NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

Bulletin of Geography. Socio-economic Series, No. 61 (2023): 59-70
http://doi.org/10.12775/bgss-2023-0025

BULLETIN OF GEOGRAPHY. SOCIO–ECONOMIC SERIES

journal homepages:
https://apcz.umk.pl/BGSS/index
https://www.bulletinofgeography.umk.pl/

Analysis of delays and cost overruns of road construction projects in the Colombian Caribbean Region

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How to cite:
Canales, F.A., Mora, O., Arrieta-Castro, M., Moreno-Natera, A. & del Savio, A. (2023). Analysis of delays and cost overruns of road construction projects in the Colombian Caribbean Region. *Bulletin of Geography. Socio-economic Series*, 61(61): 59-70. DOI: http://doi.org/10.12775/bgss-2023-0025

Abstract. Construction projects are constantly threatened by delays and cost overruns that might compromise their viability. Thus, identifying the leading causes of these issues based on the experience of experienced professionals is essential to planning and reducing these risks. This research evaluates the frequency and severity of variables causing delays and cost overruns in Colombian Caribbean Region road projects. The nine causes studied in this research were defined through a literature review, preliminary discussion and a pilot test. A survey directed to 42 road construction engineers allowed the authors to characterise these professionals' perceptions regarding the frequency and severity of these variables in terms of delay and cost overruns, with a confidence level of 80%. Statistical analyses were applied to the results of the survey to establish which variables generate the most significant impacts when building roads and related works in the Colombian Caribbean Region.

Article details:
Received: 23 January 2023
Revised: 08 July 2023
Accepted: 17 July 2023

Key words:
geography, planning & development, delays & cost overruns, road construction, construction management, Colombia

Contents:

1. Introduction

Road infrastructure is of vital importance in the development and growth of a country. As in any civil engineering endeavour, a road construction project's success is measured in terms of the time, performance and quality of the work carried out within a given budget and schedule. Therefore, adequate management includes preventing and anticipating cost overruns (Alfakhri et al., 2018), especially those related to schedule delays, which are considered the most costly, complex and risky problems in construction projects (Aziz & Abdel-Hakam, 2016; Thapanont et al., 2018).

Understanding and evaluating the causes and perceptions regarding construction delays and cost overruns have been the subject of research worldwide. Based on the considerations of 100 construction professionals in the West Bank in Palestine, Mahamid (2021) evaluated the effect of design quality on project delays and identified that the leading causes include payment delay, poor labour outputs, lack of skilled workforce, and design changes. In their paper assessing the critical factors associated with the success of construction projects in Oman, Hamad et al. (2021) found that delays by authorities in issuing permits and the approval of designs by client and consultants are the factors associated with the project schedule that most impact the successful execution of construction works. Similarly, Del Savio et al. (2022) state that communication and collaboration issues commonly arise between the entities that develop a project, and this lack of integration might result in delays between the design, execution and even procurement phases.

Roads play a pivotal role in any country's economy, significantly influencing safety, community well-being and the efficient transportation of goods to human settlements. However, as with any other civil project, they are subject to delays and cost overruns, thus justifying research related to these issues, usually relying on field records and the perceptions of different stakeholders. The systematic review by Mejía et al. (2020) identified 47 research papers in SCOPUS and Web of Science databases dealing with quantitative evidence of the causes of delays and focusing on roads or highway projects in developing countries. Similarly, the review paper by Rivera et al. (2020) determined the leading causes of delay in roadway projects in 25 developing countries worldwide.

For instance, Aziz and Abdel-Hakam (2016) found 290 causes of delays affecting highway construction in Egypt, aiming to identify the causes, severity and solutions from the stakeholders' perspective. A predictive model based on the results from the survey was employed in a case study of a road construction project, with a good fit between the predicted and actual duration. Thapanont et al. (2018) investigated the causes of delays in road construction projects in Thailand. By applying a questionnaire to the managerial staff of the Bureau of Highways Construction, they found that roadway project schedules are most commonly affected by factors specific to the planning of activities and environmental factors. Al Hadithi (2018) identified and studied the causes and frequency of highway construction delays in Iraq, assessing the differences between contractors', owners' and consultants' opinions. The author identified 64 causes of delays according to the perception of consultants and contractors, among which the most significant correspond to circumstances beyond the control of the executing party.

Alfakhri et al. (2018) conducted a study whose objective was to measure the effects of delays in road construction works in Tripoli, Libya. They conducted a survey targeting owners, consultants and contractors of road construction projects, concluding that negative impacts on the entire civil works market include disruption to traffic, litigation, loss of profit, breaches of contract and poor quality of work. The study identified that the main effects were financing-related. Stević et al. (2022) employed multicriterion analysis to calculate the independent importance of twenty delay factors related to road construction projects in the Benin Republic.

