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The Influence of Weather Conditions on Time, Cost, and Quality in Successful Construction Project Delivery

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Abstract: The effective management of the triple constraints, time, cost, and quality, is imminently essential for the success of construction projects, and it is considered a hot research topic nowadays. For this purpose, we carried out this study to systematically analyze the influence of these constraints on project success, specifically emphasizing how weather conditions intensify the difficulties associated with these constraints. A survey questionnaire was administered to 242 industry experts, and the collected data were evaluated utilizing the software named Statistical Package for Social Sciences (SPSS), Version 30.0. Further, we also analyzed the obtained data by employing Cronbach's alpha, correlation, and regression analyses, which obviously confirmed the effects of these constraints on project success. In addition, the results clearly indicated that weather-related delays increased the durations of projects by 25.7% and caused an average cost increase of 23.8%. Focused attention was required for effective management of these constraints. This study further highlights the need for strategic planning and effective risk management to mitigate weather-related risks. As a result, proficient management of these elements is imminently crucial for ensuring project success in the construction sector. Thus, we concluded that this study will allow construction projects in future endeavors to be carried out with high proficiency and effectiveness.

Keywords: constraints; weather conditions; SPSS software; project success; construction projects

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1. Introduction

The successful completion of construction projects relies significantly on a rigorous equilibrium among time, cost, and quality, a combination commonly known as the triple constraints [1,2]. In a sector characterized by stringent time constraints, constrained financial resources, and uncompromising quality benchmarks, it is imperative to sustain this equilibrium [3]. Nevertheless, external factors such as weather conditions have the potential to rapidly disturb this balance, resulting in substantial delays, budget overruns, and poor quality [3,4]. Weather conditions have a significant impact on construction projects and play a crucial role in the determination of a project's success [5]. Therefore, understanding and minimizing the hazards associated with severe weather conditions are highly crucial in a setting where even modest disturbances can have wide-ranging results [6].

It is a well-known fact that the construction sector has been deemed an essential industry that makes a substantial contribution to the global economy [7]. On the other hand, it also remains one of the most demanding sectors. It can be affected by several challenges, leading to delays in successful deliveries to communities and societies [8]. Numerous factors, which have been extensively examined by several researchers (Table 1), directly influence project performance by inducing delays. These constraints are time, cost, and quality, which are mutually dependent; a modification in one can frequently result in variation in the others [5]. For example, expediting a project to adhere to strict time constraints could result in higher expenses and reduce the quality of work. However, reducing expenses could result in greater project delays. This interrelationship has made managing these constraints a critical responsibility for project managers [9,10].

In addition, environmental factors, such as weather conditions, introduce an additional level of intricacy to construction projects [11]. In contrast to internal variables like resource allocation or project scope, weather is outside the influence of project managers but can significantly affect project results [12]. Empirical evidence indicates that weather-related disturbances frequently result in project delays and cost overruns within the construction sector [7]. Various studies have provided evidence of how severe weather conditions like floods have resulted in substantial delays in construction timelines and escalated expenses as a consequence of damage and the need for repairs [13,14]. Given the ongoing increase in the occurrence and intensity of severe weather events caused by climate change, every construction sector needs to adjust and respond to these emerging issues [15].

The limited study of the interaction between weather conditions and the triple constraints reveals a knowledge gap in the existing literature [16,17]. Numerous studies have focused primarily on the immediate impacts of weather conditions on construction operations, such as delays caused by rain or snow [18–20]. However, there is a lack of comprehensive research on how these weather-induced disruptions affect the efficient management of constraints [21,22]. A thorough understanding of this relationship is essential for formulating effective strategies to mitigate the negative impacts of weather on construction projects [23,24].

The motivation for this study arose from the escalating volatility of weather conditions caused by climate change and the rising need for construction projects to adjust to these uncertainties [25]. The construction sector faces increased hazards due to the increasing frequency and severity of extreme weather conditions, which could potentially endanger the success of development projects [26]. The conventional methodologies of project management, which are often influenced by the unpredictable nature of the weather, are no longer adequate in this emerging context [27,28]. There is an urgent need for novel approaches that incorporate weather factors into the fundamental aspects of project planning and management [29–31].

Table 1. Weather factors affecting project success.

S. No.	Weather Factors	References
1	Heavy rain	[24]
2	Snowstorms	[24]
3	High winds	[25]
4	Flooding	[25–27]
5	Extreme heat	[27]
6	Lightning strikes	[28,29]
7	Freezing conditions	[28]
8	Hailstorms	[29]
9	Fog	[29,30]
10	Hurricanes	[30]

Table 1. *Cont.*

S. No.	Weather Factors	References
11	Sandstorms	[31]
12	Humidity variations	[30–32]
13	Landslides caused by weather conditions	[33]
14	Thunderstorms	[33,34]
15	Erosion caused by wind and rain	[34]
16	Changes in barometric pressure	[35]
17	Ice accumulation on materials	[36]
18	Soil saturation due to prolonged rainfall	[35–37]
19	Flash flooding	[37]
20	Delayed drying of construction materials	[37–39]

Thus, regarding the aforementioned discussion, we deeply analyzed and focused on integrating the influence of the triple constraints on the effective execution of construction projects and how weather conditions worsen these constraints. This study also examined the complex relationship between weather conditions and project management methodologies to offer project managers critical insights for predicting and mitigating weather-related disruptions and thereby improving project success.

For more clarity, we explain the following contributions, which completely describe the present research work:

Valuable resource: this study's meticulous methodology and empirical data make it a valuable resource for construction experts, enhancing their comprehension of efficiently overseeing constraints amid adverse weather conditions.

