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Determining the Stationary Cause of Construction Delay in Highway Projects

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ABSTRACT: Delay of construction projects, particularly highway construction, is a severe issue in the developing economies. So, this study aims at determining the stationary cause of construction delay in the highway projects by utilizing prior validated data from the Egyptian developing construction market. The data represent the responses of 56 engineers working in the Egyptian highway construction companies on the effectiveness degrees of 38 causes of construction delay. By adopting Fuzzy Trapezoidal Membership Function, "insufficiency and ineligibility of the technical staff of the main contractor to accomplish the scope of the project", "mistakes in design", "delay in inspecting the project activities by the technical staff of the consultant", "poor efficiency of construction equipment", and "difficulties in funding the project by the main contractor" have been rated to be the top-five causes of delay. Also, Ginni's Mean Difference Measure of Dispersion indicated that the stationary cause of construction delay is "low productivity of labors". Additionally, in a comparison with twenty-one developing nations, it has been concluded that the top-five and stationary causes of delay are frequent in the developing economies. Nonetheless, "mistakes in design" is the most recurrent cause, influencing eighteen of the explored countries. These findings equip the practitioners in the developing construction markets with the top-critical causes of delay in their highway projects. This leads to directing their attempts toward managing these causes. Consequently, the high percentages of delay in their highway construction projects can be radically minimized.

KEYWORDS: Delay causes, highway projects, developing economies, fuzzy set theory, Ginni's mean difference measure of dispersion.

1. Introduction and Theoretical Background

The socio-economic capital infrastructure project, comprising highway construction, is a major pivot of the regional modernization of the countries worldwide. Socially, it presents a significant function for the peoples by transporting them with a focus on the safety, mobility, and accessibility aspects. This leads to creating an appropriate level of living for the nations [1, 2]. Economically, on the other side, it plays an important role in terms of transporting the goods and services of the economic activities of the countries, strengthening their short- and long-term development [3, 4]. More usefully, since the highway projects are labor- materials-, and equipment-intensive projects [5], they assist in solving the unemployment problem by creating thousands of job opportunities annually and reviving the trading in the local sectors of the countries. Remarkably, these precious benefits have been observed to be at risk of not being achieved owing to the global lesion of delay in the highway construction projects [6].

As stated by Ahmed et al. [7], construction delay is identified as "a situation where the construction project is not accomplished in accordance with the planned period". With respect to the highway projects, this issue means that the road-users and the economy must wait for the highway network longer than it is necessary. This negatively leads to limiting the growth potential of the economies at large [8]. More critically, this is a severe challenge, mostly in the developing construction markets. For instance, in Asia, Al-Battaienh [9] listed that the highway projects in Jordan are subjected to extensive delay with an average time-overrun of 60.45%. In the same region, in Sri Lanka, Pathiranage and Halwature [10] showed that the local highway construction projects are experienced 56 % to 88 % of average delay compared to the planned project duration. Similarly, in Africa, Akoa [11] stated that the mean of construction delay rate in the Cameroonian highway projects is 10.43%. Regrettably, the prior statistics of construction delays have occurred in light of a sizeable wealth of the delay-based literature considering the highway projects, particularly in the developing nations (see Table 1). However, these research works did not effectively contribute to controlling the high percentages of delay in the highway projects. This is associated with the next explanations.

1) Many of the analysts of construction delay in the highway projects have concentrated on developing models to predict their delay percentages, using either the traditional modelling tools, such as Linear Regression Analysis (e.g., [12]) or the advanced ones, comprising the Artificial Neural Network (e.g., [13]) to present more accurate prediction models. This, in turn, limits their contributions toward pinpointing the factors responsible for causing delay or their mitigation measures considering the highway projects.

2) As the last column of Table 1 demonstrates, the majority of the scholars of analyzing the causes of delay in the highway projects (e.g., [14, 15, 16]) did not concentrate on utilizing any tools of Fuzzy Set Theory (FST) to tackle the ambiguity associated with the replies of the participants in their surveys. The only exceptions are Abu El-Maaty et al. [12] in Egypt, Sharma et al. [17] in India, Stevic´ et al. [6] in Benin, Zafar et al. [18] in Pakistan, and Jindal and Singh [19] in Indonesia. This is a critical problem in the related background studies, impacting the accuracy of their results. This is due to the actuality that the tools of FST play a significant role toward tackling the ambiguity in the experts' replies; accordingly, they provide more trustworthy outputs [20].

3) Considering the analyzing tools of Table 1, it can be found that most of the academics' attempts have been relied upon the traditional analyzing tools of Relative Importance Index (e.g., [21]), Percentage of Choices by the Respondents (e.g., [22]), and Mean Score (e.g., [23]) for ranking the causes of construction delay. This, in turn, informs that to date the stationary cause of delay in the highway construction projects has not been pinpointed in any developing construction market. This stems from the actuality that the stationary cause/factor/criterion of any issue under analysis cannot be determined without utilizing the approach of Ginni's Mean Difference Measure of Dispersion [24]. According to El-Kholy and Akal [25] and Ali et al. [26], it is of a vital meaning to find out the stationary cause of the issue under analysis, because it exemplifies the major critical cause of the explored issue. As this definition of the stationary cause implies, it can be affirmed that the major critical cause of construction delay has not been determined in any of the prior studies, causing insufficient knowledge regarding controlling the severe percentages of construction delay in the highway projects considering the developing economies.

The aforesaid points encourage the researcher of the current paper to consider Egypt's developing construction market and incorporate Fuzzy Trapezoidal Membership Function along with Ginni's Mean Difference Measure of Dispersion for answering the questions: (1) what are the top-five ranking causes of delay in the Egyptian highway construction projects?, (2) what is the stationary cause of delay in the highway construction projects in Egypt?, (3) whether the identified top-five ranking and stationary causes of delay are common in the other developing economies or not?, and (4) how can the current paper assist the practitioners in managing the negative impacts of delay in their highway projects? The answers associated with these questions enhance understanding the major critical cause of delay in the highway projects and appointing its corresponding mitigation measure, either locally in Egypt or internationally in other developing contexts. This boosts the role of the highway construction sector in the developing countries toward their economies.

The rest of the present work comprises, in Section 2, the contextual background, along with the relevant justifications for being considered. Then, Section 3 includes the methodology and presents the results. Thereafter, Section 4 analyzes and discusses the findings and their consequences. After that, Section 5 lists the research's summary, limitations, and future research tendencies.

Table 1: Background Studies of Construction Delay in Highway Construction Projects.

Study	Country	Main Scope				Key Analyzing Tools
		A	B	C	D	
[27]	Nigeria	✓			✓	• Severity index.
[28]	Nepal	✓				• Ranking of impact and severity of occurrence.
[29]	Thailand				✓	• Discriminant analysis.
[30]	Zambia	✓	✓		✓	• Average weighted perceived significance.
[10]	Sri Lanka	✓				• Relative significance index.

Table 1: Continue.