The studies summarised above indicate the relevance of this research topic for developing countries, as most countries in Latin America are. Colombia's Caribbean region has a strategic geographical position facilitating foreign trade through the Caribbean Sea (Aguilera-Díaz et al., 2013). Estimates indicate that 85% of Colombian trade is carried out by sea because this is the most economical mode of transport over long distances (Viloria-de-la-Hoz, 2006). For this reason, the appropriate condition of this region's roads and the success of projects related to connecting the rest of the country with the Caribbean coast are fundamental for the Colombian economy. Some recent studies in Colombia deal with identifying and understanding the causes of delays and cost overruns in civil construction projects. For instance, the paper by Lozano Serna et al. (2018) assessed a sample of 75 construction projects in Colombia and identified that planning, logistics, communication issues, design changes, fluctuations in currency exchange rates, and type of project were some of the most significant and explained most project delays

and cost overruns. Based on the response from 44 professionals, Sánchez et al. (2021) evaluated the causes, frequency and severity of cost overruns in Colombian construction projects. Gómez-Cabrera et al. (2020) used a significant sample of 535 rural road projects in Colombia built between 2015 and 2018 and employed bivariate analysis to identify the main variables negatively affecting the schedule and budget of these projects.

Examining and comprehending the primary factors contributing to delays and cost overruns in road construction projects is pivotal for effective project management and planning. However, it is essential to acknowledge that each region has unique characteristics, making it challenging to generalise findings (Aziz & Abdel-Hakam, 2016). Any alterations to a region's road infrastructure – whether for maintenance or construction – directly impact local mobility. These changes can lead to externalities in the transportation of individuals, encompassing increased costs and travel times, reduced productivity and atmospheric pollution. Within this context, this research aims to evaluate the frequency and severity of nine major causes of delays and cost overruns in road works in the Colombian Caribbean based on the perception of professionals in road construction in this region and the analysis through statistical tests widely recognised and employed in the literature. The research questions (RQ) are the following:

- RQ1: Do all the causes evaluated in this study produce delays and cost overruns with the same frequency and severity in road works projects in the Colombian Caribbean?
- RQ2: Is there a significant difference between frequency and severity for each of the causes of delays and cost overruns?
- RQ3: What is the correlation between the frequency and severity of each of the causes of delays and cost overruns?

2. Research materials and methods

2.1. Study area

The study area is located in South America. It corresponds to the Colombian Caribbean region, which occupies the northern region of this Latin American country and covers an area of 132,244 km² (approximately 12% of Colombia's continental territory) and has approximately 10.8 million inhabitants, with 28% of this population settled in rural areas (Cantillo et al., 2022). It comprises the Departments of La Guajira, Cesar, Bolivar, Cordoba, Sucre, Atlantico and Magdalena. The region's strategic geographic position facilitates foreign trade across the Caribbean Sea. The economic activities include agriculture, livestock, mining, industry, tourism and maritime transportation (Aguilera-Díaz et al., 2013). As shown in Figure 1, between 1970 and 2015, this region's road and highway density increased by 1300%, from around 53 m/km² to 692 m/km² (Cardona-Almeida et al., 2022).

2.2. Research method and data collection

This study employed qualitative analysis software (ATLAS.ti) to systematically analyse and categorise the open responses regarding this research topic. These responses were provided by a pilot test comprised of eight civil engineering professors with experience in the construction of road works in this region. Subsequently, based on these responses and information available in the literature (Aziz & Abdel-Hakam, 2016; Rybka et al., 2017; Thapanont et al., 2018; Alfakhri et al., 2018; Rudeli et al., 2018), a list of potential causes of delays and cost overruns in road construction projects was prepared, grouping those that conveyed similar concepts and listing only those mentioned by at least 25% of the pilot sample. This final list, consisting of nine major causes of delays and cost overruns in the Colombian Caribbean region, as listed in Table 1, was then presented to the participants of the pilot sample for validation.

Based on similar studies from developing countries (Le-Hoai et al., 2008; Mahamid et al., 2015; Thapanont et al., 2018), the authors prepared and applied a questionnaire to determine the frequency and severity of the variables causing delays and cost overruns in road works in the Colombian Caribbean, as described in Table 1. The sample universe corresponds to civil construction professionals with experience in roadworks in the study region. The reader can find the survey applied in the link provided in the notes section at the end of this article (1).

