking approaches **(Gebrehiwet and Luo, 2017)**; however, detailed quantification of this relationship using project-level datasets remains limited. Furthermore, there are few comparative studies between bridge and road projects, even though they involve distinct technical complexity, construction stages, and resource demands **(Bhargava et al., 2010; Wibowo and Santosa, 2024).** From a methodological standpoint, researchers have been conducting analytical studies with various approaches to investigate the link between time and cost, including regression, earned value management, time-cost trade-off models, and statistical probability simulation models **(Hosseini et al., 2023; Wang et al., 2021).** While these have improved our understanding of time-cost relationship, these are also context-specific, particularly in the case of the setting that is mired in institutional, market, and governance complexities **(Al-Hazim and AbuSalem, 2015; Romero and Esenarro, 2024).** With this in mind, there is still a lack of empirical studies conducted on quantifying financial inflation and time inflation and its relationship with the use of actual project data, which is absent in the Middle East. To overcome this gap, this article investigates time and financial inflation in road and bridge projects in Iraq. The research aims to provide evidence-based insight for enhanced project planning and management, risk assessment and contract formation through a marriage of a limited review of peer-reviewed literature, correlation analysis, and regression analysis.

The relationship between project time and the project cost has been a subject of investigation in many studies in the literature on construction management and on road and bridge projects. The literature in construction management has shown that time inflation is strongly associated with cost overruns as a consequence of increased risking exposure of all costs including labor, equipment, time at risk, site overheads and corporate overheads **(Bordat et al., 2004; Bhargava et al., 2010).** The literature has given useful insight that time inflation is a means to translate technical, financial or project management risks into costs.

Recent research has found cost overruns and schedule growth are often not jointly-caused but, rather, occur simultaneously. Statistical and econometric evidence exhibits that time inflation causes and worsens cost inflation, mostly for public sector infrastructure projects

when rigorous procurement management procedures and lengthy decision-making processes exist **(Belay et al., 2021; Sharma et al., 2021).** This suggests that time inflation is a catalyst that increases the effects of cost drivers. On road and bridge projects, time extension is usually considered in reaction to design variations, unforeseen site circumstances, resource constraints, or other disruptions. Nevertheless, literature suggests that the formal approval of extensions does not mitigate their financial implications. Rather, extended project durations are often characterized by entrenched inefficiencies, including reduced labor productivity, prolonged site supervision, and accumulated indirect costs, particularly in technically intensive bridge projects with a closely sequenced progression of tasks **(Stoll et al., 2006; Senic et al., 2024).** Indications in developing and transitional economies have pointed out that the financial impacts of schedule extensions are more severe due to institutional constraints, market volatility, and ineffective enforcement of contracts. Surveys in Middle Eastern and other similar regional settings note that cost increases in road and bridge projects are strongly associated with cumulative overheads and vulnerability to price fluctuations **(Al-Hazim and AbuSalem, 2015; Wibowo and Santosa, 2024).** This observation is also supported by case-based research from Iraq published in the Journal of Engineering, University of Baghdad, where the concurrence of time inflation and cost overruns in government infrastructure projects is consistently observed (especially when there are funding disruptions and administrative delays) **(Nasser and Erzaij, 2025).**
Although there has been widespread agreement that there is a strong correlation between time and cost increases, the extent of this relationship, as well as the causal mechanisms, remains insufficiently explored in the current literature. Numerous studies are based on summative measures or descriptive statistics, which makes it difficult to quantitatively separate the influence of time inflation on financial inflation. Such a limitation highlights the necessity of empirical research conducted on the basis of real project experience and the use of robust statistical methods to estimate the strength and the level of the time-cost association under the conditions of particular projects.