Addressing gaps: This study aimed to rectify a notable inadequacy by providing precise data on the incidence and financial repercussions of weather-related delays. This knowledge will help the industry develop effective strategies to improve durability.

Proactive practices: this study emphasizes the significance of adopting proactive management tactics to effectively navigate the complexities of construction projects.

Future research framework: this study offers a comprehensive framework for future studies to explore other factors that influence the success of construction projects.

Policy and training impact: This study provides significant data for policy formulation, increasing training programs for project managers, and enhancing industry practices as a whole. Further, it also makes a substantial contribution to the subject of construction project management by presenting actual data on the influence of weather conditions on the triple constraints.

This study is explained in various parts as follows: Section 2 depicts a comprehensive literature review on the triple constraints with weather conditions as a factor variable, indicating their influence on these constraints and project success. Expanding on the previously mentioned basis, Section 3 provides more details on how the research was carried out from the initial design to the data analysis stage and provides the demographics of the respondents. Section 4 provides comprehensive results and indicates that Cronbach's alpha was the most important statistic for this research. However, Section 5 describes a comprehensive assessment of how weather conditions affect the triple constraints and project success. Finally, Section 6 provides a summary of the research results and suggestions for additional investigations. Further, it also presents a well-organized and detailed conclusion for this research work.

2. Literature Review

2.1. Weather Conditions in Construction

Weather is an external factor that significantly influences the results of construction projects [11]. Unfavorable weather conditions can lead to significant delays, increase costs, and affect the overall quality of construction projects [16]. Numerous studies have delved into the broader effects of external factors on construction projects, emphasizing that risks within the project management framework can significantly influence project outcomes and that insufficient communication within the construction industry can exacerbate challenges arising from external factors, leading to further delays and increased costs [29].

2.2. Impact on Project Time

Weather conditions significantly impact construction project time because extreme weather frequently disrupts scheduled plans and delays construction activity [17]. Severe weather conditions, including intense precipitation, storms, and extreme temperatures, can disrupt on-site operations, damage equipment, and impede access to construction sites, leading to prolonged project timelines [21]. These disturbances are especially evident in areas with unpredictable weather conditions, complicating adherence to timetables. Many research studies have shown that delays caused by bad weather have large effects on how well construction projects are managed in terms of time [16]. This shows that this issue needs to be more carefully considered in the planning and scheduling of projects. Hence, in Pakistan, "natural disaster", "financial and payment difficulties", "poor planning", "poor site management", "insufficient stakeholders experience", and "shortage of materials and equipment" were identified as the major factors causing construction constraints during project execution [32].

2.3. Impact on Project Cost

Weather conditions significantly influence project costs because delays due to unfavorable weather frequently result in increased expenditures [22]. Extended timelines caused by weather-related delays can lead to increased labor costs, longer equipment rental periods, and additional material storage expenditures [15]. Moreover, severe weather phenomena, including intense precipitation, storms, or temperature variations, can compromise construction components, necessitating expensive replacements or repairs [23]. In areas with unpredictable weather conditions, the financial effects are amplified, as unexpected delays burden project budgets [19]. The research indicates that weather-related cost overruns are an ongoing problem in construction projects, emphasizing the necessity of considering potential weather effects during budget estimation and cost management procedures [24].

2.4. Impact on Project Quality

Adverse weather conditions may greatly affect the quality of construction projects by impacting both materials and expertise [24]. In detail, bad weather events, including intense precipitation, extreme temperatures, and elevated humidity, can compromise construction materials such as concrete and steel, resulting in weakness [25]. Excess moisture during concrete curing might diminish its strength, while cold conditions may cause cracking [27]. Prolonged exposure to adverse weather conditions might harm on-site materials, heightening the risk of quality decline [28]. Moreover, severe weather conditions frequently hinder accurate on-site operations, especially during essential stages like foundation laying, roofing, and finishing tasks [30]. A previous study also indicated that weather-related quality issues compromise project durability and performance, leading to the need to recomplete tasks and resulting in time and expense overruns [19]. These problems highlight the need for proactive solutions to ensure building quality in weather-sensitive environments [18].

2.5. Mitigation Strategies

There are many strategic planning and risk management strategies that are crucially important for alleviating the effects of weather on construction projects [30]. This entails predicting possible disruptions, integrating buffer time into timetables, and employing weather-resistant methodologies [31]. Clear communication with all parties involved makes it easier to spot risks quickly, and regular checks of how weather affects the triple constraints allow for the right changes to be made [29]. Therefore, implementing these measures can mitigate the adverse effects of weather, thereby enhancing project control over the triple limitations [28].

2.6. Theoretical Frameworks and Models

This study was based on the triple constraint concept, highlighting the interrelationships between time, cost, and quality as essential factors for project success. It also included parts of risk management theory that were used to look at how external factors, like weather conditions, make problems with these constraints. This framework offered a systematic method for comprehending the correlations between weather-related disturbances and their effects on project success. Therefore, this study examined the impact of weather conditions on the triple constraints in construction projects based on the established theoretical framework. An analysis of a questionnaire with answers from 242 experts in the field, carried out with SPSS, showed that delays caused by bad weather conditions made projects take 25.7% longer and increased costs by 23.8%. The results make it clear that bad weather conditions cause the problems that come with these constraints. They also show how important it is to plan ahead, manage resources well, and lower risks in order to deal with weather-related problems and make sure that future construction projects are successful.