The survey encompassed questions aimed at characterising the respondents based on their educational background, years of professional experience and the geographical regions within which they had worked in Colombia. After introducing definitions for the nine considered causes, participants were requested to assess their perception of each cause using a 5-point Likert scale for the following aspects: severity of delay causes,

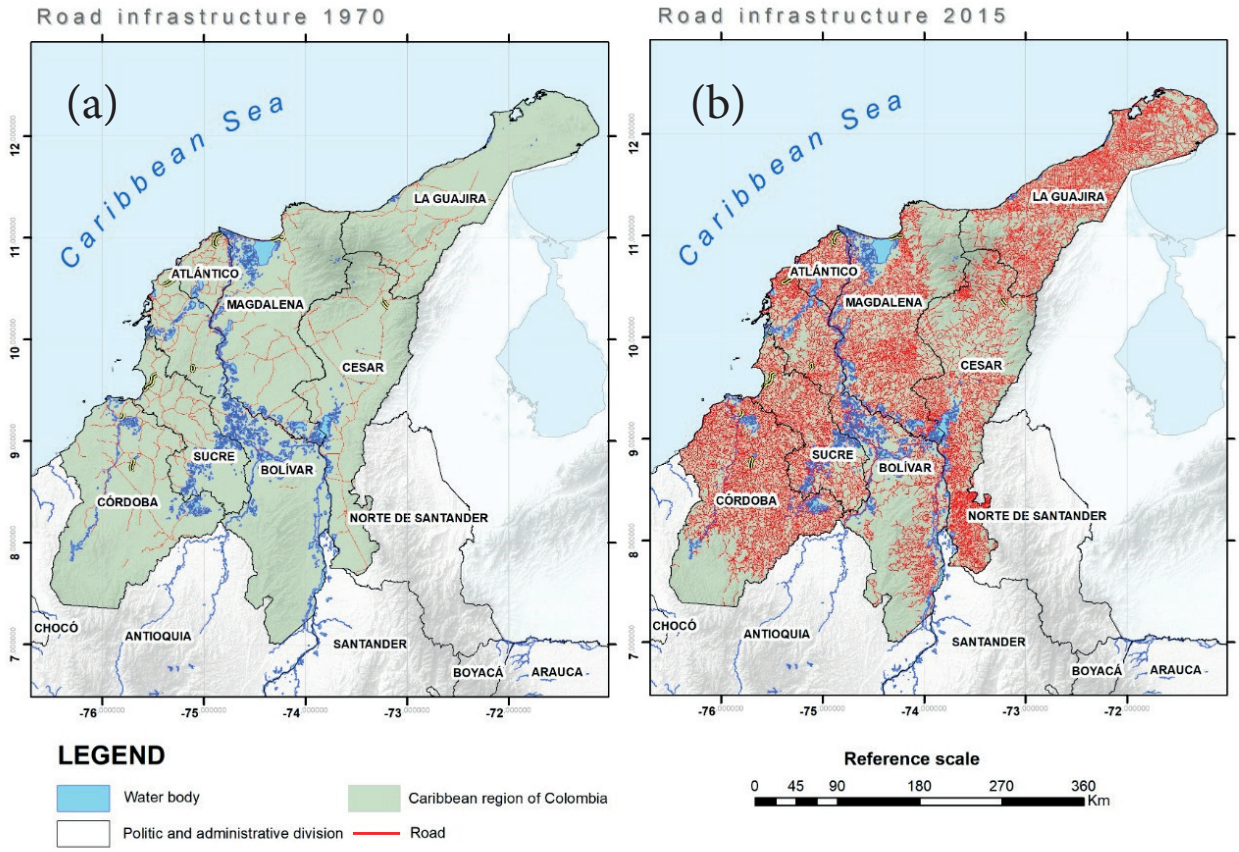

Fig. 1. Evolution of the road network in the Colombian Caribbean: a) 1970; b) 2015
Source: own elaboration

frequency of delay causes, severity of cost overrun causes, and frequency of cost overrun causes.

More than 100 requests to complete the survey were sent to companies and professionals in the civil construction industry in the Caribbean region. With an unknown quantity of professionals satisfying the population criteria (working experience in road construction projects in the Colombian Caribbean), the 42 responses obtained imply a confidence level of 80%, considering a proportion of 50% and an acceptable error in the estimate of 10% (Naing et al., 2006). On average, their experience in road construction projects was eight years, with a standard deviation of six years. Regarding their academic background, 57% had a specialisation degree and 31% had a bachelor's degree in civil engineering or related fields.

