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Stakeholders' issues as a source of project delays: a meta-analysis between building and road projects

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Abstract: Delay is one of the most common and complex issues that adversely affect the performance of construction projects. Although much research exists on project delay, only some studies have systematically summarized and compared the causes of delay by the project type. In addition, few studies have quantitatively combined the variability across studies and related them to the responsibilities of project stakeholders. This study conducted a meta-analysis to provide quantitative and reliable evidence on delay causes combining previous research. This study categorized the top ten causes of delay published in primary research studies, calculated the average aggregate relative important index (RII) of these causes, quantitatively summarized their impact on building and road projects using meta-analysis techniques, and linked them to stakeholder responsibility. Based on an initial 160 top ten-delay causes reported, the study aggregated them into sixteen factors and seven management areas. This research found a different prioritization of delays by project type. Overall, while "site management & technical processes" was the most critical delay factor for building projects, "external issue" was for road projects. The comparison by region shows that "skills, knowledge & experience" was the most critical factor for African studies, but "late delivery and material-equipment issues" was for Asian studies. These factors were related to project stakeholders for defining mitigation actions that led to better project performance. Finally, this study provides a first taxonomy of delays, where the previous causes reported in the literature were clustered into factors and management areas.

Keywords: building projects, delay causes, delay factors, meta-analysis, road projects.

1. Introduction

The construction industry plays a pivotal role in a country's development, with a significant Gross Domestic Product (GDP) share. According to the United Nations Economic Commission for Europe (UNECE) Statistical Database, the share of the construction sector in GDP is between four and ten percent for developed countries (United Nations, 2020). Thus, effective development of construction projects leads to improved well-being and progress of communities, as well as to other benefits such as housing, education, commerce, transportation, and wealth, among others (Amoatey & Okanta, 2017; Y. Wang, Han, Vries, & Zuo, 2016). Despite their importance, construction projects face diverse and unpredictable management challenges (Patil, Gupta, Desa, & Sajane, 2013) that threaten their performance, such as dealing with the increasing complexity of their requirements. In fact, for construction management, the achievement of project tasks on time, within budget, and according to specifications are required indicators of success, efficiency, and performance (Abdellatif & Alshibani, 2019; Singh, Bala, Dixit, & Varshney, 2018).

Currently, construction project delays remain an interesting research topic in developing and developed countries (Alaghbari, Kadir, Salim, & Ernawati, 2007; Amoatey & Okanta, 2017; Honrao & Desai, 2015). A preliminary search conducted on August 1, 2020, in the SCOPUS® database from 2000 to 2020 revealed an apparent increase in relevant publications over the past decade. This search identified 722 papers based on the Boolean equation [delay AND "construction projects" OR "engineering projects"]. The literature shows many studies that prioritize delay factors for different project types and regions. Delay factors differ from one type of project to another and have different levels of influence on schedule performance (Emam, Farrell, & Abdelaal, 2015; Santoso & Soeng, 2016). While the top factors for hydropower projects are environmental clearances, geological adversities, and local issues (Shengea, Misra, & Mishra, 2020), the top factors for residential projects are weather conditions, lack of skilled laborer due to the remoteness of the site location, and delay in progress payments by the client (Ramli et al., 2019).

The uniqueness of either building or road projects creates factors with different levels of influence on schedule performance (Emam et al., 2015). In road projects, the lack of material is one of the most critical delay factors due to the large number of materials required for their construction (Eldin, 2002), as well as the lack of equipment due to the high degree of mechanization of their construction processes (Barati & Shen, 2016). Road projects are more exposed to the adverse effects of weather, topography, and natural disasters than building projects (Durdyev, Omarov, & Ismail, 2017). On the other hand, the lack of labor and material supply problems are the most critical factors in building projects (Memari et al., 2014). Building projects require more activities at the construction site and face space constraints and resource availability (Durdyev et al., 2017; Sayed, Mamoua, & Novali, 2020). Building projects also involve more stakeholders, which can adversely influence the performance of the project schedule (Asiedu & Alfen, 2016).

The prioritization of delay factors also varies by region. The preliminary search for this study found several publications on delays in building and road projects built in Africa and Asia. The top factors affecting the construction industry in the United Arab Emirates are change orders, delays in client decisions and approvals, and contractor financing difficulties (Al-Gheth & Sayuti, 2019). The top delay factors in Chinese projects are the need for proper equipment, poor communication between contracting parties, and subcontractor issues (Daniel, 2017). Aibinu and Odeyinka (2006) studied 60 building projects in Nigeria and found an average delay of 90% for residential projects and 63% for office projects. Al-Hazim et al. (2017) studied 14 construction projects in Jordan, where the researchers found delays ranging from 125% to 455%, with an average of 226%. Mahamid (2017) analyzed 101 road projects in Palestine and found an average delay of 48%. Additionally, Amoatey and Okanta (2015) found that 70% of 48 road projects built in Ghana experienced delays with an average time overrun of 17 months.

The preliminary search has also identified publications that report on the accountability of the project stakeholders for the causes of delays. For example, in most construction projects, effective schedule management depends mainly on the contractor's performance, who is required by contract terms to compensate the owner for inexcusable delays. Mainly, the timely delivery of the project depends on the stakeholders involved, who influence the schedule performance of the project in different ways and levels (Wang, Ford, Chong, & Zhang, 2018). Owners, consultants, and external agents are also responsible for delays (Alaghbari et al., 2007; Amoatey & Okanta, 2017). In some cases, it may be necessary to compensate the contractor for the additional costs caused by the planned time extension (Aziz & Abdel-Hakam, 2016). Some authors argue that effective stakeholder management should satisfy the interests of stakeholders (Mok, Shen, & Yang, 2015). Future studies should provide a better understanding of such interests, the influences, accountability, and stakeholder involvement in projects. Delays occur in all types of projects and the prioritization of such delay causes differs by the project type and region. Therefore, the accountability of stakeholders for mitigation actions varies also.