2.7. Gaps in Existing Research

Although weather has been well recognized as a significant factor affecting construction projects, the existing literature still lacks detailed information on the precise financial and time-related outcomes of disruptions caused by weather conditions [32]. The majority of studies have considered weather as one of the major external variables without thoroughly exploring its distinct impact on project management issues [33]. The observed research gap highlights the need for more targeted investigations that measure the financial consequences of weather conditions on construction schedules and expenses [34]. Project managers must rely on assumptions or generalized risk assessments in the absence of empirical data, which may not provide the necessary precision for efficient planning [35].

The lack of emphasis on research specifically related to weather outcomes has also led to a shortage of strategic suggestions for reducing their effects [36]. The lack of adequate guidelines on the best practices for integrating weather-related hazards into planning processes poses a challenge for many construction firms [37]. Hence, this sector remains susceptible to disturbances induced by weather conditions, and construction projects persistently encounter substantial delays and cost overruns as a consequence of this element [38]. Further, a focus on research is still required to address these deficiencies and to provide practical and implementable knowledge for this sector [39].

The parameters depicted in Table 1 clearly illustrate various weather factors that obviously affect project success. Thus, keeping these factors in view, we used them in a questionnaire using an online Google form to collect data from respondents about how these factors affect time, cost, quality, weather conditions, and project success, which are explained in detail in the Results and Discussion Section.

Until now, studies carried out by different researchers (Table S8 in the Supporting Information) have clearly predicted valuable information about project delays and various related factors. But there is still a wide gap related to how weather conditions affect project success. For this purpose, in the present research work, we mostly focused on systematically analyzing the influence of these constraints on project success.

3. Research Methodology

In this section, we focus on the research methodology. Comprehensively, the information contained details of the participants, including this study's inclusion criteria, their identities, and the selection methods. The managerial aspects and data collection instruments were examined comprehensively. Further, this study was conducted at the worker's level. In addition, this also provided techniques for interpreting and analyzing the data.

Figure 1 illustrates the comprehensive quantitative research methodology used to examine the correlations between the triple constraints and operational outcomes of construction project success. This study identified two types of variables named dependent and independent variables. The dependent variable was project success, while the independent variables included weather conditions, time, cost, and quality.

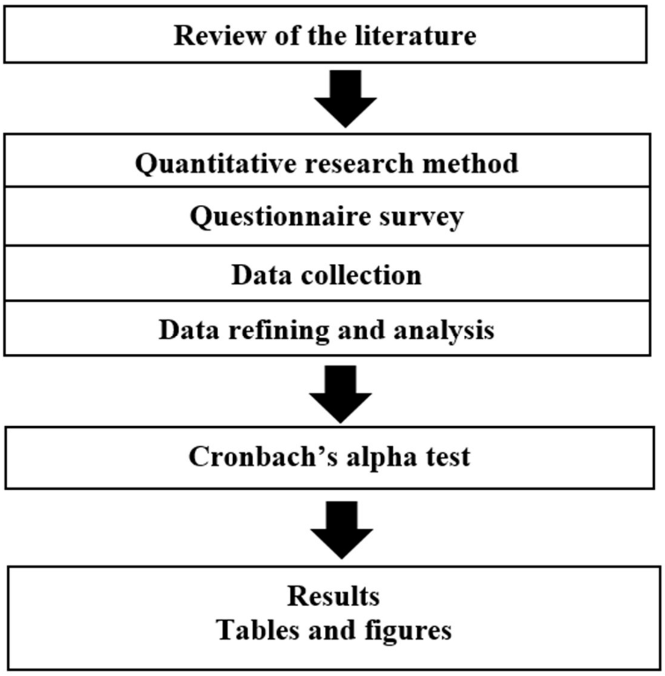

Figure 1. The research methodology adopted for this study.

The choice of a quantitative method enabled a systematic examination of the connections among time, cost, and quality by rigorous hypothesis testing [5]. The objective of this study was to generate dependable insights into the role of strategic planning and risk management in reducing external factors that affect construction projects by measuring replies from industry experts [40].

In this study, a questionnaire survey was applied as the principal tool for the collection of data (an online Google Forms link is provided in the Supporting Information). In detail, this study mainly focused on a wide range of construction professionals, including architects, construction managers, consultants, site engineers, quality coordinators, and site surveyors. This approach was chosen because of its ability to collect a substantial amount of data in a relatively short time frame of almost three months.

4. Results and Discussion

4.1. Study Sample

Quantitative research often employs procedures that involve survey questionnaires, which are well recognized as a standard way to collect data [41]. This study employed a comprehensive methodology to analyze the relationship between project planning and project success, specifically with regards to weather conditions, and aimed to collect a comprehensive range of various perspectives [32]. Therefore, purposive sampling was critical in selecting people who possessed significant and relevant expertise, which was in line with the study aims [33]. The Statistical Package for the Social Sciences (SPSS), robust software for analyzing quantitative data, was used to process data gathered from 242 industry experts.

Further, in this study data were collected from construction firms in Pakistan to ensure the generalizability of the results. The survey employed a five-point Likert scale ranging from "strongly disagree" to "strongly agree" [34,35]. After excluding incomplete responses, we deemed that 242 out of 280 questionnaires were fully answered and valid for analysis. The outcome was a response rate of 86.2%, which was satisfactory. The selected sample size was appropriate for quantitative research, as it guaranteed sufficient statistical power and reliability to investigate the relationships between variables [42].

Tables S1–S4 (Supporting Information) display the basic demographic information that the participants provided. Acquiring these demographic data was essential for understanding the makeup of the sample and ensuring the precision of this study's findings.

The dataset comprised a total of 242 individuals, including 191 males and 51 females, which is presented in detail in Table S1 and Figure S1.