The methodology adopted in this study relies on the statistical analysis of the answers provided by the professionals regarding their perception of the frequency and severity of the nine causes of delays and cost overruns of road works in the Caribbean region of Colombia. To answer the research questions presented in the introduction section, and similar to the article by Gómez-Cabrera et al. (2020), this study employs the Kruskal–Wallis (K-W), Wilcoxon matched-pairs signed-ranks, and Spearman tests, to correspondingly address research questions RQ1, RQ2, and RQ3, as these nonparametric tests are recommended to evaluate responses measured through Likert scales, as in the present study (Goss-Sampson, 2019). For additional clarity regarding the purpose of each of these tests:

- The K-W test allows testing if some independent samples come from the same population or distribution without assuming a normal distribution (Goss-Sampson, 2019). This test makes it possible to determine whether the surveyed professionals perceive that all causes of delay and cost overruns have the same severity and occur with the same frequency for each pair of causes. If the K-W results are significant, the Dunn test will allow us to identify the location of these significant differences.
- The Wilcoxon matched-pairs signed-ranks test evaluates the null hypothesis that the population mean of the difference between two dependent samples equals zero (Sheskin, 2004). In this

Table 1. Major causes of delays and cost overruns in roadworks in the Colombian Caribbean

Cause	Abbreviation	Definition
Land purchase and permits	LPP	Processes related to the acquisition of public and private land necessary for the execution of the project, as well as obtaining the necessary permits
Weather conditions	Weather	Problems related mainly to rainfall and its effects on the project construction area
Design and plans	D&P	Incorrect, insufficient or ambiguous specifications and design plans
Execution errors	Ex_Err	Poor-quality craftsmanship and materials, usually leading to rework
Geotechnical conditions	Geo	Unforeseen geotechnical failures and any problem related to the load response of soils
Machinery and Equipment	M&E	Unavailability of machinery, mechanical failures or lack of trained operators with the necessary permits
Materials	Mat	Unavailability or inadequate quality of the material required for the project
Financial and contract issues	FICC	Non-adherence or modification to contract conditions, discrepancies between owner and contractor, and delay of payments
Utility services	Ut_Srv	The need for intervention by service providers of water, natural gas, sewage, electricity, other subcontractors, and third-party activities in the area during project execution

Source: Authors' work

case, from the survey responses, we evaluate whether the professionals perceived significant differences between frequency and severity for each of the causes of delays and cost overruns.

- Spearman's rank order correlation coefficient (ρS) evaluates whether there is a correlation between the perception of the degree of severity and frequency for each of the delay and cost overrun variables evaluated (Sheskin, 2004).

Based on Meng et al. (2020), the Likert scale categories included for severity: are 1 – Irrelevant; 2 – Things to consider; 3 – Moderate; 4 – Major; 5 – Highly harmful. As for frequency, the options correspond to 1 – Rare; 2 – Unlikely; 3 – Occasional; 4 – Frequent; 5 – Almost certain. For the hypotheses tests employed in this study, the significance level (α) threshold for rejecting the null hypothesis is set at 5%, but in the result tables, we will also report those cases that correspond to α equal to 1% and 0.1%.

3. Research results

The boxplots in Figure 2 summarise the responses obtained from the survey. Based on this information, this work relies on hypothesis testing to answer the research questions presented in the introduction above. As mentioned earlier, it is worth noting that each country or region has its unique factors influencing delays and cost overruns in road construction projects (Aziz & Abdel-Hakam, 2016). Later, in the discussion section of this article, we will draw comparisons with similar studies conducted in other parts of the world to highlight parallels and differences.

3.1. Same frequency and severity regarding delays and cost overruns for all causes?

The K-W test allows us to assess whether the professionals being surveyed consider that all the causes behind delays and cost overruns are equally severe and occur at the same rate for every pair of causes, as shown in the results in Table 2.

The first line in Table 2 shows the K-W test results (K-W p-value). The rest of the lines in this table show the Z and p-values from Dunn's test for each paired comparison, as this nonparametric correction conducts multiple comparisons based on rank sums, and it is commonly used as a *post-hoc* procedure following the rejection of the K-W null hypothesis that the medians of all groups are equal (Sheskin, 2004). The sign of the Z value indicates which group has a higher median (positive if A>B, negative if A<B).

Regarding delays, both in severity and frequency, the p-values for the K-W test indicate statistically significant differences between at least a paired comparison of causes. At a 5% significance level (α), the results of the Kruskal–Wallis and Dunn tests imply that, in the opinion of the professionals

