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Exploring delay causes of road construction projects in Egypt

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Abstract Construction delays are a common phenomenon in civil engineering projects in Egypt including road construction projects. Therefore, it is essential to study and analyze causes of road construction delays. This paper studied a list of construction delay causes gathered from literature having different types of construction, different countries, different periods and different numbers of delay causes and delay groups. A questionnaire and personal interviews have formed the basis of this paper listing 293 delay causes. The questionnaire survey was distributed to 500 construction participants and 389 were received who represent consultants, contractors and site/design engineers excluding the owner representing the government in road projects as one party only. Relative Importance Index (RII) is calculated and according to the highest values the top twenty and the least twenty delay causes of construction projects in Egypt are determined. A case study is analyzed and compared to the most important delay causes in the paper. The test results reveal good correlation of causes and groups between contractors and site/design engineers and between consultants and site design engineers and a somewhat low correlation between contractors and consultants. So there are no root causes that can be taking for granted to be most or least effective delay causes. Proposed model for predicting actual road construction project duration was developed; a real case study tested the accuracy of proposed model. According to the analysis of case study, the most contributing causes and groups to delays were discussed, and some future recommendations were proposed in order to control and minimize delays in road construction projects. These findings can be helpful for project managers to mitigate the road construction delays in Egypt. In order to effectively overcome the road construction delays in developing countries, suggestions are made for fundamental and large-scale reforms in procurement systems and stakeholders' management. Also, this paper is useful for both researchers and road construction parties and allows detailed

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and repeatable analysis of the progress of a road construction project in order to facilitate and achieve a competitive level of time, cost and quality for effective road construction projects.

1. Introduction

Time is money; delay in a certain construction project affects time and thus money, which is the lifeblood of any economy. The timely completion of highway construction projects is considered one of the most important factors referring to the project success, as well as the quality and the safety. All around the world many construction projects face one of the biggest construction problems which is the delay, delays differ from a country to another, from a construction project to another and from construction type or cost to another due to every project circumstances Sullivan and Harris [55]. Delay affects every party in the construction project in a different way as for the owner or the contractor it affects differently but not the same as the consultant who is considered the least affected party of all. Many small and large size contractors in recent years have voiced their concerns over the difficulty to overcome delay problems, and the main reason is because the contractors have no ability to identify the important causes of delay occurring during the construction process. Ranking the importance of delay variables by project managers enables identification of the most important variables and assists them to seek best alternative solutions, Alwi and Hampson [8]. Effective project time management is highly dependent on the contractor, and can be adversely affected in a number of ways. Contractors must ensure that the building is constructed within the contractual completion date, or risk the imposition of financial penalties. If the principle or their agents are the cause of the delay however, the completion date may be extended to compensate the contractor. The principal and their agent must therefore ensure that they provide the contractor with information in a timely manner, to avoid causing delays. Contract conditions may also contain provisions for the contractor to be awarded extensions of time (EOT) for other types of specified delays, such as inclement weather, Finnie [19]. Project value was found to have a negative correlation with time loss due to demotivation, indicating that as project size increases time loss decreases, Ng et al. [45]. Some studies conclude that groups and factors causing delays are country, location and project specific and that there are no root causes that can be generalized, Ramanathan et al. [51]. Other studies defined the root causes of delay as situations or conditions that violated the fundamental principles and were defined in sufficient detail that allowed corrective action to be taken, Ellis and Thomas [32]. So this research studies the concept of having root delay causes affecting delay or not and ranks the causes of delay in road construction projects in Egypt The following sections present literature review, research methodology, results with discussions and conclusions with recommendations.

2. Literature review

Different definitions of delay were found, and the delay is the most common, costly, complex and risky problem encountered in construction projects, Ahmed et al. [3]. The delay is the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project, Assaf and Al-Hejji [11].

Different numbers of causes were found in each study with different important causes and ways of ranking the causes. Fig. 1 presents the classification of the causes in each research on the type of construction.