Although the overall cost overruns are clearly documented, there is little research that specifically looks at how different cost components respond to time extensions. The most prevalently recorded outcome is labor cost increment based on prolonged employment term, declining productivity, and production acceleration through overtime and shift work **(Natawidjana and Nurasiyah, 2020; Knight and Fayek, 2000).** Several research studies have indicated that efforts to recover lost time through crashing or overtime work have the effect of reducing the total project time but tend to raise direct labor expenses **(Shane et al., 2009; Jelodar et al., 2021).**

The cost of materials is more variable in response to time extensions. There are research studies indicating relatively minor material cost implications under effective procurement management, and research studies indicating comparatively huge escalation because of price inflation, supply disruptions, and reordering during extended project durations **(Admasu, 2023; Chammout et al., 2024).** These effects are particularly strong in some regions if they have volatile markets and/or supply chains that rely on imports **(Omoregie and Radford, 2006; Kaliba et al., 2009).**

Administrative and indirect costs are not as closely measured but are usually recognized. Extended supervision, site management, project coordination, and construction contract administration are all contributing to significant financial inflation in project extensions, particularly in roads and bridges projects in the public sector **(Enshassi and Kumaraswamy, 2010; Chidambaram and Narayanan, 2012).** The literature implies that there are frequently some indirect costs that silently build up and may be larger than the increase in direct costs when no proactive measures are taken to decrease the delays.

Comparative analysis has revealed that time extensions do not affect road and bridge projects in the same manner. Bridge construction projects are often reported to experience a higher percentage of cost escalations when compared to roads, primarily owing to greater technical complexity, extended project durations, and the use of specialized resources **(Munde and Waghmare, 2017; Venkateswaran and Murugasan, 2017; Touran and Lopez, 2006).** Critical-path bridge activities (e.g., piling, girder erection, or marine works) are disproportionately affected by cost escalation when project duration increases.

In contrast, land access delays, utility relocation, material supply, and traffic management restrictions more commonly affect road projects **(Kaliba et al., 2009; Welde and Dahl, 2021).** These variables are usually factors that lead to time extensions and subsequently increase costs via remobilization, extended preliminary works, and vulnerability to market price fluctuations **(Shane et al., 2009; Lee, 2024).** Nonetheless, comparisons on a case-by-case basis using unified datasets reveal that time-cost relationships between roads and bridges are generally similar **(Omoregie and Radford, 2006; Abu El-Maaty et al., 2017).**

Recent literature has expanded the scope of contextual and regional factors in time-cost performance in road and bridge projects. For example, **(Muchhara and Dhungana, 2025)** found terrain challenges, bottlenecks in procurement regulations, and contractor resource constraints to be factors contributing to cost and time escalation in bridge construction along the Prithvi Highway of Nepal. Similarly, **(Jastino, 2024)** examined the Suramadu Bridge project in Indonesia and discovered that construction delays were commonly due to design changes and administrative requirements that amplified bridge costs more significantly than in roadworks.

Simultaneously, studies have advanced risk assessment methodologies and their integration with sustainability and resilience objectives. **(Canesi and Gallo, 2023)** proposed a multi-dimensional framework on the causes and effects of linking sustainable risk assessment to cost overrun mitigation in large-scale infrastructure, with emphasis on governance and environmental variables as important mediators. Elaborating on the purpose of modeling. **(Thakur, 2023)** used fuzzy inference systems to predict delay and cost risks in local road-bridge projects, demonstrating that hybrid systems provide improved predictive capability in uncertain environments. Furthermore, **(Mohajeri Borje Ghaleh and Pourrostam, 2023)** highlighted the significance of risk management in the design of roads when risk exposure is high due to fluctuating material markets and logistical challenges, which supports the concept of integrated planning to eliminate the delay effect at the macro level.

The literature emphasizes that project typology is a key moderator in the time-cost relationship and that failure to distinguish between road and bridge typologies may obscure critical cost transmission mechanisms **(Knight and Fayek, 2000; Shane et al., 2009).**

Different research studies have focused on the identification and prioritization of the risk factors that are associated with time extensions and the consequent increase in cost. In the literature on road and bridge projects, shortages of materials, design deficiencies, poor coordination, and financial constraints are repeatedly identified as major risks **(Zhasmukhambetova et al., 2025; Momand et al., 2025; Antoniou, 2021).** Weather conditions and terrain constraints also cause additional delays and increased cost exposure, particularly in bridge construction **(Ji et al., 2022; Mortazavi and Kheyroddin, 2020).**

Risk identification and prioritization are typically conducted using expert-based and multi-criteria methodologies like the Relative Importance Index (RII), Analytic Hierarchy Process