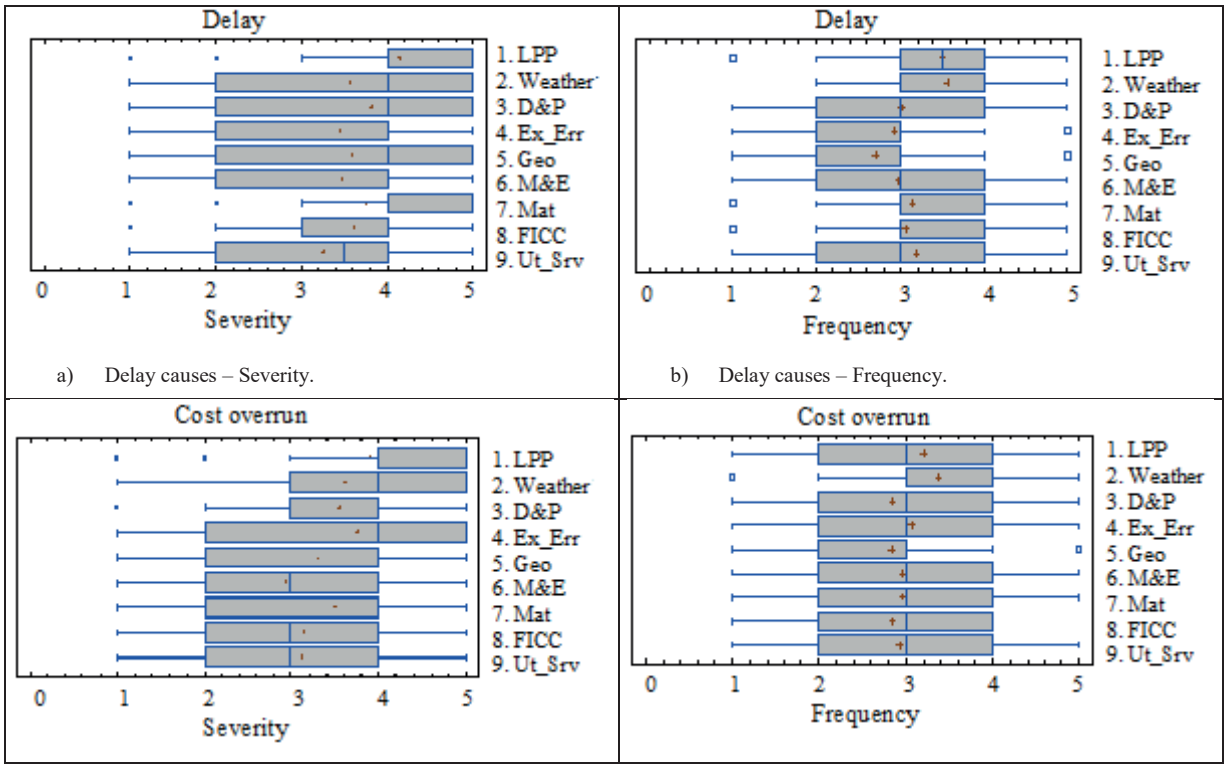

Fig. 2. Box plots summarising the survey's results: a) Severity of delay causes; b) Frequency of delay causes; c) Severity of cost overruns; d) Frequency of cost overruns
(Likert scale explanation (Severity / Frequency): 1 – Irrelevant / Rare; 2 – Things to consider / Unlikely; 3 – Moderate / Occasional; 4 – Major / Frequent; 5 – Highly harmful / Almost certain)
Source: Author's work

surveyed, issues associated with land acquisition and permits produce significantly more severe delays than the other causes. As observed in Figure 2a, 45% of the responses considered that LPP could produce highly harmful effects on the project schedule. Similarly, LPP and weather are the most frequent causes of delays in road works.

The K-W test for cost overruns indicates the existence of significant differences concerning the severity of impacts. Consequently, Dunn's test suggests that execution errors, weather and the process of acquiring land and permits stand out substantially over the other causes. It is worth highlighting that the p-value of the K-W test suggests that the null hypothesis cannot be rejected and that there are no statistically significant differences between the variables regarding the frequency of cost overruns. However, a closer inspection through Dunn's test indicates that weather-related problems present statistically significant differences when compared to most elements of the set.

3.2. Do frequency and severity have a similar magnitude for each cause?

The Wilcoxon test was used in this study to assess whether professionals, based on survey responses, perceived significant differences in frequency and severity for each cause of delays and cost overruns under analysis.

The results in Table 3 indicate that, for road works delays, the professionals perceive statistically significant differences between relevance and frequency in seven of these causes, including two (geotechnical issues and materials), with a degree of reliability of 99.9%. This observation indicates that although respondents consider them frequent, their severity may not have the same impact, or *vice versa* (See Fig. 2a and Fig. 2b).