Study	Country	Main Scope				Key Analyzing Tools
		A	B	C	D	
[11]	Cameron	✓		✓		• Percentage of choices by the respondents. • Linear regression analysis.
[31]	Palestine	✓				• Risk rating matrix.
[32]	Pakistan	✓				• Relative importance index.
[33]	Pakistan	✓				• Relative importance index.
[34]	Palestine				✓	• Severity index.
[35]	Malawi	✓				• Relative importance index.
[36]	Ethiopia	✓			✓	• Relative importance index.
[37]	Palestine	✓				• Risk rating matrix.
[38]	Palestine	✓				• Frequency index.
[39]	Bahrain	✓			✓	• Mean score.
[40]	Pakistan	✓		✓		• Multivariate regression analysis correlation. • Frequency of appearance.
[41]	Jordan	✓				• Ranking of percentage.
[23]	Ethiopia	✓			✓	• Mean score.
[42]	India	✓		✓		• Relative importance index. • Earned value management.
[43]	Kenya	✓			✓	• Relative importance index.
[44]	Ethiopia	✓			✓	• Relative importance index.
[45]	Kenya	✓		✓		• Linear regression analysis.
[46]	Kenya	✓		✓		• Mean score. • Linear regression analysis.
[47]	Egypt	✓		✓	✓	• Relative importance index.
[22]	Rwanda	✓		✓		• Percentage of choices by the respondents. • Linear regression analysis.
[48]	Cambodia	✓	✓		✓	• Importance index.
[12]	Egypt	✓		✓		• Linear regression analysis. • Fuzzy trapezoidal membership function.
[49]	Egypt	✓			✓	• Average weighted percentage.
[50]	Libya	✓				• Mean score. • Factor analysis.
[51]	Ethiopia	✓			✓	• Relative importance index.
[52]	Ghana	✓				• Relative Importance Index.
[53]	Ghana	✓				• Factor analysis.
[54]	Pakistan	✓				• Average index.
[55]	Palestine	✓		✓		• Importance index. • Linear regression analysis.
[56]	Saudi Arabia	✓		✓		• Importance index. • Linear regression analysis.

Table 1: Continue.

Study	Country	Main Scope				Key Analyzing Tools
		A	B	C	D	
[57]	Pakistan	✓			✓	• Relative importance weight. • Mean score.
[58]	Vietnam	✓				• Structural equation model.
[59]	Iraq	✓			✓	• Frequency index.
[21]	Philippines	✓				• Relative importance index.
[60]	Sudan	✓	✓		✓	• Relative importance index.
[61]	India	✓			✓	• Relative importance index.
[62]	Thailand	✓				• Mean score.
[63]	Saudi Arabia	✓				• Importance index.
[15]	Ethiopia	✓				• Relative importance index.
[64]	Nigeria	✓		✓		• Mean score. • Linear regression analysis.
[65]	Greece	✓				• Technique for order preference by similarity to ideal situation.
[66]	Iran	✓				• Analytical hierarchy process.
[17]	India	✓		✓		• Fuzzy set theory. • Frequency index. • Linear regression analysis.
[13]	Egypt			✓		• Artificial neural network.
[14]	Malawi	✓				• Qualitative and quantitative analysis.
[6]	Benin	✓				• Fuzzy pivot pairwise relative criteria relevance assessments.
[67]	South Africa				✓	• Relative importance index.
[18]	Pakistan	✓				• Fuzzy synthetic evaluation. • Factor analysis.
[68]	Saudi Arabia	✓				• Relative importance index.
[16]	Thailand	✓				• Severity index.
[69]	Colombia	✓				• Severity and frequency indices.
[19]	Indonesia	✓				• Fuzzy analytical hierarchy process.
[70]	Brazil	✓				• Analytical hierarchy process.
[71]	Indonesia	✓		✓		• Project evaluation and review technique.

Notes: A = means the scope of the analyzed study is defining and prioritizing the delay causes, B = means the scope of the analyzed study is exploring the delay effects, C = means the scope of the analyzed study is modelling or predicting the delay percentage, D = means the scope of the analyzed study is suggesting mitigations measures for controlling the delay impacts.

2. CONTEXTUAL BACKGROUND

In the regard of answering the research questions of the present paper, the Egyptian developing construction market has been taken into the account of the researcher, given two reasons.

1) According to Ismail et al. [72], 8.0% of the Gross Domestic Product (GDP) in Egypt is associated with its construction industry. Significantly, the highway projects in Egypt in terms of the services they provided to the national economy

have a considerable percentage of this contribution to the GDP. This is because of the highway network in Egypt carries out about 60% of passenger movement and 85% of domestic freight [73]. These statistics encourage the Egyptian government to invest about EGP 1.1 trillion in the highway network between 2014 and 2024 [74] to improve its economic development. Sadly, despite these benefits and the investments directed to the highway construction industry in Egypt, its performance is not at the satisfactory level [75]. Abu El-Maaty et al. [76] confirmed this information by surveying 56 highway projects in Egypt and found that these projects are subjected to construction delay and cost-overrun with average percentages of 73.80% and 46.30%, respectively. Indeed, these high percentages of delay and cost-overrun impact the successful accomplishment of the highway projects in Egypt. In the same vein, they offer an appropriate opportunity to get answers pertinent to the questions of this research, particularly Aziz and Abdel-Hakam [47], Abu El-Maaty et al. [12], Akal et al. [49], and El-Kholy [13] did not determine the stationary cause of delay in their highway projects in Egypt.

2) Previously, Akal [77] in Egypt identified, developed, validated a questionnaire, and collected data on the causes of delay in the highway projects in Egypt. As a result, his work has 111 responses from 40 owners, 15 consultants, and 56 contractors of the highway projects in Egypt on the effectiveness degrees of 38 causes of construction delay. Akal et al. [49] conducted his study based on 53.15% of the data of Akal [77], comprising 26 owners, 13 consultants, and 20 contractors. Yet, Abu El-Maaty et al. [12] carried out his paper building on 100% of the data of Akal [77]. Further, Akal et al. [49] used the Average Weighted Percentage in his study, while in Abu El-Maaty et al. [12] Fuzzy Triangular Membership Function has been adopted. In the same context, the current work will utilize the responses of 56 contractors of Akal [77] to get answers of this research questions in a fast and economic manner. This will have another important contribution to the knowledge body by comparing the findings of the current work with those of Akal et al. [49] and Abu El-Maaty et al. [12] to examine whether the ranks of delay causes are significantly influenced by the sample size and the perspectives of different project parties with different interests.

3. RESEARCH METHODOLOGY

The methodology of this research has six steps. It comprises defining the causes of construction delay from Akal [77] and Abu El-Maaty et al. [12]; describing the questionnaire survey of Akal [77] and the contextual information of the participants in his survey; and examining the adequacy and consistency of the respondents to the survey. Also, it shows how the replies of the respondents have been analyzed relying upon: (1) Fuzzy Trapezoidal Membership Function (FTMF) for determining the effectiveness degrees of the specified causes of construction delay and (2) Ginni's Mean Difference Measure of Dispersion (G.M) for specifying the stationary cause of construction delay in the Egyptian highway construction projects. The next subsections will present these steps along with their outcomes.

3.1. Defining Causes of Construction Delay

Recently, Akal [77] and Abu El-Maaty et al. [12] have identified 38 causes of construction delay in the highway projects in Egypt. These causes have been specified relying upon a broad review of papers published in well-sound and peer-reviewed academic journals and dissertations. More importantly, these 38 causes have been reviewed by 18 experts experienced in the Egyptian highway construction industry, which is the focal context of the current work. Owing to these reasons, these causes will be deemed in the current research, as Table 2 illustrates, for defining the stationary cause of construction delay in the Egyptian highway projects.