Although there are many publications that prioritize delay causes by either project type or region and others that report the accountability of the stakeholders, these studies have estimated the effect based on subjective rather than objective criteria. In addition, few studies have used quantitative techniques to aggregate the causes from different primary research and relate such causes to the responsibility of project stakeholders. In fact, meta-analysis is a quantitative technique that could provide reliable insights for providing mitigation strategies to project stakeholders based on the aggregated effects of delay factors. A meta-analysis study combines the variability of the delay cause effects across primary research and relates them to the responsibilities of project stakeholders to provide quantitative and reliable evidence of causes. This study categorized the top ten delay causes published in primary research studies, calculated the average aggregate Relative Important Index (RII) of these causes, quantitatively summarized their impact on building and road projects using meta-analysis techniques, and linked them to stakeholder responsibility. By systematically aggregating the causes reported in primary studies, the study provides a larger sample that supports reliable estimates of their impact on project delays in building and road projects built in African and Asian countries. The following sections of this paper will explain the research methodology and discuss the findings.

2. Research methodology

This research used a meta-analysis to gather evidence on stakeholder issues as a source of project delays and to highlight the key similarities and differences between building and road projects. A meta-analysis synthesizes the results of primary studies that address the same research question. This research method allows understanding the results of any study in the context of all the other studies and ensures such results are consistent across the body of data. When the results vary substantially across studies, researchers quantify this variance and consider the implications (Boreinstein, Rothstein, Hedges, & Higgins, 2009). Meta-analysis involves five steps: a) defining the variable of interest; b) gathering the sources of reliable evidence; c) applying criteria to select those studies whose results can be aggregated quantitatively; d) normalizing results across studies; and e) summarizing the cumulative research evidence.

2.1. *Relative Important Index -RII: The variable of interest*

The variable of interest in this meta-analysis is the RII. In construction management, the RII is used to assess and analyze the influence of project delays based on the perceptions of participants (Holt, 2013). Since delays occur in any project context, their causes could be different depending on the project type and region. As result, the stakeholder's perception of the priority of these causes and the resulting responsibility for the mitigation them will vary. The RII quantifies the influence of delay causes as perceived by owners, contractors, and consultants. Based on a five-point scale, Eq. (1) shows the RII used for this study.

$$RII = \frac{\sum_{i=1}^{5} S_i\, f_i}{5N} x\ 100\% \qquad \text{Eq. (1)}$$

where:
S_i =i_{th} ivalue (i = 1, 2, 3, 4, 5)
f_i = frequency of the i_{th} value
N = total of respondents.

2.2. Gathering Relevant Studies

The study adopted the PICO selection protocol based on population, intervention, comparison, and outcomes (Peters et al., 2017). Accordingly, the population of this study includes building and road projects built in Africa and Asia (i.e. population). The available publications dealing with delays in building and road projects provided the possibility to collect more RII indexes and the same method for assessing delay causes based on surveys and five-point Likert scales (i.e., intervention). These conditions made it possible to compared building and road projects built in Africa and Asia. This study analyzed only the top ten delay causes in each publication as rated by owners, contractors, and consultants (i.e. outcomes).

Scopus and Web of Science databases provided the study sample. The Boolean equation used was [("building projects" OR "road projects") AND (causes OR factors OR reasons) AND (delay OR "time overrun" OR "time deviation" OR "schedule delay" OR "schedule deviation" OR "schedule overrun")]. The period of analysis was 2000-2020. The selection process began with a preliminary identification of 1,287 articles; then, based on inclusion/exclusion criteria, a final sample of sixteen primary studies was collected (see Table 1). Eight projects of the sample were building projects, four built in Asia and four in Africa, and the remaining eight projects, road projects (four built in Asia and four in Africa) (see Supplemental File 1).

Table 1. Selection process of studies

Selection criterion	Included	Excluded	Result
Search in databases	1,287		
Duplicate and non-downloadable		132	1.155
Criterion #1. The document reports delay causes related to construction projects.	1,155	668	487
Criterion #2. The document focuses only either on road projects or only on building projects.	487	335	152
Criterion #3. The document report top ten causes with RII.	152	43	109
Criterion #4. Document with a Scimago Index or published under a peer-review process.	109	72	37
Criterion #5. Document with a comparable RII	37	21	16
Final sample			16

2.3. *Sample Composition*

The final sample included sixteen primary studies with the following Scimago classification: 38% in Q1, 44% in Q2, and the remaining 18% in Q3 y Q4. This sample showed an even composition by project type (50% building projects and 50% road projects) and region (50% built in Africa and 50% in Asia) (see Table 2). Those studies published between 2015 and 2020 provided 81% (13 out of 16) of the sample (see Table 3).

Table 2. Sample composition by region and project type (N = 16)

	Period/Region	Africa	Asia	Total
Building project	Count	4	4	8
	% within row	50%	50%	100%
	% within column	50%	50%	50%
Road project	Count	4	4	8
	% within row	50%	50%	100%
	% within column	50%	50%	50%
Total	Count	8	8	16
	% within row	50%	50%	100%
	% within column	100%	100%	100%

Table 3. Sample composition by region and period (N = 16)

Period		Africa	Asia	Total
2005-2009	Count	1	1	2
	% within row	50%	50%	100%
	% within column	13%	13%	13%
2010-2014	Count	1		1
	% within row	100%		100%
	% within column	13%		6%
2015-2020	Count	6	7	13
	% within row	46%	54%	100%
	% within column	75%	88%	81%
Total	Count	8	8	16
	% within row	50%	50%	100%
	% within column	100%	100%	100%

Since each sample study provided its top-ten delay causes, 160 top causes were initially collected. These leading causes were rated on a five-point Likert scale by 1,925 project stakeholders (22% owners, 40% contractors, 26% consultants, 3% designers, 4% sponsors, and 6% project managers). The study analyzed, classified, and normalized these causes as explained in the following sections.

2.4. *Classification of Delay Causes*

In the absence of a taxonomy of delay causes accepted by academics and practitioners, the study clustered those causes that referred to the same idea into factors using a hierarchical clustering technique of data mining (see Table 4 and Supplemental File 2). Hierarchical clustering is an unsupervised learning algorithm that identifies clusters based on semantic affinity criteria. This algorithm is an open-source data visualization, machine learning, and data mining algorithms in Python. The study identified sixteen delay factors to cluster the 160 initial delay causes. Based on the likely occurrence of these causes, they were grouped into seven project management areas (see Table 5).