The dataset in Table S2 and Figure S2 further classifies the 242 individuals according to their educational qualifications. In detail, out of the total (242), 29 individuals had a diploma, 53 had a B.Tech., 99 possessed a bachelor's degree, 48 had a master's degree, and 13 held a PhD. In Pakistan, the bachelor of engineering (B.E.) and bachelor of technology (B.Tech.) programs both emphasize engineering fields but vary in their methodologies and levels of professional endorsement. The bachelor of engineering (B.E.) degree is highly focused on theoretical knowledge, highlighting scientific concepts and analytical abilities. The Pakistan Technology Council (PTC) recognizes a bachelor of technology, while the Pakistan Engineering Council (PEC) officially recognizes a bachelor of engineering, enabling graduates to become registered engineers. In comparison, the B.Tech. program is characterized by its practicality and focus on practical application. Although the PEC was specifically tailored for technical positions in industry, it does not receive the same level of professional recognition. Bachelor of engineering graduates are generally more equipped for design and development career paths, whereas bachelor of technology graduates often occupy operational and technical management positions.

The dataset in Table S3 and Figure S3 categorizes the 242 individuals according to the type of company they worked for. Architectural firms employed 55 individuals from the total workforce. Additionally, 31 individuals worked for engineering firms, 93 for construction firms, 25 for international NGOs, and 38 for government departments, resulting in a total percentage value of 100%.

The dataset in Table S4 and Figure 2 clearly elaborates the categorization of the 242 individuals according to their levels of experience. It correspondingly presents the cumulative percentages of various experience categories, reaching 100% for individuals with over 25 years of experience, suggesting that this distribution applies to the whole dataset.

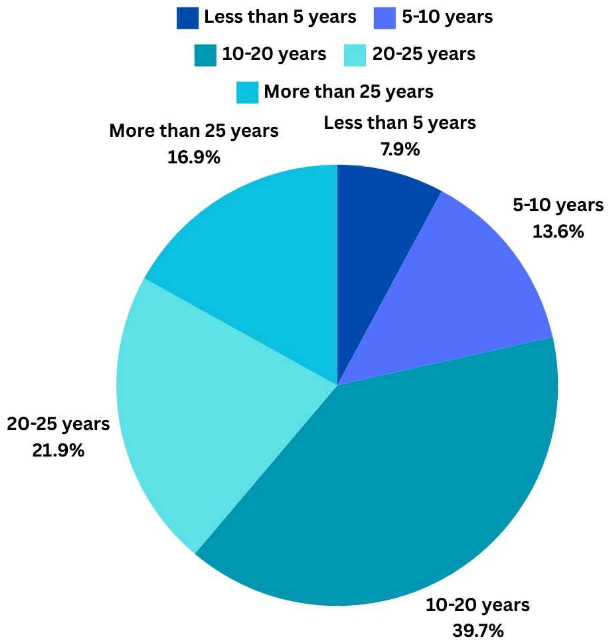

Figure 2. Experience of different individuals within construction industry.

4.2. Descriptive Statistics

The descriptive statistics phase of this study, as detailed in Table S5 and Figure 3, consisted of 242 participants who assessed several project management aspects using a five-point Likert scale. The average score for project management cost was 3.2025 with a standard deviation of 1.5339, suggesting that cost management was modest, but there was a significant range of responses. Project quality exhibited a mean score of 2.8554, indicating somewhat below-average judgments, and the standard deviation of 1.5882 indicated a large variety of opinions. The mean rating for time management was 3.0579, indicating an average level of competence. The standard deviation of 1.2870 suggests some variety in the ratings. The weather conditions had a mean score of 3.7025 and a standard deviation of 1.2299, demonstrating a consistent consensus on their major impact to projects. The evaluation of a project's overall success was slightly above average, with a mean score of 3.4545 and a standard deviation of 1.2457. This indicates that the participants had moderate satisfaction with variable replies.

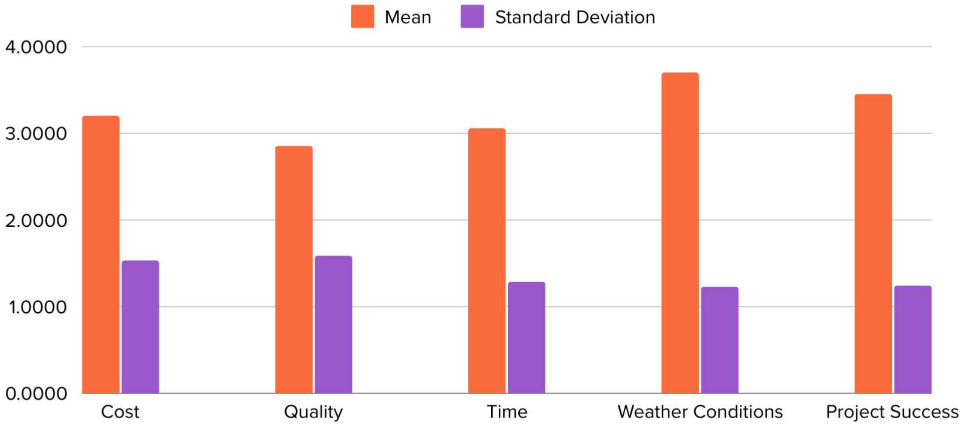

Figure 3. Descriptive statistics.