On the other hand, respondents perceive statistically significant differences (α=5%) between relevance and frequency in five causes of road works cost overruns. For example, as suggested in Figure 2c and Figure 2d, LPP issues and design are considered more severe than frequent. The

Table 2. Kruskal–Wallis (K-W) one-way analysis of variance test and Dunn's post-hoc test results on the assessment of frequency and severity regarding delays and cost overruns for all causes. Significance level: * p<.05, ** p<.01, *** p<.001

	Severity – Delay		Frequency – Delay		Severity – Cost Overrun		Frequency – Cost overrun	
	K-W p-value: 0.012*		K-W p-value: 0.002**		K-W p-value: 0.004**		K-W p-value: 0.186	
Paired comparison	**Z**	**Dunn's p-value**	**Z**	**Dunn's p-value**	**Z**	**Dunn's p-value**	**Z**	**Dunn's p-value**
LPP - Weather	2.161	0.015*	-0.237	0.406	0.989	0.161	-0.819	0.206
LPP - D&P	1.053	0.146	2.228	0.013*	1.258	0.104	1.662	0.048*
LPP - Ex_Err	2.730	0.003**	2.749	0.003**	0.339	0.367	0.685	0.247
LPP - Geo	2.026	0.021*	3.562	< .001***	2.131	0.017*	1.673	0.047*
LPP - M&E	2.719	0.003**	2.356	0.009**	3.395	< .001***	1.193	0.116
LPP - Mat	1.571	0.058	1.596	0.055	1.554	0.06	1.179	0.119
LPP - FICC	2.343	0.01**	1.916	0.028*	2.832	0.002**	1.429	0.077
LPP - Ut_Srv	3.899	< .001***	1.219	0.111	2.909	0.002**	1.363	0.086
Weather - D&P	-1.108	0.134	2.465	0.007**	0.270	0.394	2.481	0.007**
Weather - Ex_Err	0.568	0.285	2.986	0.001**	-0.65	0.258	1.504	0.066
Weather - Geo	-0.136	0.446	3.800	< .001***	1.142	0.127	2.492	0.006**
Weather - M&E	0.557	0.289	2.593	0.005**	2.407	0.008**	2.013	0.022*
Weather - Mat	-0.591	0.277	1.833	0.033*	0.566	0.286	1.998	0.023*
Weather - FICC	0.182	0.428	2.153	0.016*	1.844	0.033*	2.248	0.012*
Weather - Ut_Srv	1.738	0.041*	1.456	0.073	1.920	0.027*	2.182	0.015*
D&P - Ex_Err	1.676	0.047*	0.521	0.301	-0.919	0.179	-0.977	0.164
D&P - Geo	0.972	0.165	1.335	0.091	0.872	0.192	0.011	0.496
D&P - M&E	1.665	0.048*	0.128	0.449	2.137	0.016*	-0.469	0.320
D&P - Mat	0.517	0.303	-0.632	0.264	0.296	0.384	-0.483	0.314
D&P - FICC	1.290	0.099	-0.312	0.378	1.574	0.058	-0.233	0.408
D&P - Ut_Srv	2.846	0.002**	-1.009	0.156	1.651	0.049*	-0.299	0.383
Ex_Err - Geo	-0.704	0.241	0.814	0.208	1.792	0.037*	0.988	0.161
Ex_Err - M&E	-0.011	0.496	-0.393	0.347	3.056	0.001**	0.509	0.305
Ex_Err - Mat	-1.159	0.123	-1.153	0.125	1.215	0.112	0.494	0.311
Ex_Err – FICC	-0.386	0.350	-0.833	0.203	2.493	0.006**	0.744	0.228
Ex_Err - Ut_Srv	1.170	0.121	-1.530	0.063	2.570	0.005**	0.678	0.249
Geo - M&E	0.693	0.244	-1.207	0.114	1.265	0.103	-0.480	0.316
Geo - Mat	-0.455	0.324	-1.966	0.025*	-0.577	0.282	-0.494	0.311
Geo - FICC	0.317	0.375	-1.647	0.05*	0.702	0.241	-0.244	0.404
Geo - Ut_Srv	1.873	0.031*	-2.344	0.01**	0.778	0.218	-0.310	0.378
M&E - Mat	-1.148	0.125	-0.760	0.224	-1.841	0.033*	-0.015	0.494
M&E - FICC	-0.375	0.354	-0.440	0.330	-0.563	0.287	0.235	0.407
M&E - Ut_Srv	1.181	0.119	-1.137	0.128	-0.486	0.313	0.170	0.433
Mat - FICC	0.773	0.220	0.320	0.375	1.278	0.101	0.250	0.401
Mat - Ut_Srv	2.329	0.01**	-0.377	0.353	1.355	0.088	0.184	0.427
FICC - Ut_Srv	1.556	0.060	-0.697	0.243	0.077	0.469	-0.066	0.474

Source: Authors' work

Table 3. Results from the Wilcoxon matched-pairs signed-ranks test assessing whether the perception about frequency and severity have a similar magnitude for each cause of delays and cost overruns. Significance level: * p<.05, ** p<.01, *** p<.001