Table 4. Excerpt of the clusters

Factor	Original Delay Cause (as appear in the article)	Article
Errors & omissions	Design errors made by designers (due to unfamiliarity with local conditions and environment)	Aziz et al. (2016)
	Accepting inadequate design drawings	Akogbe et al. (2013)
	Architects' incomplete drawing	Aibinu & Odeyinka (2006)
	Changes in drawings	Akogbe et al. (2013)
	Frequent change orders	Mahamid (2017)
	Frequent changes in design	Mahamid (2017)
	Incomplete structural drawing	Aibinu & Odeyinka (2006)
	Insufficient data collection and survey before design	Hussain et al. (2018)
	Rework due to change of design or deviation order	Aziz et al. (2016)
Scope change	Change in the scope of project/extra work	Pai et al. (2018)
	Changes in project scope by the owner	Mahamid (2017)
	Changes in scope by the owner during construction (client-related)	Amoatey and Okanta (2017)
	Design changes	Durdyev et al. (2017)
	Too many change orders from owner	Sweis et al. (2008)
	Variations/changes of scope	Wang et al. (2018)

Table 5. Project management areas and main delay factors.

Project management area	Factor	Description of delay causes involved
Change management	Errors & omissions[a]	*Changes in drawings, frequent change orders, frequent changes in design.
	Scope changes	*Changes due to owner's needs, high frequency of changes from owner
Communication & reporting management	Communication process	*Inefficient communication & reporting with stakeholders and among project management teams.
	Decision making	*Slow and late process, difficulties with communication and authorization with stakeholders.
Construction site management	Mobilization & readiness of construction site	*Mobilization toward construction site, site conditions, and readiness of construction site coordinated with external stakeholders.
	Site management & technical processes	*Operation management, health, safety, environmental issues, and project complexity.
	Weather	*Flooding, rain, and severe weather conditions.
	Work supervision	*Rework, supervision and control of processes, and quality control.
Contract management	Contract conditions	*Unrealistic initial duration, lack of incentives and punishment, modifications due to omissions, and bid proposals issues.
Financial management	Financial issues	*Funding difficulties, lack of capital, limited financial capacity, lack of cash flow, and budget management issues.
	Payment issues	*Late payment, partial payment, inadequate payment for complete work, and slow process.
Planning & scheduling management	Errors & omissions[a]	*Incomplete drawings, incomplete design, mistakes, and omissions.
	External issues	*Corruption, lack of local community support, political situation
	Planning issues	*Ineffective planning and lack of previous studies. Ineffective scheduling processes, delay in land acquisition, lack of coordination and integration with subcontractors' schedule.
Resources management	Late delivery & material-equipment issues	*Late delivery of materials, quality issues, equipment breakdowns, and procurement issues.
	Shortage of resources	*Shortage of equipment, materials and skilled workforce.
	Skills, knowledge & experience	*Incompetent and inexperienced workforce and staff.

Note: [a] Delay causes clustered into errors & omissions were found influencing change management and planning & scheduling management areas. Therefore, this factor appears two times in the table.

2.5. *Normalization and Meta-analysis of RII*

A meta-analysis of RII measures provides a more accurate estimate than could be obtained from independent primary studies. The original studies must report RII in the same metric, and individual results must be standardized for comparison purposes. According to Card approach, this study normalized the RII of the articles (Card, 2016). In addition, the study considered the influence of the number of participants who assessed the delay causes in the primary studies and the variability of these causes. The RII for the delay factors was calculated using Eq. (2), and the variability of such factors with Eq. (3). The standard error of $\overline{RII}$ was calculated using Eq. (4). An example of the RII computed for the factor "*communication process*" is shown in Table 6.

$$\overline{RII} = \frac{\sum_{i=1}^{n} RII_i f_i}{N} \qquad \text{Eq. (2)}$$

where:
i = study reporting the same delay cause
RII_i = relative important index of the delay cause computed for the ith study
f_i = number of respondents rating the delay cause for the ith study
N = number total of respondents rating the same delay cause.
(RII)¯ = relative important index of the delay factor

$$S^2 = \frac{\sum_{i=1}^{n}(RII_i - \overline{RII})f_i}{N-1} \qquad \text{Eq. (3)}$$

$$SE_{\overline{RII}} = \frac{S_x}{\sqrt{N}} \qquad \text{Eq. (4)}$$

Table 6. RII for *communication process* factor in building projects

Study	Original Delay Cause	No Respondents	$RII_i f_i$	$\overline{RII}$-Factor	RII-Factor Variance	RII-Factor SE
Adeyemi and Masalila (2016)	Lack of communication between the parties	150	99.00			
Tebeje Zewdu (2016)	Insufficient coordination among the parties by the contractor	140	92.12			
Sweis et al. (2008)	Lack of effective communication	91	63.52			
	Total -Factor	381	254.64	0.668	0.0003	0.0009

Additionally, the analysis used Cohen's *d*, as an index of the standardized mean difference between building and road factors (see Eq. (5)).

$$d = \frac{RII_{building} - RII_{road}}{\sqrt{\frac{(n_{building}-1)S_{building}^2 + (n_{road}-1)S_{road}^2}{n_1+n_2-2}}} \qquad \text{Eq. (5)}$$

The variability analysis of the top ten factors used the equations of heterogeneity and the spreadsheets suggested by Neyeloff et al. (2012). The study assumed a random-effects model, which assumes that variability is due to both sampling error and variability in the population of effects. The Q test is like a t-test that measures heterogeneity among studies (see Eq. (6)). The I^2 quantifies heterogeneity, expressed in percentage measuring between-studies variability (see Eq. (7)).

$$Q = \sum(w * RII^2)\frac{|\sum(w * RII)|^2}{\sum w} \qquad \text{Eq. (6)}$$

$$I^2 = \frac{(Q - df)}{Q} * 100 \qquad \text{Eq. (7)}$$

3. Experimental results and analysis

3.1. *Stakeholders Accountability.*

The study identified six main project stakeholders (i.e., owner, contractor, subcontractor & supplier, designer & consultants, and project managers) who can mitigate specific delay factors. Table 7 shows the most important delay factors classified by both the project management area and project stakeholder responsibility.