(AHP), the Delphi method, and hybrid weighting systems **(Afzal et al., 2020; Naji et al., 2024; Pedron et al., 2025).** These methods indicate the factual difficulty of the project to obtain the total project data and emphasize the necessity to apply professional judgment to delay and cost analysis **(Kayelle et al., 2023; Vahedi Nikbakht et al., 2024).** Even though there is a broad agreement on the major types of such risks, the literature has shown variation in the prioritization of specific factors, which can be attributed largely to regional context, governance systems, and procurement systems **(Antoniou, 2021; Zhasmukhambetova et al., 2025).** To curb the adverse effects of time extensions, scholars have pursued numerous mitigation and control strategies. There are many widely studied acceleration methods, such as crashing, fast-tracking, and optimization of time-cost trade-off, which are generally shown to reduce delay exposure when applied appropriately **(Feylizadeh and Mahmoudi, 2018; Ferri and Kama, 2022; Elkliny et al., 2025).** Nevertheless, their cost-efficiency is highly context-dependent, and there is no clear consensus on the effectiveness of specific strategies, such as labor addition or extended working hours **(Sultan, 2025; Ryu, 2018).**

One of the most popular solutions to consistent time and cost performance monitoring in road and bridge construction projects developed is Earned Value Management (EVM) **(Shane et al., 2024; Ghosh, 2024).** Research has indicated that EVM indicators are able to identify early signs of schedule slippage and predict financial exposure in the longer term, but the accuracy of EVM is highly dependent on the quality of the baseline and data accuracy **(Mishra, 2025; Ferri and Kama, 2022).** Regression analysis, Monte Carlo simulation, and fuzzy logic systems are advanced modelling approaches that have been proposed to enhance understanding of the impacts of time extensions on cost outcomes **(Al Haj, 2012; Paul, 2005; Feylizadeh and Mahmoudi, 2018).** Although all these models exhibit high predictive capacity, various studies indicate that they must be localized to ensure their validity in other regions and project types **(Elkliny et al., 2025; Shane et al., 2024).**

Despite much research, there are still a number of gaps that can be seen in the literature. First, there is little empirical work disaggregating the financial impact of time extensions into labor, material, and administrative cost components for road and bridge projects in a unified framework. Second, there is insufficient comparative evidence distinguishing the differential sensitivity of roads versus bridges to time extensions. Third, some studies use qualitative or perception-based data, which again points to the need for statistically based analysis using real project data. These gaps underscore the importance of empirical research that combines quantitative research and an awareness of project typology to better understand how time inflation translates into financial inflation in road and bridge construction.

In the present research, the concept of time inflation and financial inflation is adopted to refer to the relative rise in the duration and cost of the project in relation to the initial values. These are terms used within a project-performance environment and should not be interpreted as macroeconomic indicators of inflation. The findings of this study should therefore be interpreted within the institutional, economic, and regulatory context of Iraq, which may differ from other regions.

2. METHODOLOGY

2.1 Study Design

This study adopted a quantitative record-based analysis, examining the link between time inflation and cost inflation for road and bridge projects. Descriptive and inferential statistical analyses of project-based data were also applied to assess the magnitude and direction of the link between time inflation and financial inflation. A quantitative, project-level records-based research design is adopted in this study. It did not contain non-record-based qualitative information (e.g., interviews, surveys) because of data availability concerns and the objective of drawing empirical statistical inferences. The sample includes 18 projects, as detailed in **Table 1.**

Table 1. Studied projects with their corresponding time and cost values with additions.

Project ID	Duration (Days)	Add. Duration (Days)	Total Duration (Days)	Time Inflation (%)	Contract Value (IQD)	Additional Costs (IQD)	Total Costs (IQD)	Financial Inflation (%)
p1	400	108	508	27	5,021,474,000	1,830,000,000	6,851,474,000	36.44
p2	600	805	1405	134.17	22,574,547,000	0	22,574,547,000	0
P3	600	106	706	17.67	13,340,765,000	1,554,820,000	14,895,585,000	11.65
P4	540	565	1105	104.63	9,318,073,000	11,533,688,600	20,851,761,600	123.77
P5	200	11	211	5.5	499,870,000	24,733,000	524,603,000	4.9479
P6	900	199	1099	22.11	7,205,110,000	602,470,000	7,807,580,000	8.36
P7	130	273	403	210	495,750,000	1,394,000,000	1,889,750,000	281.19
P8	400	219	619	54.75	19,097,930,000	1,712,926,500	20,810,856,500	8.96
P9	250	0	250	0	6,024,207,500	0	6,024,207,500	0
P10	250	0	250	0	2,383,207,500	0	2,383,207,500	0
P11	730	1105	1835	151.37	14,832,025,000	4,573,930,000	19,405,955,000	30.84
P12	710	77	787	10.84	10,890,400,000	761,045,000	11,651,445,000	6.99
P13	900	0	900	0	21,866,000,000	1,190,000,000	23,056,000,000	5.44
P14	610	1045	1655	171.31	6,454,275,000	333,775,000	6,788,050,000	5.17
P15	235	190	425	80.85	2,554,464,000	190,000,000	2,744,464,000	7.44
P16	1080	929	2009	86.02	35,270,198,000	6,735,960,545	42,006,158,545	19.10
P17	974	1687	2661	173.20	67,229,950,000	9,500,000,000	76,729,950,000	14.13
P18	900	921	1821	102.33	25,520,926,000	5,300,000,000	30,820,926,000	20.77