Table 2: Construction Delay Causes in the Egyptian Highway Construction Projects. [77, 12]

Causes ID	Cause Description
DC_1	Poor communication between the owner of the project and other construction parties.
DC_2	Unrealistic contract duration imposed by the owner of the project.
DC_3	Financial capabilities of the owner.
DC_4	Contract modifications by the owner (e.g., changes in the project specifications and scope of the work) during the construction phase.
DC_5	Assigning extra works to the main contractor during the construction phase.
DC_6	Delay in approving the construction materials by the technical staff of the owner.
DC_7	Late hand over the project site to the main contractor.
DC_8	Owner delay in freeing the financial payments of the main contractor.
DC_9	Late issuing/approving of the project documents by the owner.
DC_{10}	Undefined scope of working.
DC_{11}	Poor communication between the consultant and other construction parties.

Table 2: Continue.

Causes ID	Cause Description
DC_{12}	Delay in inspecting the project activities by the technical staff of the consultant.
DC_{13}	Inflexibility of consultant.
DC_{14}	The technical staff of the consultant is insufficient and incapable to supervise the construction activities project.
DC_{15}	Poor communication between the main contractor and other construction parties.
DC_{16}	Difficulties in funding the project by the main contractor.
DC_{17}	Contractor's delay in the project commencement.
DC_{18}	Poor resources management by the main contractor.
DC_{19}	The technical staff of the main contractor is insufficient and ineligible to accomplish the scope of the project.
DC_{20}	Rework owing to errors during the construction phase.
DC_{21}	Using conventional and improper methods for executing the project activities.
DC_{22}	Poor planning and management of the project schedule by the main contractor.
DC_{23}	Late design works.
DC_{24}	Mistakes in designs.
DC_{25}	Incomplete designs and drawings.
DC_{26}	Unclarity of specifications.
DC_{27}	Poor efficiency of construction equipment.
DC_{28}	Shortage of construction equipment.
DC_{29}	Shortage of building materials.
DC_{30}	Changes in materials' type and specifications during the construction phase.
DC_{31}	Low productivity of labors.
DC_{32}	Low skills of the equipment-operator's skills.
DC_{33}	Insufficient labors in the site.
DC_{34}	Poor distribution and management of the labors in the construction site.
DC_{35}	Wrong/inappropriate choice of the project site.
DC_{36}	Difficulty in reaching the project's site.
DC_{37}	The nature and type of the soil of the project.
DC_{38}	Weather conditions in the project site.

3.2. Development and Surveying of the Questionnaire

For achieving the objectives of the current study, the data of Akal [77] have been utilized. Akal [77] collected his data, using a close-ended questionnaire. The preliminary form of the questionnaire of Akal [77] has been reviewed by 18 experts with ample experience in the Egyptian highway construction projects. After piloting the questionnaire, its final form has background information about the participants and 38 causes contributing to causing construction delay in the highway construction projects. In the questionnaire, the participant has to suggest one out of four answers representing varying degrees of effect associated with each identified cause on a Likert scale of one to four. A response of 1 denotes the cause is ineffective, 2 means the cause has moderate effect, 3 indicates the cause is effective, and 4 means the cause is very effective.

Relying upon validating the questionnaire, Akal [77] carried out a survey to collect data from the highway construction companies in Egypt. As a result, 56 engineers from different construction companies have participated in the survey. By checking the gathered questionnaires, it has been showed that the respondents have the necessary knowledge to take part in the survey. This has been informed from the profiles of the experts. While 36 experts have experience up to 10 years in the Egyptian highway projects, the other 20 ones are with expertise spanning from 11 to 32 years. As for their job titles, 33 of the experts have engineering positions, encompassing: 23 executive engineers, 6 technical office engineers, and 4 quality control engineers. Yet, the other 23 ones have leading management positions, including: 14 executive/projects managers, 4 technical office managers, 1 quality control manager, and 4 general/sector managers. These wide experiences and job titles imply that the gathered data represent perspectives of engineers and managers with ample working practice in the highway projects in Egypt, which can be used for conducting further analysis.

3.3. Adequacy of the Responses of the Survey

Before analyzing the responses of the highway experts, their sample size has been empirically and statistically examined to authenticate that it is adequate to present reliable outcomes. Empirically, several studies have been conducted, either locally in Egypt or globally in foremost construction markets such as the US, using small sample sizes, comprising 37 experts [78] and 48 experts [79], respectively. Similarly, Ginni's Mean Difference Measure of Dispersion has been used by several scholars relying upon small sample size of 49 experts (e.g., [80]). This, in turn, shows that the collected sample size (i.e., 56 questionnaires) is empirically sufficient for being considered and Ginni's Mean Difference Measure of Dispersion can be conducted relying upon its basis. Statistically, Abdul Nabi and El-adaway [79] figured out the minimum required sample size to authenticate the exemplification of a survey-based data, using the frequently utilized sampling formula of Cochran [81]. The result showed that the acceptable norm of a sample size must be ≥ 43. This standard statistical norm proves that the collected sample is statistically suitable to get consistent outcomes.

3.4. Reliability of the Responses of the Survey

To examine the reliability of the survey, the procedure of Cronbach's alpha has been utilized. In Cronbach's alpha, the reliability of the survey is acceptable when its value is > 0.7 [82]. In this respect, Cronbach's alpha of the data of the survey has been calculated, using the SPSS version 16.0. The finding showed that its value is 0.912, indicating enough reliability of the assembled data.

3.5. Fuzzy Trapezoidal Membership Function

For assessing and ranking the effectiveness degrees of the causes of construction delay in the Egyptian highway construction projects, Fuzzy Trapezoidal Membership Function (FTMF) has been utilized, as shown in Fig. 1. According to Gunduz et al. [83] and Akal [84], the steps of evaluating the effectiveness degrees of the specified delay causes based on FTMF are:

1) Specifying the Trapezoidal Fuzzy Number (TFN) of each linguistic expression (LE). In this paper, four linguistic expressions, comprising ineffective, moderate effect, effective, and very effective are considered to appraise the effect of each delay cause. Figure 1 shows the TFN of each LE, indicating that each LE has four numbers (a, b, c, d). Further, Table 3 illustrates the TFN of each LE.

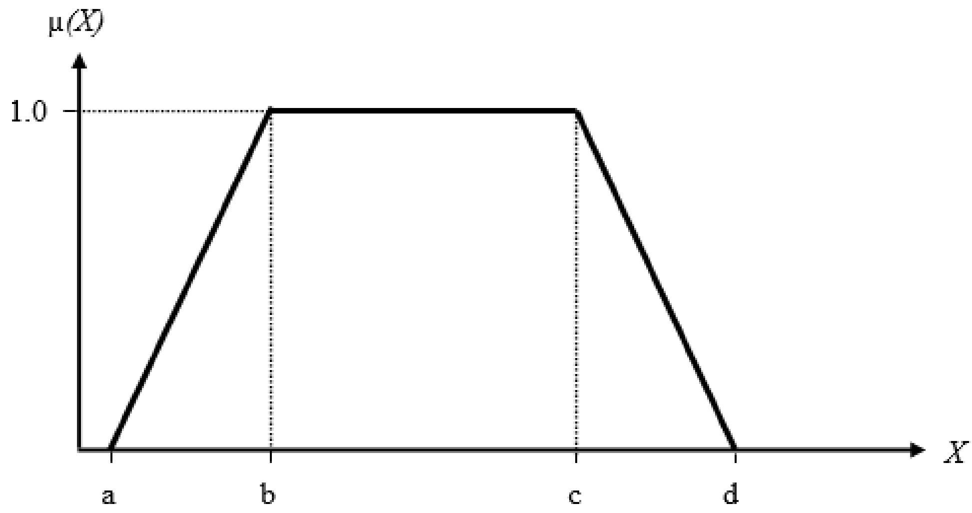

Fig. 1. Fuzzy Trapezoidal Membership Function.