Table 7. Main delay factors according to project stakeholders

	Owner	Contractor	Subcontractor & Supplier
Change management	*Errors & omissions. *Scope change.		
Communication & reporting management	*Decision-making.	*Communication process.	
Construction site management	*Mobilization & readiness of construction site.	*Mobilization & readiness of construction site. *Site management & technical processes. *Weather. *Work supervision.	*Mobilization & readiness of construction site. *Work supervision.
Contract management	*Contract conditions.		
Financial management	*Financial issues. *Payment issues.	*Financial issues.	*Financial issues.
Planning & scheduling management	*Errors & omissions. *External issues. *Planning issues.	*External issues. *Planning issues.	
Resources management	*Skills, knowledge & experience.	*Shortage of resources. *Skills, knowledge & experience.	*Late delivery and material-equipment issues. *Shortage of resources. *Skills, knowledge & experience.

	Designer & Consultant	Project manager
Change management	*Errors & omissions. *Scope change.	
Communication & reporting management	*Decision-making.	*Communication process. *Decision-making.
Construction site management	*Mobilization & readiness of construction site.	
Contract management		*Contract conditions.
Planning & scheduling management	*Errors & omissions.	*Planning issues.
Resources management		*Skills, knowledge & experience

3.2. *Frequency of Project Delay Factors*

Once the study classified the causes of the delay, a frequency analysis identified the five most frequent factors reported in the primary studies as the top ten causes. In descending order, the factors for building projects were "*financial issues*", "*planning issues*", "*shortage of resources*", "*skills-knowledge & experience*", and "*work supervision*". On the contrary, for road projects were "*financial issues*", "mobilization and readiness of construction site", "*skills-knowledge & experience*", "*contract conditions*", "*payment issues*", and "*planning issues*". Delay factors named "*shortage of resources*" were 3.3 times more frequent in building projects than road projects. On the contrary, delay factors named "*mobilization & readiness of construction site*" were 9.0 times more in road projects than building projects (see Table 8).

Table 8. Factor frequency within project type

Delay factor (N = 160)	Building % (n = 80)	Road % (n = 80)	Building/ Road	Road/ Building
Communication process	3.75	1.25	3.0	-
Contract conditions	5.00	8.75	-	1.8
Decision making	5.00	2.50	2.0	-
Errors & omissions	6.25	5.00	1.3	-
External issues	1.25	6.25	-	5.0
Financial issues	12.50	11.25	1.1	-
Late delivery and material-equipment issues	6.25	2.50	2.5	-
Mobilization and readiness of construction site	1.25	11.25	-	9.0
Payment issues	6.25	8.75	-	1.4
Planning issues	12.50	8.75	1.4	-
Scope change	3.75	3.75	1.0	1.0
Shortage of resources	12.50	3.75	3.3	-
Site Management & technical processes	6.25	7.50	-	1.2
Skills, Knowledge & experience	7.50	11.25	-	1.5
Weather	2.50	3.75	-	1.5
Work supervision	7.50	3.75	2.0	-

Although this study calculated the frequency of delay factors reported by primary studies, it is clear that frequency does not imply relevance. Therefore, a meta-analysis of the RII of such factors was performed.

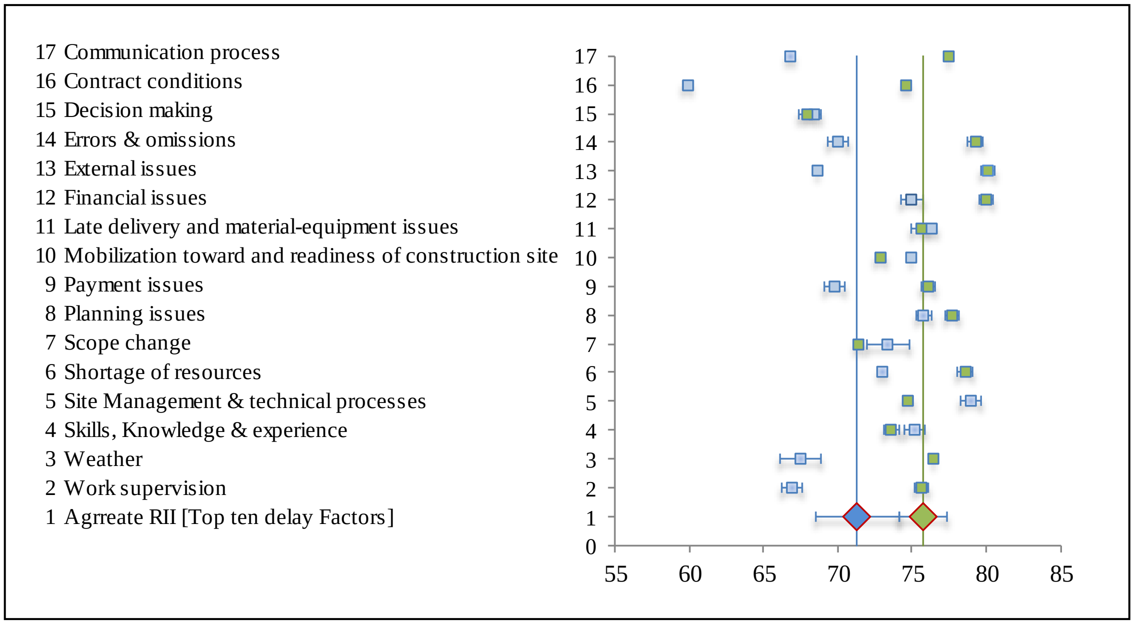
3.3. *Meta-analysis of RIIs*

The aggregated RII for each delay factor and the 95% confidence interval revealed some interesting findings (see Table 9). The five most important factors, analyzed in descending order, differed from the order of frequency. For building projects, the factors were "*site management & technical processes*", "late delivery and material-equipment issues", "*planning issues*", "*skills, knowledge & experience*", and "*financial issues*". While "*financial issues*" was the most frequent factor, "*site management & technical processes*" was the most critical factor. On the contrary, the five most important factors for road projects were "*external issues*", "*financial issues*", "*errors & omissions*", "*shortage of resources*", and "*planning issues*". In this case, while "*financial issues*" was the most frequent factor, "*external issues*" was the most critical factor.