Cause	Delay - Severity and frequency		Cost overruns - Severity and frequency	
	W-statistic	p-value	W-statistic	p-value
Land purchase and permits	588.0	0.0061 **	587.0	0.0062 **
Weather conditions	813.0	0.5226	727.0	0.1491
Design and plans	536.5	0.0015 **	570.0	0.0041 **
Execution errors	620.5	0.0160 *	565.5	0.0034 **
Geotechnical conditions	515.5	< .001 ***	654.0	0.0355 **
Machinery and equipment	632.5	0.0203 *	883.5	0.9926
Materials	523.0	< .001 ***	621.5	0.0155 *
Financial and contract issues	618.5	0.0147 *	778.5	0.3409
Utility services	856.0	0.8096	799.0	0.4458

Source: own elaboration

opposite is true for the causes of execution errors and geotechnical issues, which are considered more frequent than significant in terms of their negative impacts on costs.

3.3. What is the correlation between the frequency and severity of each cause?

Table 4 shows the resulting Spearman's rank order correlation coefficients (ρS), which might be used for assessing whether there is an association between the perceived severity and frequency for each of the causes of delays and cost overruns in road construction projects in the study area.

Regarding delays and using the scale presented by Sheskin (2009) for its interpretation, the results presented in Table 4 show moderate ($0.5 < |\rho S| < 0.8$) or strong correlations ($|\rho S| \geq 0.8$) between the severity and frequency in only three of the causes under analysis, with third-party works being the element with the higher ρS of the set. In contrast, most causes present at least a moderate correlation for cost overruns.

4. Discussion

In addition to the construction of new roads, a good quality road network requires the maintenance of existing infrastructure, road widening and construction of lined canals, culverts and bridges and other works. The proper management, planning and execution of these projects are valuable to all

Table 4. Spearman's rank order correlation coefficients between severity and frequency for both delay and cost overruns

Cause	Delay - Severity and frequency Spearman's correlation coefficient	Cost overruns - Severity and frequency Spearman's correlation coefficient
Land purchase and permits	0.4878	0.5351
Weather conditions	0.7088	0.3473
Design and plans	-0.2138	0.7516
Execution errors	0.1531	0.7364
Geotechnical conditions	0.2084	0.6396
Machinery and Equipment	-0.1541	0.2507
Materials	-0.1454	0.4185
Financial and contract issues	0.5914	0.8146
Utility services	0.9220	0.6456

Source: Authors' work

parties involved (Aziz & Abdel-Hakam, 2016). For the regional governments, it promotes the region's development and guarantees safety and comfort to the citizens, and for construction companies, the execution of the project within the schedule and budget improves their performance and credibility. For users, traffic jams in a city affect their quality of life, and some estimates indicate that in Colombia, about 2% of GDP is lost annually due to traffic jams (COLPRENSA, 2015). For these reasons, avoiding or limiting delays and cost overruns in road projects can reflect positively on other vital areas of society, such as health, commerce and industry.

Because they are perceived as severe but mostly occasional, problems related to LPP are a factor to which particular attention should be paid in the planning stages of road projects. These results coincide with the findings of Sánchez et al. (2021), also for the Colombian territory, in which they identified that the primary cause of cost deviation in construction projects is associated with delays in issuing permits by local authorities. Regarding frequency, both for delays and cost overruns, the magnitude of LPP is only behind that of weather, as observed in Figure 2b and Figure 2d. This cause has also been found as a major delaying factor by Idrees and Tariq Shafiq (2021).

On average, weather-related problems are considered the most frequent cause of delays, highlighting the importance of weather forecasts, including in some cases (e.g., when cranes are required or there is a risk of air pollution from construction activities) wind speed forecasts for the site area (Neitzel et al., 2001). This perception might explain the high p-value for delays and the relatively high correlation in Table 3 and Table 4. At the same time, the inevitability of these phenomena and the knowledge of the behaviour of rainfall patterns mean that schedule and budget planning result in relatively low risks in terms of weather-related cost overruns, except for extreme events, as also seen in previous literature (Le-Hoai et al., 2008; Idrees & Tariq Shafiq, 2021; Sánchez et al., 2021).

From the survey results, the professionals expressed that issues associated with design and plans are predominantly occasional causes of delays and overruns, similarly to the outcomes from Aziz & Abdel-Hakam (2016). Even if they can significantly delay the project schedule, the severity of the corresponding overruns is mainly moderate. These observations are contrary to the findings of Le-Hoai et al. (2008), as both frequency and severity indices associated with design changes had the same magnitude and were in the top 5 causes for all parties surveyed in their study (owners, contractors, consultants).

Comparable to other studies (Al Hadithi, 2018; Gómez-Cabrera et al., 2020), execution errors present the highest severity value in terms of cost overruns, besides a moderately high correlation between their relevance and periodicity, highlighting the importance of clear and open communication between all stakeholders, correct field supervision, and hiring skilled workforce and operators (Idrees & Tariq Shafiq, 2021).