4.3. *The t-Test Analysis*

The participants' responses, compared to their project success indicators and decisions, validated this study's research model and assumptions. The *t*-test statistics from SPSS, as shown in Table S6 and Figure 4, show that the average values for the dependent variable (project success) and the weather conditions were significantly higher, at 3.4545 and 3.7025, respectively. Figure 4 also indicates a favorable response from the participants, emphasizing the substantial influence of weather conditions on project success. In contrast, the average values for cost, time, and quality were relatively low, suggesting that the respondents do not place as much importance on these aspects when evaluating the effectiveness of project management. Although the independent variables (cost, quality, and time) had consistent standard deviations, the standard deviation for weather conditions was significantly larger, while the standard deviation for project success was slightly lower.

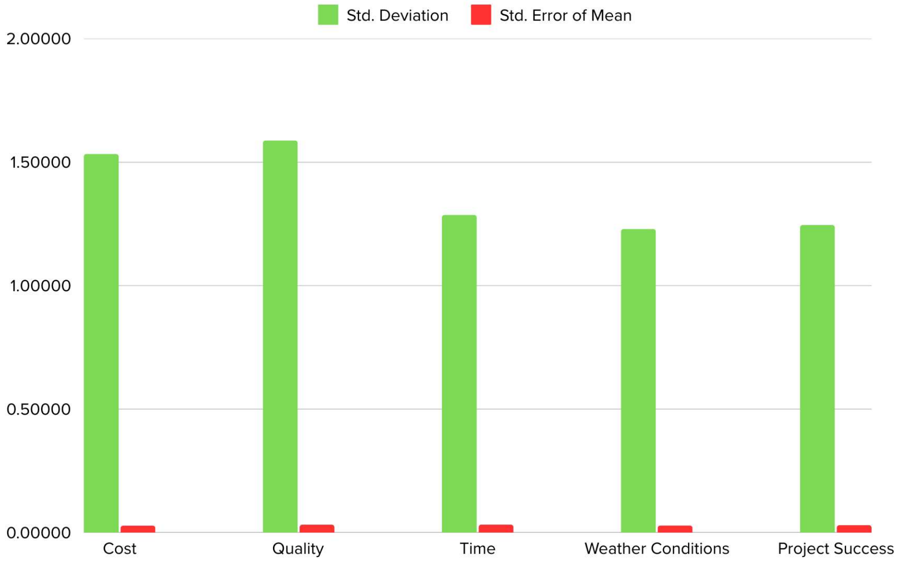

Figure 4. One-sample statistics.

This implies more diverse considerations of weather conditions and a more dependable correlation between weather conditions and project success. The small standard error of the mean, which is less than 0.05, emphasizes the accuracy and consistency of the responses, confirming the data's genuineness. The statistical data in Table S6 and Figure 4 underscore the importance of considering weather conditions in strategic planning and risk management to enhance project outcomes.

4.4. *One-Sample t-Test*

The *t*-test results for a second sample, as displayed in Table 2, provide substantial evidence about the factors that impact project success. The *t*-value for the dependent variable "Project Success" is 46.139 with a mean value of 3.75455. There is substantial evidence to support the concept that elements such as cost, time, quality, and weather conditions have significant impacts on a project's success. The hypothesis that weather conditions greatly affect project success is supported by a *t*-value of 43.829 and a two-tailed significance level of 0.001. This emphasizes the vital importance of weather conditions in the construction industries, as evidenced by the substantial average discrepancy, which further validates the strong impact of weather conditions on project success.

Table 2. One-sample test.

Variables	t	df	Significance (Two-Tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Project Success	46.139	242	<0.001	3.75455	3.2968	3.6123
Cost	32.477	242	<0.001	3.20248	3.0082	3.3967
Quality	27.967	242	<0.001	2.85537	2.6543	3.0565
Time	36.961	242	<0.001	3.05785	2.8949	3.2208
Weather Conditions	43.829	242	<0.001	3.40248	3.5467	3.8582

In addition, a t-value of 36.961 at a significance level of 0.001 demonstrates the impact of time on project success, providing moderate evidence in support of the hypothesis. This implies that while project time is currently crucial for success, its significance may increase in the future. The cost management variable has an average t-value of 32.477, which suggests that cost has a substantial impact on project success when compared to the other factors. The p-value of 0.001 suggests that the supply chain makes decisions with a positive and advantageous approach towards costs. This suggests that the importance of cost management in achieving project success may become even more evident with increased awareness and education.

4.5. Reliability Analysis

Reliability analysis is a crucial aspect of research, as it evaluates the consistency of variables across various contexts. A key statistic, Cronbach's alpha coefficient, measures the internal consistency of a set of scales or survey questions. Cronbach's alpha is a statistical measure that ranges from 0 to 1. Stronger interrelationships among the measured items indicate higher values of Cronbach's alpha. This indicates that the items consistently evaluate the same fundamental concept. Social science research typically regards a Cronbach's alpha score above 0.7 as adequate, indicating a reliable measurement tool. Values lower than 0.5 suggest weaker correlations between items, which could indicate issues with a measurement's reliability. Understanding and recording Cronbach's alpha helps to ensure the precision and reliability of research findings by confirming the consistency of collected data.

Table 3 presents a brief overview of the case processing, including information on the data used in the analysis. Table 3 indicates that this study encompassed a total of 242 authentic cases, representing the entirety of the dataset. The "Excluded" category had a value of 0, indicating the inclusion of all cases. Therefore, we retained all data points for analysis, ensuring thoroughness and reliability. The note "listwise deletion based on all variables in the procedure" clarifies the application of listwise deletion, which involves only including cases that have complete data for all variables. This methodology guarantees the reliability and accuracy of research.

Table 3. Case processing summary.

Cases	**Valid**	242	100.0
	Excluded	0	0
	Total	242	100.0

Note: listwise deletion based on all variables in the procedure.