Table 9. RII of factor delay by project type

Delay factor	Building			Road		
	RII	95% CI lower	95% CI upper	RII	95% CI lower	95% CI upper
Communication process	66.8	66.6	67.0	77.5	77.5	77.5
Contract conditions	59.9	59.5	60.2	74.6	74.3	74.9
Decision making	68.4	67.9	68.9	67.9	67.4	68.4
Errors & omissions	70.0	69.3	70.7	79.3	78.8	79.8
External issues	68.6	68.6	68.6	80.1*	79.6	80.6
Financial issues	75.0	74.3	75.7	80.0	79.5	80.5
Late delivery and material-equipment issues	76.3	75.9	76.7	75.6	74.9	76.3
Mobilization toward and readiness of construction site	75.0	75.0	75.0	72.9	72.5	73.3
Payment issues	69.8	69.1	70.5	76.1	75.7	76.6
Planning issues	75.8	75.3	76.3	77.7	77.2	78.2
Scope change	73.4	72.0	74.8	71.4	71.2	71.7
Shortage of resources	73.0	72.8	73.3	78.6	78.1	79.1
Site Management & technical processes	79.0*	78.3	79.7	74.7	74.4	75.0
Skills, Knowledge & experience	75.2	74.5	75.9	73.6	73.1	74.1
Weather	67.5	66.1	68.9	76.5	76.5	76.5
Work supervision	66.9	66.3	67.6	75.6	75.2	76.1
Aggregate index [for top ten factors]	71.3	68.5	74.1	75.8	74.2	77.4

This analysis showed a noticeable difference between the average RIIs of building and road projects calculated for the top ten delay factors. The top ten factors for building projects have a lower average RRI (Building RRI = 71.3) than those for road projects (Road RII = 75.8). The results also show how the importance given to each factor differs between building and road projects (see Figure 1). Based on a standardized mean difference between road and building projects, this study found a d-index of 0.18 for "*contract conditions*"; that is, the mean of the road RII is 18/100ths of a standardized deviation to the right of the building RII. Conversely, a d-index of -0.05 for "*site management & technical processes*" means the building RII is 5/100ths of a standardized deviation to the left of the road RII.



Note: Blue boxes for building projects; green boxes for road projects.

Figure 1. RII of the leading top ten delay factors

The Q_v statistic evaluates the null hypothesis of homogeneity versus the alternative hypothesis if heterogeneity, assuming a random-effects model. The Qv for building projects was 11.02, the Q_v for road projects was 15.08, and the critical value for 15 degrees of freedom is $\chi^2 = 24.90$. These results indicate that there is no statistical evidence to reject the null hypothesis. Therefore, this analysis shows that the RIIs are all estimates of a single population. On the other hand, the I^2 index is the variability between studies relative to the total variability. Assuming a random-effects model, the I^2 for building projects was 36%, and for road projects it was 1%. A value close to 0% indicates no observed heterogeneity. The results show that the top ten factors are higher and narrower assessed in road projects than in building projects.

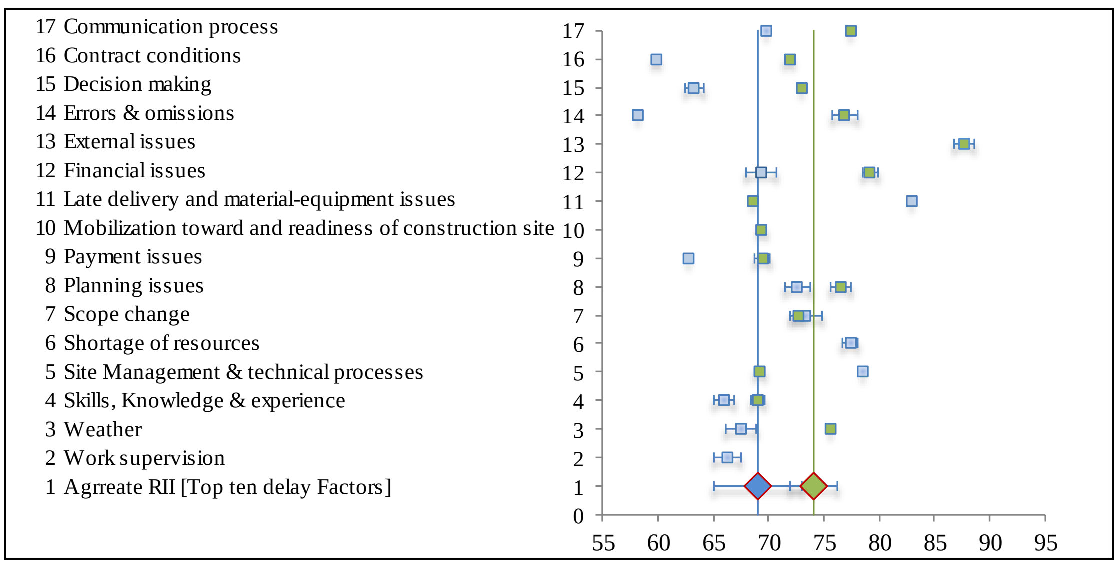
3.4. *Meta-analysis of RIIs Controlled by Region*

The analysis by region showed the influence of the countries on the behavior of the RIIs. For African studies, the top five factors analyzed in descending order differed from the general analysis (see Table 10). For building projects, these factors were "*skills, knowledge & experience*", "*financial issues*", "*site management & technical processes*", "*planning issues*", and "*late delivery and material-equipment issues*". While "*site management & technical processes*", was the most critical factor for building projects at the general level, "*skills, knowledge & experience*" was the most critical factor for African projects. In contrast, the top five factors for road projects were "*late delivery and material-equipment issues*", "*financial issues*", "*errors & omissions*", "*payment issues*", and "*planning issues*". In this case, while "*external issues*" was the most important for road projects at the general level, "*late delivery and material-equipment issues*" was the most critical factor for African projects. This study found that the relevance of the aggregated causes varied by region.