2.2 Data Source and Study Sample

Our analysis used a sample of 18 completed projects (Valid N = 18) with no missing data for the variables under consideration. An observation is a completed or evaluated project case. Owing to restricted public availability of project data for Iraq, and the difficulties in accessing many government project data sets, the present data set includes the available data for a total of eighteen completed projects from which sufficient information could be obtained. Further, the dataset includes both road and bridge infrastructure projects. Given the limited pool of observations, the analysis combined the two types of projects to explore the general relationship between time and cost inflation for the two groups. As a result, no additional comparative studies were undertaken as this analysis would not support statistically valid sub-analyses. Moreover, the project records obtained for the analysis contained overall project contracts, along with additional costs arising from extensions. Not all projects provided breakdowns of the costs into components such as labor, material and equipment, or administration. As such, the analysis was conducted on overall financial inflation (project level). The data did not always include the actual period of construction for all projects. It is, however, worth noting that external factors such as the security environment, funding shortfalls and governmental bureaucracy in Iraq can impact project duration. Four quantitative variables were extracted and analyzed for each observation:

- Additional duration
- Time inflation
- Additional cost
- Financial inflation

Specifically, while additional cost represents the absolute increase in monetary terms, financial inflation expresses this increase as a percentage relative to the original project cost.

2.3 Measures and Operational Definitions

To ensure clarity and consistency, the variables were operationalized as follows:

- **Additional duration:** The absolute amount of time added beyond the original contractual or planned project duration.
- **Time inflation:** A normalized indicator representing the magnitude of schedule increase relative to the baseline duration.
- **Additional cost:** The absolute monetary amount added to the original project cost as a result of extensions or associated changes.
- **Financial inflation:** A normalized indicator representing the magnitude of cost increase relative to the baseline project budget.

These measures allow both absolute and relative assessment of time and cost growth across the analyzed projects.

2.4 Statistical Analysis Procedures

The statistical analysis was conducted in three sequential stages:

1. **Descriptive analysis**: Descriptive statistics—including minimum, maximum, mean, median, and standard deviation—were computed for all variables to characterize central tendency and dispersion within the dataset.
2. **Correlation analysis**: Spearman’s rank correlation coefficient (Spearman’s rho) was used to assess the monotonic relationship between time inflation and financial inflation. This non-parametric approach was selected due to the relatively small sample size and the potential non-normal distribution of the variables.
3. **Regression analysis**: A simple linear regression model was estimated with financial inflation as the dependent variable and time inflation as the independent variable. The model was used to quantify the extent to which variation in time inflation explains variation in financial inflation. Model performance was evaluated using the coefficient of determination, analysis of variance (ANOVA), and regression coefficients.

Prior to correlation analysis, the similarities of the distributions were examined. The sample size was small and may not have followed a normal distribution, so the non-parametric test of Spearman's rank correlation coefficient was chosen as this does not assume normality and is robust against this assumption. The choice of a Spearman's rank correlation analysis was therefore particularly suited to the set of data as non-parametric tests are adequate for relatively small samples and when assumptions about the distribution of the data cannot be met. The study included a bivariate descriptive regression analysis of the direct link between time inflation and financial inflation. An ANOVA test was further used to assess the statistical significance of the regression analysis, and the extent to which the independent variables explain variations in the dependent variable competing variables, such as project optimization, procurement, market and residential oversupply, were not included in the study because appropriate data for these variables over the entire project sample set could not be obtained. So, the variance that cannot be explained by this analysis, presumably, is influenced by other attributes of the projects in the study, such as technical complexity, procurement method, market price movements, and management practices that could not be obtained from the project database. Due to the small sample size and possible variance in the data, the results of the regression equation should be regarded as informative rather than conclusive.