The variation in the number of delay causes for each type of construction as in general type of construction, number of delay causes studied in different research's ranging from 113 delay cause in Malaysia to 7 delay causes in Hongkong. General construction type projects is studied in 16 various countries all over the world showing that a country like Malaysia is studied in two different researchs with two different numbers of delay causes (113) and (28). The majority of the researchs studied the causes of delay affecting general construction projects followed by research's studying causes of

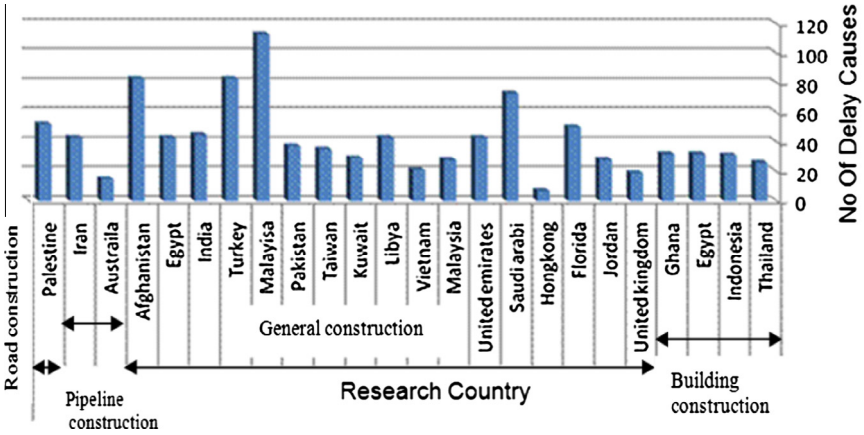

Figure 1 Classification of number of causes gathered from the literature review.

delay affecting building construction projects in different four countries, then research's studying pipeline construction projects in two different countries and finally only one research studied the causes of delay affecting the road construction project in Palestine. Causes of delay in road construction projects are taken to these studies purpose to widen the research's studying the road projects since the timely completion of highway construction projects is a national priority. Identifying the root causes and recognizing fundamental principles is a starting point.

Menesi [44] classified the types of delay into two different types according to liability as follows: (1) Excusable delays which are divided into (a) Compensable (Owner) and (b) Non-Compensable; (2) Inexcusable delays; and Concurrent delays. Kraiem and Diekmann [36] mentioned time allowed for construction project performance is usually an important consideration for both the project owner and the project contractor. Yet, it is typical for construction projects to be delayed. Delays may be caused by the owner (compensable delay), by the contractor (nonexcusable delay), by acts of god, or a third party (excusable delay), or several different kinds of delays may happen concurrently.

Ogunlana et al. [48] identified 26 delay causes affecting construction industry in a fast-growing economy in Thailand categorized them into 6 groups, and data were collected by visiting sites and mailing to 17 contractors, 18 consultants and design firms and one project owner. 8 contractors and 6 consultants gave approval of which only 12 projects were selected for visits. Interviews were conducted on site using structured and unstructured interview schedules. A total of 30 persons, representing 2.5 persons per project, were interviewed. The results of the survey have been compared with studies from other developing economies. The results of the study support the view that construction industry problems in developing economies can be nested in three layers: (a) problems of shortages or inadequacies in industry infrastructure (mainly supply of resources); (b) problems caused by clients and consultants and (c) problems caused by contractor incompetence/inadequacies.

Greenwood et al. [23] declared that hospital projects are particularly susceptible to delays, some of which appear to be common to the construction of large hospitals wherever they are built. In a number of surveys of construction professionals, one of the most influential causes of delay on large public projects has been found to be administrative reasons, and aimed to use these studies as a basis for exploring the impact of administrative delays on the construction of hospitals.

Odeh and Battaineh [47] identified 28 delay causes affecting construction projects with traditional type of contracts in Jordan; first, a survey questionnaire was developed to assess the perceptions of contractors and consultants of the relative importance of construction delay causes. Second, the questionnaire was distributed to a random sample of contractors and consultants working on large projects in Jordan. The Spearman's rank correlation coefficient was then used to test association between the contractors and consultants ranking. The study revealed that Owner interference, inadequate contractor experience, financing and payments, labor productivity, slow decision making, improper planning, and subcontractors are among the ten most important factors, according to contractors, and labor productivity was the most important delay factor. Inadequate contractor experience was the most important delay factor to consultants.