The problems associated with geotechnical conditions are deemed capable of producing considerable delays and cost overruns, although they are infrequent. This perception can be mainly explained because the soils of the Colombian Caribbean have well-known characteristics associated with their origin, human activities and the region's climate (González-Pedraza et al., 2022; Malagón Castro, 2003), as well as the low seismicity of the country. Regarding machinery and equipment, the development and growth of the region's road infrastructure in recent decades, as evidenced in Figure 1, has led to a sufficient supply of construction equipment services in the study area; thus, problems associated with M&E are generally resolved in the field without significantly impacting on the project's schedule or budget. According to respondents, problems in the availability and transportation of materials are the second most severe cause of delays in the execution of road projects, and their frequency is occasional, suggesting that precautions are usually taken to avoid these issues. Regarding frequency, these results are different from the findings of Aziz and Abdel-Hakam (2016) for Egypt and Karimi and Piroozfar (2022) in Afghanistan but similar to those of Al Hadithi (2018) for Iraq.

Problems associated with financial issues and contractual situations exhibited the highest correlation between severity and frequency of cost overruns, although their Likert scale scores mainly indicate moderate impacts and occasional occurrences. These results suggest that the professionals' opinion regarding FICC is associated with the internal processes of the institutions and companies where they work and the characteristics of the project's owner (usually a public entity). Therefore, effective communication between the parties involved is fundamental to minimising adverse effects associated with FICC (Rivera et al., 2020). Similarly, with medium scores on the Likert scale, problems associated with third parties and public services present the highest correlation between severity and frequency regarding delays

caused. These results align with the review conducted by Mejía et al. (2020) but oppose the findings by Thapanont et al. (2018), who found that this was the third major cause of delay among the 26 under evaluation in their study for Thailand.

Based on the above, it is observed that even for the same type of project, the leading causes of delay and cost overruns differ from place to place, a conclusion similar to that reached by Aziz and Abdel-Hakam (2016), who stated that cost and project schedule deviations in construction projects across the world have different causes depending on the country, region and socio-economic context. For instance, the study by Lozano Serna et al. (2018) based on information from 75 construction projects of all types in Colombia identified that the primary causes of delays were associated with the planning of activities, availability of machinery and equipment, changes in designs, currency fluctuations and the type of economic activity associated with the project. Regarding cost, they corresponded with delays in the supply of materials, communication problems among stakeholders, currency fluctuations, fraudulent practices and the type of project.

Analogous to most articles cited in this research, this study relies on a survey to investigate the perception of professionals with experience in the region and subject of study. Despite the practicality of this research method, its validation in future studies requires comparison of its results against quantitative data from project logs, daily reports and financial reports to separate out the noise associated with the intrinsic subjectivity of the surveys (Rudeli et al., 2018). However, it is understandable that this feature is not commonly easy to achieve due to the confidentiality that is part of project contracts and the practices that allow the competitiveness of construction companies.

5. Conclusions

Based on inferential statistical tests and the responses of 42 road construction professionals, this research evaluates the severity and frequency of nine primary causes that can generate cost overruns and delays in road projects in the Colombian Caribbean.

Concerning the research questions, we can conclude the following:

- RQ1: In the opinion of the professionals surveyed, the causes evaluated have different levels of impact on delays and cost overruns in road projects. The cause associated with land purchasing and the issuance of permits presents the highest scores in terms of severity in both dimensions. Regarding the frequency of delays, the most significant are problems associated with weather conditions. Interestingly, the Kruskal–Wallis test suggests no significant differences between the causes in terms of the frequency with which the variables studied produce cost overruns. However, a more detailed evaluation suggests significant differences between climate and most other causes.
- RQ2: There is a perception that most of the causes present significant differences between their frequency and severity for both delays and cost overruns, except for those associated with weather and third-party activities.
- RQ3: In line with the previous paragraph, the higher correlations between the severity and frequency of delays also correspond to climate and third-party activities. Regarding cost overruns, most causes present at least a moderate correlation, except those linked to weather, materials, and machinery and equipment.

Determining the leading causes of delays and cost overruns in road works in a region serves as input for planning actions of public and private entities in the management, planning and execution of road works, considering the characteristics and context of each territory. Besides a larger sample, future research about delays and cost overruns in the Latin American region would benefit from contrasting with primary information, such as project logs, daily reports, and financial reports, for determining the match between the perceptions and records.

Notes

1. The survey and the Excel file containing the answers from 42 professionals (both files in Spanish) are available at https://tinyurl.com/4a3cf923.

Acknowledgments

The authors are grateful to Luis Villa Sanmiguel for his participation in this work's initial stages and discussion.

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