Table 10. RII of factor delay by project type in Africa

Delay factor	Building			Road		
	RII	95% CI lower	95% CI upper	RII	95% CI lower	95% CI upper
Communication process	65.9	65.9	65.9	-	-	-
Contract conditions	-	-	-	76.7	76.4	77.0
Decision making	71.8	71.6	72.0	65.7	65.7	65.7
Errors & omissions	74.3	74.3	74.3	81.0	81.0	81.0
External issues	68.6	68.6	68.6	77.3	77.3	77.3
Financial issues	79.2	79.0	79.4	81.2	80.7	81.7
Late delivery and material-equipment issues	75.5	75.1	75.9	81.3	81.3	81.3
Mobilization toward and readiness of construction site	75.0	75.0	75.0	74.9	74.5	75.4
Payment issues	75.1	74.3	75.2	80.0	79.8	80.2
Planning issues	77.2	76.7	77.8	78.7	78.4	79.0
Scope change	-	-	-	70.1	70.1	70.1
Shortage of resources	71.7	71.6	71.8	78.6	78.1	79.1
Site Management & technical processes	79.1	78.3	79.9	77.5	77.4	77.6
Skills, Knowledge & experience	80.6	80.6	80.6	78.6	78.3	78.9
Weather	-	-	-	77.0	77.0	77.0
Work supervision	67.4	66.7	68.1	75.6	75.2	76.1
Aggregate index [for top ten factors]	74.0	72.2	75.7	76.9	76.1	77.8

Similar to the previous cases, this analysis showed a noticeable difference between the average RII of building and road projects, calculated for the top ten delay factors. The top ten factors for building projects show an average RRI lower than that in road projects (Building RRI = 69.1; Road RII = 74.1) (see Figure 3).



Note: Blue boxes for building projects; green boxes for road projects

Figure 2. RII of the leading top ten delay factors for Asian studies

For the Asian studies, the Q_v statistic assessed the homogeneity, assuming a random-effects model. The Q_v for building projects was 11.5, and the critical value for eight degrees of freedom is χ^2 = 15.5. These results indicate that there is no statistical evidence to reject the null hypothesis. The Qv for road projects was 20.47, and the critical value for 13 degrees of freedom is $\chi^2 = 22.4$. These results indicate there is no statistical evidence to reject the null hypothesis. Therefore, this analysis shows that the RII are all estimates of a single population. On the other hand, the I^2 for building projects was 30%, and it was 36% for road projects.

3.5. *Stakeholder Issues as Source of Delay Factors*

After analyzing the importance and the homogeneity of the top ten delay factors, this study proposes the five most critical factors related to the stakeholder responsibility and classified by project management area. In addition, this classification identifies the region and type of project where these factors are critical to facilitate the definition of mitigation actions by stakeholders (see Table 12).

Table 11. Stakeholder accountability

	Owner	Contractor	Subcontractor & Supplier
Change management	Scope change [Building-Asia]		
Construction site management		Site Management & technical processes [Building-Africa-Asia]	
Financial management	Financial issues [Building-Africa] [Road-Africa] Payment issues [Road-Africa]	Financial issues [Building-Africa] [Road-Asia]	Financial issues [Building-Africa]
Planning & scheduling management	Planning issues [Building-Asia] [Road-Asia] External issues [Road-Asia]	Planning issues [Building-Africa-Asia] [Road-Africa]	
Resources management		Skills, knowledge & experience [Building-Africa]	Late delivery & material-equipment issues [Building-Africa-Asia] [Road-Africa] Shortage of resources [Building-Asia] Skills, knowledge & experience [Building-Africa]
	Designer & Consultant	**Project manager**	
Change management	Errors & omissions [Road-Africa-Asia] Scope change [Building-Asia]		
Communication & reporting management		Communication process [Road-Asia]	
Planning & scheduling management		Planning issues [Building-Asia]	

4. Discussion

This study found that the importance of delay causes, when aggregated into factors and quantitatively assessed with RIIs, differed from the results of other studies. Based on a meta-analysis technique, the results of this study provide a quantitative and more objective estimate of the effects by the aggregation of a larger sample size of the delay causes. This allows for a reliable estimate of the effect of the delay causes in building and road projects built in African and Asian countries. The classification of the delay factors by region and project type, and in relation to both project management area and stakeholder responsibility, provides a reliable and sound support for defining mitigation actions by stakeholders that lead to better project performance.

4.1. *Owner Accountability*

The owner issues that caused the most critical delay factors for building projects were "scope change", "financial issues", and "planning issues". In contrast, the owner issues that caused the most critical delay factors for road projects were "financial issues", "payment issues", "planning issues", and "external issues" (see Table 11). The "financial issues" included several owner conditions such as lack of capital, limited financial capacity and capability, lack of cash flow, and inefficient budget management (Aibinu & Odeyinka, 2006; Amoatey et al., 2015; Khair, Mohamed, Mohammad, Farouk, & Ahmed, 2017; Youniss, Ismail, Khoiry, Arhad, & Irtema, 2017). To mitigate these issues, owners could develop early financing strategies for the construction phase, such as public-private partnership (PPP) models for public projects. In addition, a recommended practice suggests developing detailed cash flow planning in coordination with the stakeholders (Khair et al., 2017; Oyegoke & Al Kiyumi, 2017; Rachid, Toufik, & Mohammed, 2018).

On the other hand, in order to face problems caused by scope changes (Chang, 2002), by the change of partners in the project organization and disputes with stakeholders (Alinaitwe, Mwakali, & Hansson, 2007; Larsen, Shen, Lindhard, & Brunoe, 2016), the authors suggest the implementation of project delivery methods. Project delivery methods, such as Integrated Project Delivery – IPD, improve communication and collaboration among stakeholders (Love, Smith, Simpson, Regan, & Olatunji, 2015). Finally, recommendations to address "planning issues" may include implementing change control systems, setting clear contract terms that regulate the influence of stakeholders due to unnecessary changes, and aligning project objectives and requirements with the owner and stakeholders (Amoatey et al., 2015; Yates & Eskander, 2002).

This study shows that owner issues can have a significant impact on project schedule slippage. Therefore, this study suggests the adoption of practices that include open communication environments to address the owner requirements from the early stages of the project. In addition, scenarios should be facilitated where the owner can provide feedback to add value to the project.