2.5 Significance Level and Analysis Environment

All statistical inferential tests were performed at a significance level of 0.05 (two-tailed). The analysis results are reported in systematic statistical reporting formats in line with the leading statistical software used in engineering and construction research.

3. RESULTS AND DISCUSSION

3.1 Studied Data and Descriptive Statistics

The statistical study was conducted using a sample of 18 project observations (Valid N = 18) with no missing data for the variables under study. The variables analysed in this study were additional duration, time inflation, additional cost and financial inflation. Descriptive statistics are in **Table 2.**

Table 2. Descriptive statistics of the studied variables (N = 18)

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Additional duration	18	0.00	1687.00	413.0556	505.59219
Time inflation	18	0.00	210.00	67.6439	70.30534
Additional cost	18	0.00	11,533,688,600.00	2,624,297,146.9444	3,488,175,227.01226
Financial inflation	18	0.00	281.19	32.5121	68.21595

These findings suggest significant variability in the execution performance of the sampled projects. The significant variability in time inflation and finance inflation rates indicates that not all projects have experienced the same degree of escalation; indeed, some projects have not escalated, and some projects have escalated in a very serious manner. This variability implies that escalation and inflation in Iraqi road and bridge projects are subject to different project-specific and environmental influences, such as contract management, project funding, market forces and implementation issues. The high standard deviations compared with the mean also confirm that the sample is characterized by high variability of the projects' performance.

3.2 Median Values

To complement the descriptive analysis and reduce sensitivity to extreme values, median statistics were also examined. **Table 3** summarizes the median values for each variable.

Table 3. Median values of the studied variables

Variable	Median
Additional duration	194.5000
Time inflation	40.8750
Additional cost	1,292,000,000.0000
Financial inflation	8.6654

The comparison between the mean and the median stresses that all variables are heavily positively skewed, in particular, additional cost and financial inflation. For instance, the mean financial inflation is 32.5121% while the median is 8.6654%, suggesting that the average is being skewed by a relatively few numbers of projects with high-cost overruns. This is also the case for time inflation and additional cost. This confirms that there are outlier cases and that the mode of most projects is smaller than the mean value. As a result, the combined use of mean and median values offers a more informative insight into the data and the need to factor in skewness when analyzing project success in Iraq.

3.3 Correlation Analysis

To determine the correlation between time inflation and financial inflation, we used the Spearman rank correlation coefficient (Spearman's ρ). The complete correlation matrix, including correlation coefficient, significance and sample sizes, is presented in **Table 4.** Further, the relation between time inflation and financial inflation is also depicted as a scatter plot in **Fig. 1,** with a positive monotonic relationship in agreement with the correlation computed for the Spearman correlation coefficient in **Table 4.**

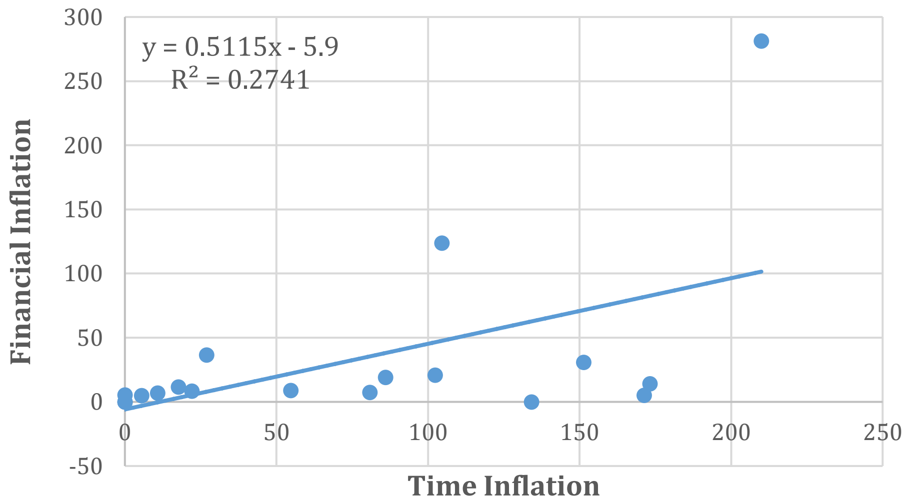

Figure 1. Scatter plot showing the relationship between time inflation and financial inflation