Table 3: Linguistic Expression, Trapezoidal Fuzzy Numbers, and Crisp Numbers.

Linguistic Expression	Trapezoidal Fuzzy Number				Crisp Number
	a	b	c	d	
Ineffective	0.0	0.0	0.0	0.3	0.075
Moderate effect	0.0	0.3	0.3	0.5	0.275
Effective	0.2	0.5	0.5	0.8	0.500
Very effective	0.5	0.7	0.7	1.0	0.725

2) De-fuzzifying the TFN of each LE for identifying its Crisp Number (CN). Equation (1) clarifies how the CN of a TFN can be determined. Also, the last column of Table 3 comprises the CNs of the TFNs of the used LEs.

$$CN = \left[\frac{a+b+c+d}{4}\right] \quad (1)$$

3) Aggregating the views of the highway experts concerning the effectiveness degree of a particular delay cause, using Equation (2).

$$ED_j = \left[\frac{\sum_{i=1}^{N} CN_i}{N \times G}\right] \times 100\% \quad (2)$$

Where EDj is the effectiveness degree of a construction delay cause j; CNi is the crisp number of a linguistic expression of ith expert, spanning from 0.075 to 0.725 (see Table 3); N is the overall number of the experts; and G is the highest CN, i.e., 0.725.

Relying upon the aforesaid steps of FTMF, Table 4 shows the effectiveness degree and ranking of each cause of construction delay toward delaying the Egyptian highway projects. As Table 4 explains, the effectiveness degrees of the 38 causes of construction delay span from 64.41% to 93.90%, where DC19, DC24, DC12, DC27, and DC16 are the top-five causes of construction delay in the Egyptian highway construction projects.

Table 4: Effectiveness Degrees and Ranking of Construction Delay Causes.

Cause ID	Effectiveness Degree (%)	Ranking
DC_1	79.19	28
DC_2	84.48	18
DC_3	86.76	11
DC_4	74.63	34
DC_5	69.15	37
DC_6	86.70	12
DC_7	80.11	26
DC_8	86.15	13
DC_9	85.59	16
DC_{10}	73.28	35
DC_{11}	83.44	19
DC_{12}	90.02	3
DC_{13}	80.60	25
DC_{14}	88.92	9
DC_{15}	86.15	14
DC_{16}	89.47	5
DC_{17}	85.04	17
DC_{18}	88.36	10
DC_{19}	93.90	1
DC_{20}	86.15	15
DC_{21}	75.62	33
DC_{22}	83.44	19
DC_{23}	82.33	22
DC_{24}	90.09	2
DC_{25}	78.51	29
DC_{26}	80.73	23
DC_{27}	89.53	4
DC_{28}	89.47	5
DC_{29}	89.47	5
DC_{30}	77.34	31
DC_{31}	83.37	21
DC_{32}	89.47	5
DC_{33}	77.83	30
DC_{34}	80.67	24
DC_{35}	76.79	32
DC_{36}	72.35	36
DC_{37}	79.62	27
DC_{38}	64.41	38

3.6. Ginni's Mean Difference Measure of Dispersion

In general, the stationary cause of the issue under analysis elucidates that it is the key critical cause of the explored issue. This definition has been clearly portrayed in many studies in the construction management-related literature, comprising Samuel and Ovie [24], El-Kholy and Akal [25], and Ali et al. [26]. Hence, Ginni's Mean Difference Measure of Dispersion (G.M) has been adopted by the researcher for defining the stationary cause of construction delay in the Egyptian highway projects. According to Samuel and Ovie [24], the steps of G.M for pinpointing the stationary cause of construction delay are:

1) Calculating the mean of dispersion of the ED numbers of construction delay causes, using Equation (3).

$$G.M = \frac{G}{M} \tag{3}$$

Where G.M stands for the Ginni's mean difference measure of dispersion; G represents the sum of the differences between all the numbers of the ED of construction delay causes; and M reflects the full number of differences between all the numbers of the ED of construction delay causes, where $M = \frac{N(N-1)}{2}$ and N exemplifies the number of construction delay causes.

For calculating G.M of the ED of construction delay causes, Table 5 has been presented. In this table, G and M are 5205.91 and 703, respectively. Further, by using Equation (3), G.M is 7.405.

2) Determining the equivalent weight (Wi) of each ED number of each construction delay cause by utilizing Equation (4).

$$W_i = G.M \times \frac{ED_i}{ED_1} \tag{4}$$

Where Wi stands for the equivalent weight of the EDi of a cause of delay i; EDi is the effectiveness degree of the cause of delay i, and ED1 represents the highest effectiveness degree of all the causes of construction delay.

Relying upon the inputs of Equation (4), Table 6 illustrates the equivalent weight (Wi) of each ED number of each construction delay cause.

3) Specifying the weighted geometric mean (G.M. (w)) of the ED numbers for representing the stationary central value and fit it on the ED calibration for pinpointing the stationary cause of construction delay, (see Equation (5)).

$$G.M\ (W) = Antilog \times \frac{\Sigma W_i.\ Log\ ED}{\Sigma W_i} \tag{5}$$

Where G.M. (W) represents the weighted geometric mean of the ED numbers and ΣWi stands for the summation of the weights of the ED of all the causes of construction delay.

By considering the inputs of Equation (5), Table 6 shows that ΣWi and ΣWi. Log ED are 247.563 and 474.922, respectively. By using these values in Equation (5), it can be found that G.M (W) is 82.869%. This value of G.M (W) on the ED calibration, as shown in Table 6, is very near to the ED number of "low productivity of labors" (DC31). This major result, in turn, tells that this is the stationary cause of construction delay in the Egyptian highway projects.

4. Analysis and Discussion

This section analyzes and discusses the outcomes building on FTMF and G.M in terms of: (1) the top-five ranking causes of construction delay and (2) the stationary cause of construction delay. This is with a support of the pertinent references to improve the understanding and propose the mitigating measures of the impacts of the top-ranked and stationary causes of construction delay in the highway construction projects. Also, this section illustrates two comparisons. The first comparison includes the top-five ranking causes of construction delay of the present study along with their counterparts in the prior-related studies in Egypt to state whether they are significantly influenced by the sample size and the perspectives of different project parties with different interests. On the other side, the second comparison examines the occurrence of the top-ranked and stationary causes of delay of this paper in the developing nations to explore whether they are common and critical in the global context or not. Accordingly, more broad implications can be presented from this work.