4.2. *Contractor Accountability*

The contractor problems that caused the most critical delay factors for building projects were "financial issues", "site management & technical processes", "planning issues", and "skills, knowledge & experience". In contrast, the most critical factors for road projects were "financial issues" and "planning issues" (see Table 11). The delay causes aggregated into the "financial issues" included limited financial capacity, lack of cash flow, and budget issues (Akogbe et al., 2013; Meeampol & Ogunlan, 2006; Pai et al., 2018). The day-to-day activities of construction projects require contractors that spend high expenses to pay for resources. Therefore, if owners pay late for the work done, contractors could face problems in financing the construction activities, and consequently, there is a high chance of work disruptions and delays. The lack of funds could put the contractor in a critical situation that adversely affects project schedule performance (Aforla, Woode, & Amoah, 2016; Honrao & Desai, 2015; Mahamid, Bruland, & Dmaidi, 2012). To avoid cash flow problems, some authors suggest providing funding for contractual guarantees from owners and contractors (Nasir, Gabriel, & Choudhry, 2015). To address the problems of unrealistic initial duration and bid proposals (Pai et al., 2018; T. Wang et al., 2018), some authors suggest other methods of contractor selection than the lowest bidder approach, include selection criteria such as bonus for early delivery and implementing incentives for early completion of activities (Othuman Mydin, Sani, Taib, & Mohd Alias, 2014; Santoso & Soeng, 2016). To address the problems of incompetent and inexperienced workforce and staff (Hussain et al., 2018; Pai et al., 2018), some strategies could include implementing an effective selection process for workers and crews, as well as training programs that focus on improving the knowledge and skills of workers and staff, and ensuring a verifiable level of experience of the contractor (Famiyeh, Amoatey, & Adaku, 2017; Patil et al., 2013; Rachid et al., 2018). Other recommendations to address these issues may include implementing new technologies to manage construction sites, lean construction techniques to improve productivity, and new control techniques such as last planner (Daniel, 2017) and earned value (Ballesteros-Pérez et al., 2019).

The contractor is primarily responsible for the development of the construction process; therefore, shortcomings in the selection of the contractor can lead to scenarios that compromise the continuity of the construction process. Therefore, the experience and knowledge of the contractor are essential to ensure that the project activities are carried out as planned in the early stages of the project. It is recommended that in the selection process a rigorous analysis of the requirements of the construction process be carried out during the selection process in order to define the terms that will guide the process. Adequate definition of terms can help to mitigate the occurrence of delay causes related to the contractor.

In the case of actions to be developed by contractors, it is recommended to have an adequate organizational system to ensure efficient communication with other project stakeholders, such as: designers, owners, suppliers, and others. Efficient communication will make it possible to remove restrictions on the construction activities, which is essential to achieve compliance with the planned schedule. In addition, it is recommended that the contractor assemble a team of competent professionals who have the necessary experience and expertise to support the decision-making processes required during the construction process. It is also recommended that the contractor adopt strategies for the efficient selection and deployment of workers based on the competencies and skills.

4.3. *Subcontractor and Suppliers Accountability*

The problems related to subcontractors and suppliers that caused the most critical delay factors for building pro-jects were "financial issues", "skills, knowledge & experience", "late delivery and material-equipment issues", and "shortage of resources". In contrast, those problems that originated the most critical delay factors in road projects were "late delivery & material-equipment issues" (see Table 11). "Skills, knowledge & experience" included incompetent and inexperienced workforce and staff (Aziz & Abdel-Hakam, 2016; Khair et al., 2017). Building and road projects require the hiring of qualified personnel for site management and supervision (Mate & Hinge, 2015). "Late delivery & material-equipment issues" involved late delivery of materials, equipment breakdown, and procurement issues (Akogbe et al., 2013; Kaliba, Muya, & Mumba, 2009; Santoso & Soeng, 2016; Sayed et al., 2020). "Shortage of resources" included shortage of equipment, shortage of materials and skilled workforce (Akogbe et al., 2013; Durdyev et al., 2017).

Scarcity price fluctuation of materials can affect the progress of work (Aforla et al., 2016). Projects must carry out effective allocation of equipment and tools on construction sites and thorough constraints analysis before starting construction phase to avoid delays (Ahiwako, Oloke, Suresh, & Khatib, 2015; Famiyeh et al., 2017). Subcontractors should include equipment maintenance programs at construction sites and ensure the availability of the necessary equipment for specific scheduled activities (Mahamid et al., 2012). In addition, to avoid shortage of resources subcontractors should implement supply chain management strategies and early integration into the project life cycle (Eriksson, 2015; Oyegoke & Al Kiyumi, 2017).

The performance of suppliers and subcontractors can have a significantly impact on the schedule of a construction process. The high interdependency between activities, which is characteristic of construction projects means that the lack of inputs and services of one activity can have an impact on several interdependent activities. The impact on the schedule of several activities increases the possibility of the occurrence of the delay phenomenon. Both road and building projects require significant amounts of resources that affect the planning and execution of the construction phase. Therefore, it is recommended that project managers promote an organizational culture focused on early anticipation of constraints affecting project activities. In this way, it will be possible to manage the supply of inputs and services with suppliers and subcontractors sufficiently in advance to avoid affecting the schedule. Planning must be done with the understanding that supplies must be delivered just in time; not before because they may cause disruptions to the construction process, nor after because they may cause delays.

4.4. *Designer and Consultant Accountability*

The problems related to designer and consultant that caused the most critical delay factors for building projects were "scope change", and for road projects, "errors & omissions" (see Table 11). "Scope change" included changes due to engineering decisions (Ellis, 2003). To avoid delay problems in road projects, designers must analyze any constraint before construction starts. Some recommendations to achieve a high level of design maturity before construction begins include conducting a detailed site investigation during the design phase to identify underground conditions, and using new technology to locate underground utilities (Ahiwako et al., 2015; Othuman Mydin et al., 2014). Designers and consultants with sufficient experience and good management skills enable the project team to focus on completing each phase of the project without room for delays (Honrao & Desai, 2015).