Aibinu and Odeyinka [4] assessed causes of delays by focusing on actions and inactions of project participants and external factors. The study analyzed quantitative data from completed building projects to assess the extent of delays, and data obtained from a questionnaire survey of construction managers to assess the extent to which 44 identified factors contributed to overall delays on a typical project they have been involved with. The findings showed that the factors could be prioritized. However, Pareto analysis revealed that 88% of the factors (representing 39 highest priority factors) were responsible for 90% of the overall delays. There is no discernable difference among the different delay factors and none really stands out as contributing to a large percentage of the problem. A one-sample t test further confirmed that most of the factors are important contributors to delays.

Abdul-Rahman et al. [2] described the importance of applying proper management in dealing with delays in construction for a growing economy. The main objective of this paper was to identify the management tools that were practiced in the local construction industry in mitigating delay. It also aims to identify the main factors that lead to project delays and to suggest recommendations on how to overcome or mitigate effects of the problem. Then they highlighted the importance of having more experienced and capable construction managers as well as skilled laborers to enable the industry to develop at a faster rate either nationally or internationally.

Lo et al. [39] aimed for gathering the perceptions of civil construction practitioners on how significant are the causes of delay. The extent of the differences in perception among the different respondent groups was also examined using the rank agreement factor (RAF), percentage agreement (PA), and percentage disagreement (PD). The differences in the perceptions of the respondents on the significance of delays and the actual causes of delays for the six projects studied were also examined. A strong consensus was found between the client and consultant groups on the significance of the various causes of delay (PA = 74%) and the effectiveness of mitigation measures (PA = 67%) compared with the other pairs of groups. The consultant and contractor groups held extremely different perceptions regarding the significance of various delay causes (RAF = 4.9 and PD = 32%) and the effectiveness of corresponding mitigation measures (RAF = 6.2 and PD = 47%). It is believed that the findings can provide much more insight for the construction practitioners as well as the researchers and thus help to improve the productivity and overall performance of civil engineering projects in Hong Kong.

Hegab and Smith [29] defined delay in microtunneling as the nonworking time of a microtunneling project due to any reason other than scheduled stops. There were more reasons for delay such as mechanical failure of system components, leakage of hydraulic hoses, blockage of slurry pipes, and waiting time for excavated materials hauling equipment. Delay data were collected from 35 microtunneling projects. Collected delay data were delay duration, delay reason, time, and location from the start to the stopping point. Five categories of delay causes were used in the analysis. Prediction of delay time will enhance the estimation accuracy of microtunneling project duration. A predictive model using a probabilistic approach was selected to represent the delay time. Based on data characteristics, a Weibull distribution was determined to best

represent the overall delay duration in microtunneling projects. Using "regression with life data," expected overall delay in a microtunneling project could be predicted as a function of driven length. The model will help contractors to estimate total project time with reasonable accuracy. Knowing the anticipated delay time will allow contractors to have a point of comparison for actual performance.

Le-Hoai et al. [38] identified 21 delay causes of large construction projects in Vietnam, listed in six respective groups through field survey methodology and literature reviews, a pilot questionnaire was prepared and 6 experts in Vietnamese construction industry (VCI) were involved to critically review the design and structure of the questionnaire then it was ready to survey. A total of 285 questionnaires are sent to construction professionals, and 87 full responses are obtained showing a response rate of 30.5%. The data are processed through three indices: frequency index, Severity index, and importance index and then to analyze the agreement between each two parties in respect to the causes of delay was measured using Spearman's rank correlation coefficients. From the results it is noted that poor site management and supervision, poor project management assistance, financial difficulties of owner, financial difficulties of contractor, design changes are five most frequent, severe and important causes.

Toor and Ogunlana [57] developed questionnaire surveys and interviews that were conducted on a major construction project in Thailand to explore the most significant problems causing construction delays. Factors related to designers, contractors and consultants were rated among the top problems. Issues such as lack of resources, poor contractor management, shortage of labor, design delays, planning and scheduling deficiencies, changed orders and contractors' financial difficulties were also highlighted during the interviews. Notably, problems such as 'multicultural and multilingual environment causing ineffective communication', 'large number of participants of project' and 'involvement of several foreign designers and contractors' were rated among the bottom 10 problems in the 75-item problem inventory.