4.1. Top-Five Ranking Causes of Construction Delay

4.1.1 Technical Staff of the Main Contractor is Insufficient and Ineligible to Accomplish the Scope of the Project

. Clearly, as Table 5 shows, the delay factor of "technical staff of the main contractor is insufficient and ineligible to accomplish the scope of the project" (DC19) is the most effectiveness cause of delay in the Egyptian highway projects. This result is not unexpected given the actuality that the majority of the Egyptian construction workforce is untrained along with inadequate vocational education [85]. Similarly, many construction engineers and managers are not acquainted with the up-to-date construction techniques and technologies [86]. These challenges, in turn, lead to limiting the number of the qualified staff in the Egyptian highway projects to implement and manage the associated construction activities in accordance with the requirements of the project, particularly in terms of quality and time. Definitely, this causes the issues of poor site management [50], unqualified workforce [51], and poor workmanship [43]. As indicated by Mahamid et al. [34] in Palestine and Kamanga and Steyn [35] in Malawi, these problems are among the major factors of delay in the highway projects. To manage these negative impacts, Akal and El-Kholy [86] listed that the contracting firms should assign adequate financial budget for providing their workforce, engineers, and managers with the needed vocational education courses and training programs. According to Love and Edwards [87], this mitigation measure is not only important to up skill the technical competencies of the project staff, but also boosts the process of site management. This improves the quality level of the implemented activities within the project time schedule.

4.1.2 Mistakes in Design

Building on Table 4, "mistakes in design" (DC24) rated to be the second most effective cause contributing to delaying the highway projects in Egypt. This issue frequently occurs in many developing countries, comprising Jordan [41], Palestine [55], and Saudi Arabia [56]. Unfortunately, the culprits of this issue are the owners of the projects and their consultants; however, the contractors are the victims. This is associated with the owners' non-professional management practice during the design stage in terms of appointing tight schedule for the design offices and consultancy firms to finish the designs of the projects [88]. This, in turn, limits their skills to prepare the designs and in, most cases, compels them to satisfy the owner desire at the expense of the quality of designs [89]. More criticality, in contracting with the design offices and engineering consultancy firms, the owners concentrate on the lowest financial offer, neglecting any technical competencies that are fundamentally needed to achieve the design tasks. As a result, the design works are assigned to design firms with low technical skills which finish the designs and drawings with critical mistakes [86]. Emphatically, discovering these mistakes, either before or after implementing their designs and drawings requires additional time for being corrected, causing the projects to be significantly delayed. To address this cause, the owners should pay more attention toward the importance of the design stage by: (1) allocating sufficient schedule and budget for the tasks of the designs stage and (2) selecting qualified designs offices and consultancy firms to perform the designs based on their prior track records not on their financial offers.

4.1.3 Delay in Inspecting the Project Activities by the Technical Staff of the Consultant

Based on Table 4, "delay in inspecting the project activities by the technical staff of the consultant" (DC12) has been identified in this research as the third effective cause of delay. Again, this result shows that the consultants have significant role toward delaying the highway construction projects in terms of their inflexible, long routine, and complicated procedures regarding inspecting the activities of the construction projects. Alfakhri et al. [50] in Libya, Amare et al. [51] in Ethiopia, Khair et al. [60] in Sudan, and Ayudhya [16] in Thailand also rated this factor among the causes of delay in the highway projects. This wide frequency of this cause in the developing nations has a significant massage to the consultants in these countries: their roles are to cooperate with the contractors and assist them to finish their construction activities in accordance with time, cost, and quality standards of the projects. Further, their roles are to discover and avoid the incidence of the construction errors before their occurrence, not to wait until inducing the construction errors and imposing penalties and fines on the contractors. If they well-understand these roles, they contribute to achieving the projects without delay and quality shortfall.

4.1.4 Poor Efficiency of Construction Equipment

According to Table 4, "poor efficiency of construction equipment" (DC27) has the fourth position towards causing delay in the Egyptian highway projects. By reviewing the related literature, it has been noticed that this cause is frequent in many developing nations, including for instance, Nigeria [64], Greece [65], and India [19]. Mahamid et al. [34] and Santoso and Soeng [48] showed why this cause is frequent in these developing economies that, first, most of the contracting firms are small- or medium-sized companies. Accordingly, they do not have the needed equipment for implementing the activities of the highway projects. Second, even the big-sized companies do not own sufficient equipment to execute these projects. Alternatively, they rent the construction equipment when required. Hence, when there are several highway projects, the construction equipment becomes in short supply and poorly maintained. Third, it is a familiar practice in the developing nations that maintenance of construction equipment does not receive sufficient attention. Combining these agents together, the end output is that breakdown and shortage of construction equipment, leading the highway projects to be delayed. As the definitions of these three problems imply, their major cause is: awarding the highway projects to non-professional and un-financially sound contractors. This affirms that status of construction companies' assets, comprising equipment, machinery, and human resources must be included when evaluating the contracting firms for awarding the highway projects. This procedure will limit the risk of having contractors with improper or unqualified technical and financial resources [48].

Table 5: Differences of all Possible Pairs of ED Numbers.

Rank	Cause ID	ED (%)	Difference									
			1	2	3	4	5	6	7	8	9	10
1	DC_{19}	93.90	29.49*									
2	DC_{24}	90.09	24.75	25.68**								
3	DC_{12}	90.02	21.55	20.94	25.61							
4	DC_{27}	89.53	20.62	17.74	20.87	25.12						
5	DC_{16}	89.47	19.27	16.81	17.67	20.38	25.06					
5	DC_{28}	89.47	18.28	15.46	16.74	17.18	20.32	25.06				
5	DC_{29}	89.47	17.11	14.47	15.39	16.25	17.12	20.32	25.06			
5	DC_{32}	89.47	16.56	13.3	14.4	14.9	16.19	17.12	20.32	25.06		
9	DC_{14}	88.92	16.07	12.75	13.23	13.91	14.84	16.19	17.12	20.32	24.51	
10	DC_{18}	88.36	15.39	12.26	12.68	12.74	13.85	14.84	16.19	17.12	19.77	23.95
11	DC_{3}	86.76	14.71	11.58	12.19	12.19	12.68	13.85	14.84	16.19	16.57	19.21
12	DC_{6}	86.70	14.28	10.9	11.51	11.7	12.13	12.68	13.85	14.84	15.64	16.01
13	DC_{8}	86.15	13.79	10.47	10.83	11.02	11.64	12.13	12.68	13.85	14.29	15.08
13	DC_{15}	86.15	13.30	9.98	10.4	10.34	10.96	11.64	12.13	12.68	13.3	13.73
13	DC_{20}	86.15	13.23	9.49	9.91	9.91	10.28	10.96	11.64	12.13	12.13	12.74
16	DC_{9}	85.59	13.17	9.42	9.42	9.42	9.85	10.28	10.96	11.64	11.58	11.57
17	DC_{17}	85.04	11.57	9.36	9.35	8.93	9.36	9.85	10.28	10.96	11.09	11.02
18	DC_{2}	84.48	10.53	7.76	9.29	8.86	8.87	9.36	9.85	10.28	10.41	10.53
19	DC_{11}	83.44	10.46	6.72	7.69	8.8	8.80	8.87	9.36	9.85	9.73	9.85
19	DC_{22}	83.44	10.46	6.65	6.65	7.2	8.74	8.80	8.87	9.36	9.3	9.17
21	DC_{31}	83.37	9.42	6.65	6.58	6.16	7.14	8.74	8.80	8.87	8.81	8.74
22	DC_{23}	82.33	8.86	5.61	6.58	6.09	6.1	7.14	8.74	8.80	8.32	8.25
23	DC_{26}	80.73	8.31	5.05	5.54	6.09	6.03	6.1	7.14	8.74	8.25	7.76
24	DC_{34}	80.67	7.75	4.5	4.98	5.05	6.03	6.03	6.10	7.14	8.19	7.69
25	DC_{13}	80.60	7.75	3.94	4.43	4.49	4.99	6.03	6.03	6.1	6.59	7.63
26	DC_{7}	80.11	7.75	3.94	3.87	3.94	4.43	4.99	6.03	6.03	5.55	6.03
27	DC_{37}	79.62	7.2	3.94	3.87	3.38	3.88	4.43	4.99	6.03	5.48	4.99
28	DC_{1}	79.19	7.14	3.39	3.87	3.38	3.32	3.88	4.43	4.99	5.48	4.92
29	DC_{25}	78.51	5.54	3.33	3.32	3.38	3.32	3.32	3.88	4.43	4.44	4.92
30	DC_{33}	77.83	4.98	1.73	3.26	2.83	3.32	3.32	3.32	3.88	3.88	3.88
31	DC_{30}	77.34	4.43	1.17	1.66	2.77	2.77	3.32	3.32	3.32	3.33	3.32
32	DC_{35}	76.79	4.43	0.62	1.1	1.17	2.71	2.77	3.32	3.32	2.77	2.77
33	DC_{21}	75.62	4.43	0.62	0.55	0.61	1.11	2.71	2.77	3.32	2.77	2.21
34	DC_{4}	74.63	4.43	0.62	0.55	0.06	0.55	1.11	2.71	2.77	2.77	2.21
35	DC_{10}	73.28	4.37	0.62	0.55	0.06	0	0.55	1.11	2.71	2.22	2.21
36	DC_{36}	72.35	3.88	0.56	0.55	0.06	0	0	0.55	1.11	2.16	1.66
37	DC_{5}	69.15	3.81	0.07	0.49	0.06	0	0	0	0.55	0.56	1.6
38	DC_{38}	64.41	0	0	0	0	0	0	0	0	0	0
Total			429.07	288.10	285.58	268.43	266.39	266.39	266.39	266.39	249.89	233.65