Designers play an indispensable role in preparing the documents that will guide the construction process. Therefore, shortcomings in the activities developed by the designers can have a significant impact on the project schedule during the construction phase. Failures in aspects such as communication, coordination, conflicts, disputes, and others can affect the quality of the construction documents. It is recommended that designers adopt methodological and technological approaches to facilitate the automation of design review in the early phases and improve the management of the volume of information that is captured, analyzed and processed. Proper design quality control and information management will reduce the number of information requests and design changes during the construction process. Timely response to design issues helps to avoid wait times that can lead to delays. It is recommended that design contracts included clauses to ensure a quick and efficient response from the design discipline teams.

4.5. *Project Manager Accountability*

The problems related to project manager that caused the most critical delay factors for building projects were "planning issues", and for road projects, "communication process" (see Table 11). "Planning issues" included ineffective planning (Zafar, Wuni, Shen, & Ahmed, 2019). Effective planning is one of the most important factors for the success of projects, considering the high investments made in the early stages of the project (Mahamid, 2017). Therefore, adequate planning requires a proper selection of planning techniques that estimate the impact of all constraints and uncertainties on the project performance (Emam et al., 2015). Some recommendations to address these issues include assessing the capacity of contractors, availability of resources and other constraints during project planning and allocating sufficient time and effort for planning, design, and information documentation (Mahamid et al., 2012; Rachid et al., 2018). On the other hand, slow and late processes and difficulties in communication and approval with stakeholders (Sayed et al., 2020; Walker & Vines, 2000; T. Wang et al., 2018) threaten the decision-making processes. The diversity of stakeholders in projects threatens clear and effective communication during project development.

If the interventions of stakeholders in the project decisions are frequent and without any reason, it may lead to restrictions in the activities and consequently delays (Honrao & Desai, 2015). Therefore, the implementation of IPD could improve the communication and collaboration among stakeholders (Love et al., 2015). In fact, the implementation of good communication and motivation strategies with workers on construction sites could avoid failures in the supervision of work (Patil et al., 2013).

The project manager can significantly influence the adoption of measures to ensure that project activities are performed on schedule. The relationship between the manager and other stakeholders can be focused on workflows that maximize value to the client, which results in the alignment of team objectives with project requirements. Organizing the team towards a common goal influences process efficiency, leading to continuous improvement systems that promote the mitigation of delays. The complexity and variables of construction projects present managers with several challenges during project life cycle activities.

5. Conclusion

Based on a final sample of 16 primary studies from different countries and most of them from Scimago Q1-journals, this research initially identified 160 top ten-delay causes, which were clustered into sixteen factors and seven project management areas, and related to project stakeholders. Based on the classification methodology of delay causes used, this study provides a first taxonomy of delays, where the causes were clustered into factors and management areas. This classification is presented in the supplemental file 2.

In addition, this study found that the importance of delay causes, when aggregated into factors and quantitatively assessed with RIIs, differed from the results of other studies. Based on a meta-analysis technique, the results of this study provide a classification of the delay factors by region and project type, and in relation to both project management area and stakeholder responsibility. Thus, the study provides a reliable and sound support for defining mitigation actions by stakeholders that lead to better project performance. The recommendations for stakeholders become a first guide to mitigate such delays in building and road projects to be built in countries similar to Asian or African countries.

The analysis by regions showed the region's effect on the RIIs' behavior. For African studies, the five most important factors, analyzed in decreasing order, varied compared to the general analysis. For building projects, those factors were "*skills, knowledge & experience*", "*financial issues*", "*site management & technical processes*", "*planning issues*", and "*late delivery and material-equipment issues*". While "*site management & technical processes*", was the most critical factor for building projects at the general level, "skills, knowledge & experience" was the most critical factor for African projects. On the contrary, the five most important factors for road projects were "*late delivery and material-equipment issues*", "*financial issues*", "*errors & omissions*", "*payment issues*", and "*planning issues*". In this case, while "*external issues*" was the most important for road projects at the general level, "late delivery and material-equipment issues" was the most critical factor for African projects. This study found that the factors' relevance when were aggregate varies with the region.

Similarly, for Asian studies, the five most important factors, analyzed in decreasing order, varied compared to the general analysis. For building projects, the five most critical factors were "*late delivery and material-equipment issues*", "*site management & technical processes*", "*shortage of resources*", "*scope change*", and "*planning issues*". While "*site management & technical processes*", was the most critical factor for building projects at the general level, "*skills, knowledge & experience*" was for African studies, and "*late delivery and material-equipment issues*" was for Asian studies. On the contrary, the five most important factors for road projects were "*external issues*", "*financial issues*", "*communication process*", "*errors & omissions*", and "*planning issues*". In this case, while "*external issues*" was the most important for road projects at the general level, "*late delivery and material-equipment issues*" was for African studies, and "*external issues*" was for Asian studies.

Finally, this study shows that problems related to either the owner, contractor, subcontractor, designer, or project manager can have a significant impact on project schedule slippage. As a result, this study provides some recommendations for mitigating delays in building and road projects. Although most studies have provided recommendations for owners and contractors, fewer studies have addressed delays issues related to other stakeholders. This study suggests the adoption of practices that include an open communication environment to address the owner requirements from the early stages of the project and feedback to add value to the project. Shortcomings in contractor and subcontractor selection can lead to scenarios that threaten the continuity of the construction process.

Therefore, it is recommended that the selection process of contractors and subcontractors should include a rigorous analysis of the construction process requirements to define the contract terms. In addition, this study suggests that designers adopt methodological and technological approaches to facilitate the automation of design review in the early phases and improve the management of the volume of information that is captured, analyzed and processed. Organizing the team around a common goal influences process efficiency and leads to continuous improvement systems that promote the reduction of delays. Future studies could analyze in more depth the relationship between delays and other types of stakeholders, other than owners and contractors, as well as conduct studies in regions outside of Asian and African countries, in order to enhance the sample of studies for comparative analysis between regions.

6. Data availability statement

Author contributions: G. Mejia: Conceptualization, methodology, data collection, results' analysis, document writing, review and supervision, and enhancement of manuscript. O. Sánchez: Data collection, methodology, document writing, and results' analysis. K. Castañeda: Methodology, data collection, results' analysis, and document writing. E. Pellicer: Document writing, review, supervision, and enhancement of manuscript.

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