Table 4 displays the reliability statistics for the variables in this study, utilizing Cronbach's alpha as a metric to assess internal consistency. Table 4 shows a Cronbach's alpha coefficient of 0.519 for the five items under investigation. This result shows a moderate level of dependability, implying that the items were moderately correlated but not strongly consistent in measuring the same underlying concept. Although the current degree of reliability is satisfactory for exploratory research, it emphasizes the need for future improvements in the consistency of the items to ensure they more precisely represent the desired measurement construct. Furthermore, the equation used to calculate Cronbach's alpha is detailed in the Supporting Information.

Table 4. Reliability statistics.

Cronbach's Alpha	No. of Items
0.519	5

Table S7 and Figure 5 present the item-total statistics for our analysis's primary variables. Each row corresponds to a specific variable, notably cost, quality, time, weather conditions, and project success. The column labeled "Scale Mean if Item Deleted" shows the effect of removing each variable from the scale's average value, highlighting their contributions. The variation in the "Scale Variance if Item Deleted" column indicates the extent to which removing each variable affects the dispersion of the scores. The "Corrected Item-Total Correlation" measures the degree of association between each variable and the overall scale score, considering any potential overlap with the other items. The "Cronbach's Alpha if Item Deleted" column shows Cronbach's alpha coefficients that assess the scale's reliability after removing each variable. This study aimed to identify the key factors that significantly influence measurement results and to understand their role in ensuring consistent and reliable outcomes.

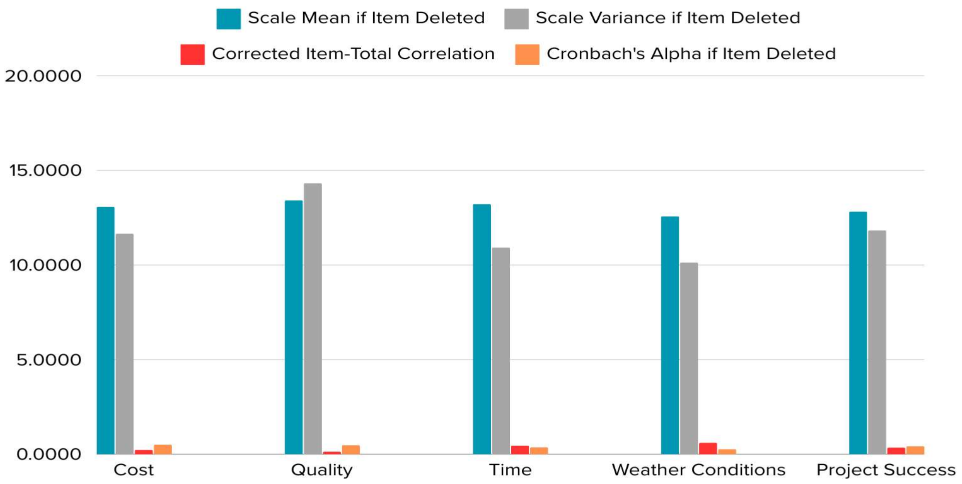

Figure 5. Item-total statistics.

4.6. Correlation Analysis

A correlation analysis examined the connections between the variables, specifically the relationship between the triple constraints (cost, quality, and time) and project success, as well as the influence of weather conditions. Pearson correlation analysis was employed to unveil the characteristics and intensity of these associations, with coefficients spanning from −1 to +1. Coefficients ranging from 0.1 to 0.3 indicated weak relationships; values between 0.3 and 0.5 suggested moderate correlations; and coefficients over 0.5 indicated strong correlations. This study emphasized several levels of correlation, offering insights into the extents of the relationships between various components in a specific situation.

Table 5 displays Pearson correlation coefficients that indicate the associations between important project management elements. The results show relationships that are statistically significant at the 0.01 level. Cost exhibits positive correlations with time (0.250), weather conditions (0.325), and project success (0.373), while it has an adverse correlation with quality (−0.252). There is a positive association between time and weather conditions (0.488), as well as between time and project success (0.336). There are positive correlations between weather conditions and both time (0.488) and project success (0.322). With a value of −0.113, the association between quality and project success is poor and non-significant. These data demonstrate the interrelationship of cost, time, and weather conditions in determining project success, but the relationships between quality and other variables are less pronounced.

Table 5. The results of the correlations between different factors.

Variables	Cost	Quality	Time	Weather Conditions	Project Success
Cost	1				
Quality	−0.252 **	1			
Time	0.250 **	0.057 **	1		
Weather Conditions	0.325 **	0.260 **	0.488 **	1	
Project Success	0.373 **	−0.133 **	0.336 **	0.322 **	1

Note: ** the correlation is significant at the 0.01 level (2-tailed).

4.7. ANOVA for Cost, Quality, and Time Variables

An analysis of variance (ANOVA) was employed to examine the differences in the means among the groups for the triple project constraints (cost, quality, and time) and their associations with the dependent variable (project success). The findings (Table 6) demonstrated markedly positive values, signifying robust associations between these limitations and a project's achievement. More precisely, the analysis of variance for cost, quality, and time showed positive values, indicating their significant effects on the dependent variable.

Table 6. The results of the ANOVA test.