Table 5: Continue.

Rank	Cause ID	ED (%)	Difference									
			11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	DC_{19}	93.90										
2	DC_{24}	90.09										
3	DC_{12}	90.02										
4	DC_{27}	89.53										
5	DC_{16}	89.47										
5	DC_{28}	89.47										
5	DC_{29}	89.47										
5	DC_{32}	89.47										
9	DC_{14}	88.92										
10	DC_{18}	88.36										
11	DC_{3}	86.76	22.35									
12	DC_{6}	86.70	17.61	22.29								
13	DC_{8}	86.15	14.41	17.55	21.74							
13	DC_{15}	86.15	13.48	14.35	17	21.74						
13	DC_{20}	86.15	12.13	13.42	13.8	17	21.74					
16	DC_{9}	85.59	11.14	12.07	12.87	13.8	17	21.18				
17	DC_{17}	85.04	9.97	11.08	11.52	12.87	13.8	16.44	20.63			
18	DC_{2}	84.48	9.42	9.91	10.53	11.52	12.87	13.24	15.89	20.07		
19	DC_{11}	83.44	8.93	9.36	9.36	10.53	11.52	12.31	12.69	15.33	19.03	
19	DC_{22}	83.44	8.25	8.87	8.81	9.36	10.53	10.96	11.76	12.13	14.29	19.03
21	DC_{31}	83.37	7.57	8.19	8.32	8.81	9.36	9.97	10.41	11.2	11.09	14.29
22	DC_{23}	82.33	7.14	7.51	7.64	8.32	8.81	8.8	9.42	9.85	10.16	11.09
23	DC_{26}	80.73	6.65	7.08	6.96	7.64	8.32	8.25	8.25	8.86	8.81	10.16
24	DC_{34}	80.67	6.16	6.59	6.53	6.96	7.64	7.76	7.7	7.69	7.82	8.81
25	DC_{13}	80.60	6.09	6.10	6.04	6.53	6.96	7.08	7.21	7.14	6.65	7.82
26	DC_{7}	80.11	6.03	6.03	5.55	6.04	6.53	6.4	6.53	6.65	6.1	6.65
27	DC_{37}	79.62	4.43	5.97	5.48	5.55	6.04	5.97	5.85	5.97	5.61	6.1
28	DC_{1}	79.19	3.39	4.37	5.42	5.48	5.55	5.48	5.42	5.29	4.93	5.61
29	DC_{25}	78.51	3.32	3.33	3.82	5.42	5.48	4.99	4.93	4.86	4.25	4.93
30	DC_{33}	77.83	3.32	3.26	2.78	3.82	5.42	4.92	4.44	4.37	3.82	4.25
31	DC_{30}	77.34	2.28	3.26	2.71	2.78	3.82	4.86	4.37	3.88	3.33	3.82
32	DC_{35}	76.79	1.72	2.22	2.71	2.71	2.78	3.26	4.31	3.81	2.84	3.33
33	DC_{21}	75.62	1.17	1.66	1.67	2.71	2.71	2.22	2.71	3.75	2.77	2.84
34	DC_{4}	74.63	0.61	1.11	1.11	1.67	2.71	2.15	1.67	2.15	2.71	2.77
35	DC_{10}	73.28	0.61	0.55	0.56	1.11	1.67	2.15	1.6	1.11	1.11	2.71
36	DC_{36}	72.35	0.61	0.55	0	0.56	1.11	1.11	1.6	1.04	0.07	1.11
37	DC_{5}	69.15	0.06	0.55	0	0	0.56	0.55	0.56	1.04	0	0.07
38	DC_{38}	64.41	0	0	0	0	0	0	0	0	0	0
Total			188.85	187.23	172.93	172.93	172.93	160.05	147.95	136.19	115.39	115.39

Table 5: Continue.

Rank	Cause ID	ED (%)	Difference									
			21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	DC_{19}	93.90										
2	DC_{24}	90.09										
3	DC_{12}	90.02										
4	DC_{27}	89.53										
5	DC_{16}	89.47										
5	DC_{28}	89.47										
5	DC_{29}	89.47										
5	DC_{32}	89.47										
9	DC_{14}	88.92										
10	DC_{18}	88.36										
11	DC_{3}	86.76										
12	DC_{6}	86.70										
13	DC_{8}	86.15										
13	DC_{15}	86.15										
13	DC_{20}	86.15										
16	DC_{9}	85.59										
17	DC_{17}	85.04										
18	DC_{2}	84.48										
19	DC_{11}	83.44										
19	DC_{22}	83.44										
21	DC_{31}	83.37										
22	DC_{23}	82.33	18.96									
23	DC_{26}	80.73	14.22	17.92								
24	DC_{34}	80.67	11.02	13.18	16.32							
25	DC_{13}	80.60	10.09	9.98	11.58	16.26						
26	DC_{7}	80.11	8.74	9.05	8.38	11.52	16.19					
27	DC_{37}	79.62	7.75	7.7	7.45	8.32	11.45	15.70				
28	DC_{1}	79.19	6.58	6.71	6.1	7.39	8.25	10.96	15.21			
29	DC_{25}	78.51	6.03	5.54	5.11	6.04	7.32	7.76	10.47	14.78		
30	DC_{33}	77.83	5.54	4.99	3.94	5.05	5.97	6.83	7.27	10.04	14.1	
31	DC_{30}	77.34	4.86	4.5	3.39	3.88	4.98	5.48	6.34	6.84	9.36	13.42
32	DC_{35}	76.79	4.18	3.82	2.9	3.33	3.81	4.49	4.99	5.91	6.16	8.68
33	DC_{21}	75.62	3.75	3.14	2.22	2.84	3.26	3.32	4	4.56	5.23	5.48
34	DC_{4}	74.63	3.26	2.71	1.54	2.16	2.77	2.77	2.83	3.57	3.88	4.55
35	DC_{10}	73.28	2.77	2.22	1.11	1.48	2.09	2.28	2.28	2.4	2.89	3.2
36	DC_{36}	72.35	2.70	1.73	0.62	1.05	1.41	1.60	1.79	1.85	1.72	2.21
37	DC_{5}	69.15	2.64	1.66	0.13	0.56	0.98	0.92	1.11	1.36	1.17	1.04
38	DC_{38}	64.41	1.04	1.6	0.06	0.07	0.49	0.49	0.43	0.68	0.68	0.49
Total			114.13	96.45	70.85	69.95	68.97	62.60	56.72	51.99	45.19	39.07

Table 5: Continue.