Table 4. Spearman correlation matrix between time inflation and financial inflation

		Time inflation	Financial inflation
Time inflation	Correlation coefficient	1.000	0.743**
	Sig. (2-tailed)	.	0.000
	N	18	18
Financial inflation	Correlation coefficient	0.743**	1.000
	Sig. (2-tailed)	0.000	.
	N	18	18

The analysis reveals a positive and significant monotonic correlation between time inflation and financial inflation ($\rho = 0.743$, $p < 0.01$). So, projects with longer time inflation tend, on average, to also have higher financial inflation. The scatter plot displays a similar pattern in that there is an upward trend in the points, but it is not perfectly linear. This finding is in line with the construction management literature, which suggests that longer project time frames expose the project to higher risks of labor, equipment, supervision, overhead and materials costs. The dispersion of the points suggests that the relationship is not deterministic, however. In fact, some projects seem to have faced significant time inflation without commensurate financial inflation, while other projects have seen significant cost escalation with relatively lower time inflation. This would suggest that time inflation is one significant factor in the escalation of costs, but not the only one. Time inflation may be driven by variation orders, funding shortfalls, design revisions, cost inflation, site conditions and management efficacy. In that respect, the correlation finding confirms a link but also suggests that cost inflation is driven by multiple factors.

3.4 Regression Model Summary

To quantify the effect of time inflation on financial inflation, a simple linear regression model was estimated with financial inflation as the dependent variable and time inflation as the independent variable. The model summary is reported in **Table 5**.

Table 5. Regression model summary

R	R Square	Adjusted R-Square	Std. Error of the Estimate
0.573	0.329	0.287	57.60535

The regression output shows that 32.9% of the variation in financial inflation is explained by time inflation ($R^2 = 0.329$). This demonstrates that schedule inflation has some explanatory power, but is not the primary cause of cost growth. In real terms, time inflation explains much of the variation in financial inflation, but there is still much cost growth that can be excluded from the model. This is as expected with infrastructure projects, which are not financed by schedule performance. These include creep in project scope, poor procurement practices, type of contract, claims, input price inflation and institutional factors. An adjusted R^2 of 0.287 (slightly lower than the unadjusted R^2) indicates that the model's explanatory value is moderate, given the simplicity of the model and the sample size. Therefore, while time inflation is expected to be an explanatory variable, it also suggests that cost overrun is not a univocal phenomenon and calls for a more comprehensive model for future studies.

3.5 Analysis of Variance (ANOVA)

The overall statistical significance of the regression model was assessed using analysis of variance (ANOVA). The ANOVA results are presented in **Table 6.**

Table 6. ANOVA results for the regression model

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	26,014.057	1	26,014.057	7.839	0.013
Residual	53,094.018	16	3,318.376		
Total	79,108.075	17			

The ANOVA results illustrate that the regression model is significant (F = 7.839, p = 0.013). This suggests that the relationship between time inflation and financial inflation cannot be explained by random sample characteristics. Accordingly, the time inflation can be considered statistically significant in explaining financial inflation in our projects. However, statistical significance does not imply that there are no other explanatory factors. The overall model is significant, but there is still appreciable residual variance, as can be seen from the residual sum of squares and the R^2 value. As such, the ANOVA result justifies the relationship and urges caution in interpreting cost inflation as exclusively attributable to time.

3.6 Regression Coefficients

The estimated regression coefficients for the model are reported in **Table 7**, including unstandardized coefficients, standardized coefficients, test statistics, and significance levels.