		Sum of Squares	Df	Mean Square	F	Sig.
Cost	Between Groups	211.700	4	52.925	35.295	<0.001
	Within Groups	355.379	238	1.499		
	Total	567.079	242			
Quality	Between Groups	96.683	4	24.171	11.205	<0.001
	Within Groups	511.255	238	2.157		
	Total	607.938	242			
Time	Between Groups	139.959	4	34.990	31.989	<0.001
	Within Groups	259.231	238	1.094		
	Total	399.190	242			

The ANOVA test findings, as displayed in Table 6, indicate statistically significant variations in the means of the cost, quality, and time variables across the groups. The cost analysis revealed that the sum of squares between the groups is 211.700. The F-value is 35.295, and the significance level is less than 0.001, showing a robust and statistically significant difference. The sum of squares between the groups is 96.683, showing a high degree of quality. The F-value is 11.205, which further supports the significant difference between the groups. The significance level is less than 0.001, confirming the statistical importance of the difference. Similarly, the sum of squares between the groups over time is 139.959. The F-value is 31.989, and the significance threshold is less than 0.001, indicating a significant difference. These findings emphasize the substantial influence of these factors on a project's success.

4.8. Regression Analysis

The data in Table 7 examine project success as an outcome variable, with project cost, project quality, and project time as predictors. To assess their influence on project success, linear regression analysis was employed, indicating that all three variables have favorable impacts on project success. This analysis revealed a noteworthy positive correlation (B = 0.238, $p < 0.05$) between project cost and project success, suggesting that higher costs are linked to greater levels of achievement. This study found a significant positive relationship between project quality and project success (B = 0.143, $p < 0.05$), indicating that higher quality is associated with greater project success. Similarly, the analysis showed that there is a positive relationship between project time and project success. The coefficient (B = 0.257) indicates that longer project durations are associated with higher levels of project success. This relationship is statistically significant at a p-value of less than 0.05. In addition, this investigation showed how weather conditions influence these correlations.

Table 7. Linear regression.

Model		Under Standardized Coefficients		Standardized Coefficients	*t*	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.031	0.267		7.606	<0.001	1.505	2.557
	Cost	0.238	0.050	0.293	4.710	<0.001	0.138	0.337
	Quality	0.143	0.047	0.055	0.910	<0.001	0.136	0.050
	Time	0.257	0.058	0.265	4.406	<0.001	0.142	0.372

Note: dependent variable: project success.

The model summary of the linear regression analysis in Table 8 reveals a positive association (R = 0.452) between the predictors (time, quality, and cost) and the dependent variable (project success). The model accounts for approximately 20.4% of the variability in project success, as indicated by an R square value of 0.204. When considering the number of predictors, the adjusted R square value is 19.4%. The estimator's standard error is 1.11817, which is the average amount by which the observations deviate from the regression line. The Durbin–Watson statistic of 1.714 is within the permissible range of 1 to 3, indicating that the assumption of independence of observations is satisfied.

Table 8. Model summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin–Watson
1	0.452a	0.204	0.194	1.11817	1.714

Note: Predictors: constant, time, quality, and cost. Dependent variable: project success.

The residual statistics in Table 9 show that the predicted values range from 2.4394 to 4.4603, with a mean of 3.4545 and a standard deviation of 0.56315. The residuals span values ranging from −2.31854 to 1.87611, with an average of 0.00000 and a standard deviation of 1.11118. The standardized residuals fall within the permitted range of −3.29 to

+3.29, indicating the accuracy of the analysis and the absence of significant outliers. These statistics confirm the regression model's suitability and dependability for the investigation.

Table 9. Residual statistics.

Prediction	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2.4394	4.4603	3.4545	0.56315	242
Residual	−2.31854	1.87611	0.00000	1.11118	242
Std. Predicted Value	−1.803	1.786	0.000	1.000	242
Std. Residual	−2.074	1.678	0.000	0.994	242

Note: dependent variable: project success.

The weather has been considered an external factor that is mostly beyond the influence of project managers, yet its effect on the three core limitations of time, cost, and quality is significant [33]. Researchers have consistently shown a clear link between unfavorable weather conditions and delays in projects [37]. Over 30% of construction projects experience longer project schedules due to weather disruptions [38]. These delays not only lengthen project durations but also increase costs due to the need to redistribute resources to accommodate weather disturbances [39].

Further, reported research also indicated that construction projects impacted by unfavorable weather conditions might incur cost overruns of up to 15% [40]. Increased labor expenses, the need to risk equipment, and structure damage are the economic consequences of weather. Weather-induced delays and the need to recomplete tasks can also impact quality, leading to construction flaws [41]. The inherent volatility of weather conditions constitutes a crucial risk element that intensifies the already challenging endeavor of effectively managing the triple constraints in construction projects [42].

Projects that successfully addressed these obstacles were more likely to achieve their objectives and fulfil the expectations of stakeholders. Nonetheless, external factors, such as weather conditions, had a significant impact on a project's success. Construction professionals can make tangible use of these data. Obtaining a deeper understanding of how the triple constraints and external factors, such as weather, influence each other helps improve project planning and strategies for managing risks. Construction managers can devise contingency plans to mitigate the detrimental impacts of unfavorable weather, allocate more workers to handle any delays, and impose quality assurance techniques to uphold standards under challenging circumstances [41,42].