Rank	Cause ID	ED (%)	Difference							Total
			31	32	33	34	35	36	37	
1	DC_{19}	93.90								
2	DC_{24}	90.09								
3	DC_{12}	90.02								
4	DC_{27}	89.53								
5	DC_{16}	89.47								
5	DC_{28}	89.47								
5	DC_{29}	89.47								
5	DC_{32}	89.47								
9	DC_{14}	88.92								
10	DC_{18}	88.36								
11	DC_{3}	86.76								
12	DC_{6}	86.70								
13	DC_{8}	86.15								
13	DC_{15}	86.15								
13	DC_{20}	86.15								
16	DC_{9}	85.59								
17	DC_{17}	85.04								
18	DC_{2}	84.48								
19	DC_{11}	83.44								
19	DC_{22}	83.44								
21	DC_{31}	83.37								
22	DC_{23}	82.33								
23	DC_{26}	80.73								
24	DC_{34}	80.67								
25	DC_{13}	80.60								
26	DC_{7}	80.11								
27	DC_{37}	79.62								
28	DC_{1}	79.19								
29	DC_{25}	78.51								
30	DC_{33}	77.83								
31	DC_{30}	77.34	12.93							
32	DC_{35}	76.79	8.19	12.38						
33	DC_{21}	75.62	4.99	7.64	11.21					
34	DC_{4}	74.63	4.06	4.44	6.47	10.22				
35	DC_{10}	73.28	2.71	3.51	3.27	5.48	8.87			
36	DC_{36}	72.35	1.72	2.16	2.34	2.28	4.13	7.94		
37	DC_{5}	69.15	0.55	1.17	0.99	1.35	0.93	3.2	4.74	
38	DC_{38}	64.41	0	0	0	0	0	0	0	
Total			35.15	31.3	24.28	19.33	13.93	11.14	4.74	G = 5205.91
Notes: *29.49 = 29.49 -- 64.41 **25.68 = 90.09 -- 64.41										

Table 6: Weighted Geometric Mean of Construction Delay Causes.

Rank	Cause ID	ED (%)	W_i	Log ED	W_i. Log ED
1	DC_{19}	93.90	7.405	1.973	14.608
2	DC_{24}	90.09	7.105	1.955	13.888
3	DC_{12}	90.02	7.099	1.954	13.874
4	DC_{27}	89.53	7.061	1.952	13.782
5	DC_{16}	89.47	7.056	1.952	13.771
5	DC_{28}	89.47	7.056	1.952	13.771
5	DC_{29}	89.47	7.056	1.952	13.771
5	DC_{32}	89.47	7.056	1.952	13.771
9	DC_{14}	88.92	7.013	1.949	13.667
10	DC_{18}	88.36	6.968	1.946	13.562
11	DC_{3}	86.76	6.842	1.938	13.262
12	DC_{6}	86.70	6.837	1.938	13.251
13	DC_{8}	86.15	6.794	1.935	13.148
13	DC_{15}	86.15	6.794	1.935	13.148
13	DC_{20}	86.15	6.794	1.935	13.148
16	DC_{9}	85.59	6.750	1.932	13.044
17	DC_{17}	85.04	6.707	1.930	12.941
18	DC_{2}	84.48	6.662	1.927	12.837
19	DC_{11}	83.44	6.580	1.921	12.643
19	DC_{22}	83.44	6.580	1.921	12.643
21	DC_{31}	83.37	6.575	1.921	12.630
22	DC_{23}	82.33	6.493	1.916	12.437
23	DC_{26}	80.73	6.367	1.907	12.141
24	DC_{34}	80.67	6.362	1.907	12.130
25	DC_{13}	80.60	6.356	1.906	12.117
26	DC_{7}	80.11	6.318	1.904	12.027
27	DC_{37}	79.62	6.279	1.901	11.937
28	DC_{1}	79.19	6.245	1.899	11.858
29	DC_{25}	78.51	6.192	1.895	11.733
30	DC_{33}	77.83	6.138	1.891	11.608
31	DC_{30}	77.34	6.099	1.888	11.518
32	DC_{35}	76.79	6.056	1.885	11.417
33	DC_{21}	75.62	5.964	1.879	11.204
34	DC_{4}	74.63	5.886	1.873	11.023
35	DC_{10}	73.28	5.779	1.865	10.778
36	DC_{36}	72.35	5.706	1.859	10.610
37	DC_{5}	69.15	5.453	1.840	10.033
38	DC_{38}	64.41	5.080	1.809	9.189
Sum			**ΣW_i = 247.563**		**ΣW_i. Log ED = 474.922**

4.1.5 Difficulties in Funding the Project by the Main Contractor

In accordance with the outcomes of Table 4, "difficulties in funding the project by the main contractor" (DC16) is the fifth most effective agent responsible for causing delay in the Egyptian highway projects. Sadly, this is a common phenomenon in the developing construction markets, such as Bahrain [39], Ghana [52], Pakistan [57], and Palestine [55]. The key factor of this critical issue in these countries is pertinent to the poor practice of the owners of the construction projects in terms of utilizing the policy of assigning the project to the lowest bidder without considering the financial and technical capabilities of the awarded bid [68]. According to Bagay and Song [90], the lowest bidders are always having low technical skills, limited financial strengths, and insufficient expertise. As a result, they may not have sufficient and highly qualified technical staff to implement the activities of the highway projects. Hence, the management, construction, and supervision processes are poorly planned, managed, and completed. This negatively impacts the project performance and ultimately causes construction delays in completing the project activities. Radically, these severe effects can be managed by considering the technical and financial pre-qualifications of the contractors who are qualified to bid for the projects [48] rather than following the policy of selecting the contracting firms on financial ground only [86]. This can be realized by checking the track record of construction companies on prior projects in terms of their financial capabilities, assets of machinery and equipment, and human resources skills [48].

4.2. Comparison with the Prior Related-Studies in Egypt

The top-five ranking causes of delay of the present work have been compared with those of Akal et al. [49] and Abu El-Maaty et al. [12] in Egypt, as presented in Table 7. According to Table 7, either the sample size or the interests of the participants in each study is totally different. However, “technical staff of the main contractor is insufficient and ineligible to accomplish the scope of the project” (DC19) has the first position toward delaying the highway projects in all the studies. This implies that this is a severe issue from the perspectives of the owners, consultants, and contractors in Egypt. More importantly, this critical cause of delay is not sensitive to the changes in the sample size of the participants in the investigated studies. In contrast, the other top-four causes of delay are somewhat different, indicating that the ranking of delay causes in the highway projects are affected by the population and sample size of the study. This analysis has a general implication that the analysts of delay in the highway projects have to build their studies on ample sample sizes, using sound statistical approaches along with a more balanced consideration of the perspectives of owners, consultants, and contractors. This assures the accurateness of their research works for enriching the knowledge body and industry practitioners with reliable outputs to control the negative impacts of delay in the highway projects.