Table 7. Regression coefficients

Predictor	B	Std. Error	Standardized Beta	t	Sig.
Constant	−5.125	19.106	—	−0.268	0.792
Time inflation	0.556	0.199	0.573	2.800	0.013

The coefficient for time inflation is positive and statistically significant (B = 0.556, p = 0.013), which suggests that, on average, a 1% overrun in project duration relative to the baseline leads to a 0.556% overrun in project cost relative to the baseline. This translates the regression model into a practical reading and demonstrates that time inflation is not only related to financial inflation (in a broad sense), but also has an incremental effect on it. The beta coefficient (β = 0.573) also suggests a moderately positive relationship between time inflation and financial inflation. However, the constant is not significant (p = 0.792), which is to be expected in this case because the focus of the analysis is on the slope coefficient. The positive slope coefficient is consistent with the idea that time inflation will increase the financial load of projects through ongoing risk of spending money, delay in completion, and opportunity cost. However, the coefficient should also be viewed as a general response rather than a rule of thumb for every project. The impact of delay on cost will vary among projects, depending on their procurement policy, resource management strategy, contractual arrangements and risk exposure. Hence, the regression coefficient should be interpreted as an empirical mean for the Iraqi road and bridge projects.

3.7 Comparative Reflections with Literature

The findings are in line with the findings in developing countries, where the institutional and market environment amplify the cost impact of delays. This link is confirmed by large-scale project databases, which indicate that variation orders can significantly affect the costs (up to 95.6% projects, average ≈16%) or times (98.7%, average ≈46.3%) of projects - meaning there is a ubiquitous, quantifiable significant relationship between time and cost overruns in construction projects - in a statistically significant way in terms of their mutual impact **(Mohammad et al., 2021).** Delay impact assessment in construction projects remains method-specific and context-dependent, as the effect of using different delay analysis methods can be different under different circumstances, such as limited data, analysis time point, and resource availability **(Mohammed and Jafar, 2011).** The strong relationship detected in this study is corroborated in other similar contexts (South Asia and Africa) with a strong dependence relation between time and cost delays. The relatively low explanatory power of the regression model in this study echoes findings in the literature for more disaggregated, context-sensitive analyses where the time cost relationships may hide other dynamics specific to certain cost items (labour, materials, administration costs) or project types (roads, bridges, etc). The correlation observed in this study ($\rho = 0.743$) is in line with other studies of a similar nature in developing countries, but there are variations based on the project context and the analysis methods used. The differences in the correlation can be explained by the project size, procurement methods and economic phases. For instance, studies based on perception data or small sample sizes may report weaker or more variable relationships, while empirical studies at the project level tend to report stronger relationships. The coefficient of determination (R^2) of the regression model (0.329) is reasonably high and confirms the results of other studies that note cost overruns are influenced by multiple factors other than schedule performance. Variations between studies can also be due to different data quality, market and institutional factors in different regions.

3.8 Overall Interpretation

In summary, the findings suggest that time inflation is a significant factor in explaining financial inflation in Iraqi road and bridge projects, but it is clearly not the sole factor. The descriptive statistics and median values show a high level of variability in the projects studied, with data sets that include both average and a few extreme cases. The correlation analysis reveals a high degree of association between time overruns and financial overruns, while the regression analysis also reveals that the longer the project, the higher the project cost, even though time inflation is not the only factor in explaining financial inflation.

Our results must be interpreted within the scope of this study. The results reflect broad trends across all projects rather than the particular behavior of subcategories of projects, and they rely on quantitative data alone. It therefore does not explicitly capture the effects of management quality, stakeholder actions, contractual arrangements, governance problems, and other qualitative factors. Also, the use of the term "inflation" in this study refers to the relative increase in cost compared to the baseline of the original project, not to the usual economic meaning of inflation. This is especially relevant in the Iraqi environment, where the performance of projects may also be affected by external factors including security, political stability, administrative disruption and market forces. As such, the findings should be evaluated as proof of a time-cost relationship in a difficult project environment.

4. CONCLUSIONS

This paper examined the empirical relationship between the time inflation as well as the financial inflation on road and bridge projects in Iraq, whereby the dataset relied on 18 completed projects. The correlation between schedule extensions and cost overruns is found to be statistically significant and strong, which supports the fact that time and cost performance are highly interdependent in infrastructure projects, as it has been widely believed. The rank correlation coefficient ($\rho = 0.743$, $p < 0.01$) indicates a strong monotonic relationship, and this means that it is consistently associated with delays and the corresponding increase in project costs. The regression analysis was also carried out to further quantify this linkage, and it was identified that time inflation explained about 32.9% of financial inflation, and the increase in costs per 1% increase in project duration averaged 0.556%. Although certainly significant, the moderate explanatory power of the model suggests the importance of other factors - the complexity of the project, the type of contract, the conditions of the market, and the effectiveness of the managerial performance, which also contributes to the increase in costs. The remarkable difference in projects as observed in the analysis highlights the issue of the fact that not all delays necessarily result in the same amount of financial overrun, implying the effectiveness of risk management practices, resources, and contracts in some instances. On the other hand, some projects were massively overrun with relatively small increases in their costs, particularly in time terms, and it was necessary to have direct cost drivers like the volatility in material prices, the alteration of design, and unforeseen site conditions. The implications of these findings for the stakeholders of the project in Iraq and other situations like Iraq are significant. They stress the importance of active schedule management as a bottom-line cost reduction mechanism and require the inclusion of effective monitoring techniques such as Earned Value Management to help provide early warning signs of any deviations. In addition, the article explains the need to specify the terms of the contract that explicitly address the cost implications of time extensions and, in particular, volatile institutions and markets.