Thus, this study conclusively highlighted the significant impacts of weather conditions and the triple constraints on project success. Descriptive, *t*-test, ANOVA, and regression analyses confirmed that cost, quality, and time positively influence project success, with weather conditions amplifying their effects. This inquiry aimed to provide a comprehensive understanding of how the triple constraints, along with weather conditions, impact the success of construction projects. We employed descriptive statistics, such as means, standard deviations, and frequency distributions, to effectively condense the survey results. The results obtained from Tables 6–8, as demonstrated above, emphasized the widespread occurrence of and fluctuation in delays, cost overruns, and quality problems in the analyzed projects. The mean values provided a measure of the average evaluation of these occurrences, while the standard deviations offered information about their variability. Additionally, the frequency distributions revealed patterns and trends within the data [37]. We also conducted a multivariate regression analysis to obtain a more comprehensive understanding of the intricate relationships between the triple constraints and a project's success. This methodology was particularly advantageous for examining the influence of multiple autonomous factors, such as time, cost, and quality, on a dependent factor, specifically project success [38]. The regression analysis revealed the extent and significance of these connections, offering a comprehensive understanding of how each constraint, both individually and collectively, affects a project's overall outcomes. This study also investigated the effect of weather conditions on these constraints. The regression models incorporated weather-related factors and showed that adverse weather significantly exacerbates issues related to time, cost, and quality. Adverse weather conditions have a substantial influence on projects, resulting in higher rates of delays and cost overruns, as well as a deterioration in the quality of work [39]. These results highlight the importance of efficiently managing time, expenses, and excellence to achieve favorable project results.

5. Conclusions

The present study emphasizes the need to effectively control the triple constraints in order to obtain favorable results in construction projects. The results also demonstrate that the ability to keep these constraints in equilibrium is essential since inadequate control of any aspect can result in delays, exceeding a budget, and degraded quality, all of which greatly affect project achievement. Therefore, it is crucial to efficiently handle these constraints in order to successfully complete projects within the allocated time-period according to the financial constraints and prescribed quality benchmarks.

The key conclusions of this study are as follows:

The impact of weather-related delays: the analysis demonstrated that weather-related delays significantly affected the projects under investigation, influencing both project time and associated costs.

The time factor: Regression analysis revealed a positive association between an extended project duration and project success (B = 0.257, $p < 0.05$). This finding indicates a positive correlation between a longer project duration, often due to adverse weather conditions, and improved project outcomes.

The cost factor: A significant positive correlation was identified between increased project costs and project success (B = 0.238, $p < 0.05$). This result further indicated that weather-induced cost increases contributed to higher levels of project achievement.

The quantitative impact: the data strongly indicate that weather-related delays led to an average project delay of 25.7% and caused an average cost increase of 23.8% in the studied projects.

Alignment with the existing literature: these findings, derived from primary data, align with the broader understanding of weather impacts that has been reported in the literature [39–42], which provides additional context and supports this study's results.

The correlation study validated the robust interrelationship among time, cost, and weather-related variables, indicating a need to effectively manage these constraints in a systematic manner. Effective management of these constraints increased the likelihood of success for projects, but failure to do so resulted in substantial setbacks. The aforementioned discovery emphasizes the importance of adopting a comprehensive strategy for handling the triple constraints in order to improve project performance and minimize the likelihood of delays and exceeding a budget. In addition, this study primarily examined the direct influence of weather conditions on the triple constraints. Although this offered valuable information, it failed to consider indirect elements such as interruptions in the supply chain that can exacerbate difficulties associated with weather.

To overcome these constraints, it is necessary to conduct more extensive and geographically tailored research that combines existing project management methodologies with sophisticated analytical tools such as machine learning. This will allow for more accurate predictions of the combined impacts of weather and other external variables. Furthermore, future research could investigate the long-term financial consequences of weather disturbances, going beyond immediate cost overruns to evaluate total life-cycle expenses and quality results. We can obtain a more comprehensive perspective of how construction managers might enhance their ability to predict and alleviate external disruptions by broadening the field of inquiry to encompass other external risks, such as supply chain volatility or labor shortages.

6. Limitations and Directions for Future Research

This study provides useful insights, but it is crucial to acknowledge its limits. First, the sample size of 242 industry professionals, although strong, may not completely reflect the range of practices and experiences in different areas and types of construction projects. The utilization of data that were self-reported via surveys presents the possibility of response bias, as participants may exaggerate or downplay their experiences and perceptions. Furthermore, while this study's focus on weather conditions as a moderating factor was important, it may have led to other crucial external influences being overlooked, such as economic fluctuations, political instability, or technological advancements, which could also impact project success. Limiting the scope of this research to the construction business may impede the ability to apply the findings to other sectors. Furthermore, this inquiry prioritized quantitative approaches, which produced measurable data but may not have sufficiently captured the qualitative and significant aspects of project management challenges.

Subsequent investigations are also recommended to augment the sample size to tackle these constraints and encompass a broader range of participants from distinct geographical regions and various sorts of construction projects. A longitudinal study has the potential to provide a more thorough understanding of the long-term impacts of meteorological conditions and the triple constraints on project success. Incorporating qualitative methods, such as interviews or case studies, might improve our understanding of the complex dynamics involved in project management. To provide a more thorough comprehension of the challenges faced in construction projects, further research should explore additional external aspects such as economic, political, and technological effects. Furthermore, a study could direct its focus towards advancing and testing adaptive strategies and technologies enabling project managers to promptly and flexibly address disruptions, including those arising from climatic circumstances. The use of cutting-edge technology, such as artificial intelligence and machine learning, may lead to creative ways to effectively manage the triple constraints and improve project outcomes. In conclusion, we intend to clearly verify the results and extend this research to provide wider relevance in other sectors, thereby enriching the entire body of knowledge related to project management.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings15030474/s1, Figure S1: Graph showing gender profile; Figure S2: Graph showing academic qualification; Figure S3: Various type of company take part in survey; Table S1: Gender Profile of Respondents; Table S2: Academic Qualification; Table S3: Type of Company; Table S4: Experience within construction industry; Table S5: Descriptive Statistics; Table S6: One Sample Statistics; Table S7: Item- Total Statistics; Table S8: Summary of Literature Review.

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