Table 7: Top-Five Ranking Causes of Delay in Highway Projects in Egypt.

Study	Sample Size	Top-Five Ranking Causes of Delay				
		1st	2nd	3rd	4th	5th
Current study	Fifty-six engineers from contracting firms.	DC_{19}	DC_{24}	DC_{12}	DC_{27}	DC_{16}
[49]	Fifty-nine engineers: 26 form owner organizations, 13 form consultant firms, and 20 from contracting companies.	DC_{19}	DC_{8}	DC_{27}	DC_{16}	DC_{28} & DC_{29}
[12]	One hundred and eleven engineers: 40 form owner organizations, 15 form consultant firms, and 56 from contracting companies.	DC_{19}	DC_{16}	DC_{27}	DC_{28}	DC_{29}

4.3. Stationary Cause of Construction Delay

With 82.869% as a weighted geometric mean of the ED numbers of the causes of construction delay in the present paper, this shows that the stationary cause of delay in the Egyptian highway projects is “low productivity of labors” (DC31). In general, the construction projects, comprising highway construction, are labors intensive industry. Consequently, the construction productivity is significantly relied upon the human efforts and their performance [85]. In spite of this significance toward the successful implementation of the construction projects, the labors productivity in the developing nations is not at the desired level of performance. This has been seen in Palestine [34], Ethiopia [44], India [19], and Saudi Arabia [68]. Santoso and Soeng [48] in Cambodia discussed why this cause is frequent in the developing nations that the contracting firms do not have or not interested in providing their labors with the needed training programs, preliminary owing to their limited financial resources or to achieve more profits. This, in turn, limits the technical capabilities of the labors to finish the construction activities at the required quality level of the project, leading to re-implementing the same construction activities more than once. This requires additional resources, time, and cost, leading to delaying and increasing the cost of the construction project as a whole. This analysis has a serious message to the contracting firms that they have to set adequate plans for training their labors. This will lead to up skilling the technical competencies of their labors, maximizing the profits of their business.

4.4. Comparison with other Developing Nations

This comparison examines the worldwide perception concerning the frequency of occurrence of the top-five and stationary causes of construction delay in the Egyptian highway projects among 21 developing economies in Africa, Asia, Europe, and South America. By analyzing the studies of these nations, as Table 8 illustrates, it has been realized that "mistakes in design" (DC24) is not only the most encountered cause of construction delay in the Egyptian highway construction sector, but as well appears in eighteen developing economies with a high rate of occurrence of 85.71%. It has been followed by "difficulties in funding the project by the main contractor" (DC16), "delay in inspecting the project activities by the technical staff of the consultant" (DC12), "technical staff of the main contractor is insufficient and ineligible to accomplish the scope of the project" (DC19), "poor efficiency of construction equipment" (DC27), and "low productivity of labors" (DC31) which yield 80.95%, 71.43%, 47.62%, 47.62%, and 47.62%, respectively. The result of this comparison has a noteworthy practical implication. It authenticates the outputs of the current paper that the top-five and stationary causes of construction delay are severe risks facing the construction industry not only in Egypt, but as well in many other developing nations elsewhere. Consequently, the results relevant to the present work can be adopted by the scholars and practitioners in other developing nations for managing the risks of construction delay in particular and improve the performance of their construction markets as a whole.

Table 8: Top-Five Ranking Causes of Delay in Highway Projects in Egypt.

Study	Country	Top-Five Ranking Causes of Delay					Stationary Delay Cause
		DC_{19}	DC_{24}	DC_{12}	DC_{27}	DC_{16}	DC_{31}
[27, 64]	Nigeria		✓	✓	✓		
[11]	Cameroon		✓	✓			
[11, 34, 37, 38, 55]	Palestine	✓	✓	✓	✓	✓	✓
[35, 14]	Malawi	✓	✓	✓		✓	✓
[39]	Bahrain	✓	✓	✓		✓	
[40, 57, 18]	Pakistan		✓			✓	✓
[23, 44, 51]	Ethiopia	✓	✓	✓	✓	✓	✓
[41]	Jordan		✓		✓		
[43]	Kenya		✓	✓		✓	
[48]	Cambodia	✓	✓	✓	✓	✓	✓
[52]	Ghana		✓			✓	
[50]	Libya	✓	✓	✓		✓	
[56, 63, 68]	Saudi Arabia		✓	✓	✓	✓	✓
[58]	Vietnam					✓	
[59]	Iraq		✓			✓	
[61, 17, 19]	India	✓	✓	✓	✓	✓	✓
[60]	Sudan	✓		✓	✓	✓	
[62, 16]	Thailand	✓	✓	✓	✓	✓	✓
[65]	Greece		✓	✓	✓	✓	✓
[70]	Brazil	✓					✓
[91, 71]	Indonesia		✓	✓		✓	
Frequency	10	18	15	10	17	10	
Percent (%)	47.62	85.71	71.43	47.62	80.95	47.62	

5. Conclusions

By considering the socio-economic environment of the developing countries, this paper discusses the issue of construction delay in the highway construction projects in Egypt's developing construction market. Thirty-eight causes of delay have been analyzed building upon the views of 56 engineers from the contracting firms in Egypt for defining the top-five ranking and stationary causes of delay. Based on the analysis of Fuzzy Trapezoidal Membership Function, "insufficiency and ineligibility of the technical staff of the main contractor to accomplish the scope of the project", "mistakes in design", "delay in inspecting the project activities by the technical staff of the consultant", "poor efficiency of construction equipment", and "difficulties in funding the project by the main contractor" have been rated as the top five important causes of delay in the Egyptian highway projects. By comparing these top-five ranking causes along with their counterparts in the prior-related studies in Egypt considering different populations and sample sizes, it has been summarized that these two variables have significant effects on the ranks of delay causes in the highway projects. On the other side, relying upon the of analysis Ginni's Mean Difference Measure of Dispersion "low productivity of labors" has been identified to be the stationary cause contributing to delaying the highway projects in Egypt. More importantly, in a comparison with twenty-one developing economies, it has been realized that the top-five ranking and stationary causes of delay are recurrent in the developing construction markets. Nevertheless, "mistakes in design" is the most recurrent cause, influencing eighteen of the surveyed countries.

Like any research work, this paper includes the next limitations. First, in this research, the top-ranking and stationary causes of delay have been evaluated relying upon their severity of effects. Thus, future efforts should highlight also assessing these causes by considering their frequency of occurrence to get more in-depth conclusions about the critical causes of delay in the highway projects. Second, the findings represent the interests of the contracting firms only. Therefore, future research should analyze the perspectives of the owners and consultants toward the top-five ranking and stationary causes of delay. Third, the contributions of the present paper are associated with the socio-economic environment of the developing nations. This proposes that the analysts must explore the stationary cause of delay in the developed countries. This boosts the comparison and expands the understanding of the critical causes of delay within the similar or dissimilar contexts.

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