NOMENCLATURE

Symbol	Description	Symbol	Description
ac	Additional cost incurred due to project extension	r^2	Coefficient of determination
ad	Additional duration beyond the original contractual period	sd	Standard deviation
b	Unstandardized regression coefficient	se	Standard error
f	F-statistic from ANOVA	t	t-statistic
fi	Financial inflation (normalized increase in project cost)	ti	Time inflation (normalized increase in project duration)
max	Maximum observed value	α	Significance threshold ($\alpha = 0.05$)
mean	Arithmetic mean of the observed values	β	Standardized regression coefficient
median	Median value of the observed distribution	ρ	Spearman's rank correlation coefficient
min	Minimum observed value	n	Number of project observations
r	Correlation coefficient of the regression model	p	Probability value (significance level)

Credit Authorship Contribution Statement

Zainab Saad Falih: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. Kadhim Raheim Erzaij: Supervision, Conceptualization, Methodology, Validation, Writing – review & editing.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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العلاقة بين التضخم الزمني والتضخم المالي في مشاريع الطرق والجسور في العراق: تحليل تجريبي

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الخلاصة

تهدف هذه الدراسة إلى فحص العلاقة التجريبية بين تضخم الوقت (TI)، والذي يُعرَّف على أنه نسبة الزيادة في مدة تنفيذ المشروع مقارنةً بالجدول الزمني الأصلي، وتضخم الكلفة المالية (FI)، والذي يُعرَّف على أنه نسبة الزيادة في كلفة المشروع مقارنةً بالميزانية الأصلية، وذلك في مشاريع الطرق والجسور في العراق. تتمثل المشكلة التي تسعى الدراسة إلى معالجتها في تصاعد كلف المشاريع المرتبط بتأخر التنفيذ، مع هدف كمي يتمثل في تحديد طبيعة هذه العلاقة بما يدعم تخطيط المشاريع وإدارة المخاطر. اعتمدت الدراسة المنهج الكمي، حيث تم تحليل بيانات 18 مشروعًا منجزًا باستخدام الإحصاءات الوصفية، ومعامل ارتباط سبيرمان للرتب (ρ)، وتحليل الانحدار الخطي البسيط. أظهرت النتائج وجود علاقة رتيبة موجبة قوية جدًا بين التضخم الزمني والتضخم المالي ($\rho = 0.743$، $p < 0.01$). كما بيّن تحليل الانحدار أن متغير تضخم الوقت يفسّر نحو 32.9% من التباين في متغير تضخم الكلفة ($R^2 = 0.329$)، وأن زيادة مقدارها 1% في تضخم الوقت تؤدي، في المتوسط، إلى زيادة قدرها 0.556% في تضخم الكلفة. وتخلص الدراسة إلى أنه على الرغم من أن تمديد المدد الزمنية يُعد سببًا رئيسيًا لتجاوزات الكلفة في مشاريع الطرق والجسور في العراق، فإن هناك عوامل أخرى ذات تأثير ملحوظ على النتائج المالية للمشاريع. وتؤكد هذه النتائج على أهمية التحكم الاستباقي في الجداول الزمنية بوصفه استراتيجية أساسية للسيطرة على الكلفة، كما تشير إلى ضرورة تحسين الأطر التعاقدية وأنظمة المتابعة والرقابة للحد من الآثار المالية الناجمة عن التأخيرات.

الكلمات المفتاحية: تجاوز التكاليف، التضخم المالي، العراق، مشاريع الطرق والجسور، التضخم الزمني.