Sweis et al. [56] identified and classified the causes of construction delays in residential projects according to Drewin's Open Conversion System. The most common causes were evaluated by using both, the data collected in a survey conducted to residential projects consultant engineers, contractors, and owners, and interviews with senior professionals in the field. Most correspondents agreed that, financial difficulties faced by the contractor and too many change orders by the owner are the leading causes of construction delay. Severe weather conditions and changes in government regulations and laws ranked among the least important causes.

Hegazy and Menesi [30] introduced improvements to a computerized schedule analysis model so that it will produce accurate and repeatable results. The model considered multiple baseline updates due to changes in the durations of the activities and the logical relationships among them, as well as the impact of resource overallocation. The model used a daily window size in order to consider all fluctuations in the critical paths and uses a legible representation of progress information to accurately apportion delays and accelerations among project parties. A simple case study has been implemented to demonstrate the accuracy and usefulness of the proposed delay analysis model.

Kaliba et al. [34] aimed to identify causes and effects of cost escalation and schedule delays in road construction projects. Using a detailed literature review, structured interviews and questionnaire surveys, the results of the study confirmed the prevalence of cost escalation and schedule delays in road construction projects in Zambia. The study established that bad or inclement weather due to heavy rains and floods, scope changes, environmental protection and mitigation costs, schedule delay, strikes, technical challenges, inflation and local government pressures were the major causes of cost escalation in Zambia's road construction projects.

Al-Kharashi and Skitmore [6] reported A new survey in Kingdom of Saudi Arabia that uses all the variables from the previous work and measures for both current degree of effect on delays and the extent to which each can be practically improved. These are contained in seven groupings: client, contractor, consultant, materials, labor, contract and relationship-related causes. The survey covers a sample of 86 clients, contractors and consultants working in the Saudi construction industry. The analysis found that the most influencing current cause of delay is the lack of qualified and experienced personnel attributed to the considerable amount of large, innovative, construction projects and associated current undersupply of manpower in the industry.

Yang and Wei [61] identified 35 delay causes, 15 causes in the planning phase and 20 causes in the design phase for construction projects in Taiwan by sending a structured questionnaire to engineers at the A/E companies for public construction projects in Taiwan resulting in 95 valid responses identifying the delay causes. This study used the Likert scale in questionnaire design to plot the importance-frequency matrix and ranked the factors by the importance and frequency of delays using the Relative Importance Index then calculated the severity index. Analytical results reveal that changes in clients requirement are the main causes of delay in both planning and design phases.

Soliman [54] identified 29 delay causes affecting construction projects in Kuwait through refining previous researches, categorized them into six groups then subjected to a questionnaire survey including 30 respondents made up of 9 contractors, 5 owners and 16 consultants. Data collected were analyzed by importance index and then an agreement analysis was calculated using the Spearman's rank correlation coefficient to show the degree of agreement between the rankings of any two parties. The study revealed that the financial and design related causes of delays are the most important and frequent causes. The top five delay causes that were resulted from contractors category were: delay of document submission from consultant, delaying of payments from owner, conflict between contractor and consultant, in-appropriate owner representative's management style and owner financial problems, While the five top delay causes from consultants category are: owner financial problems, contractor financial problems, inefficient management capability of contractor staff, conflict between contractor and consultant, and no planning before project start.

Orangi et al. [49] identified 15 delay causes affecting pipeline projects in Victoria-based pipeline in Australia. the research methods include detailed literature review, targeted interviews with several project managers, and case-study based knowledge mining from some pipeline projects. A set of root

causes for delays in pipeline infrastructure works have been identified such as design changes, design errors, design submission delays, lack of communication between designers and contractors, lack of communication between client and project team, customer/end-user related issues, inadequate geotechnical investigations, issues regarding client approvals, issues regarding permissions, adverse weather conditions, delays by material suppliers, poor site management practices, planning and scheduling errors, construction rework, cultural and heritage management issues and subcontractor issues.

Hasseb et al. [28] identified 37 delay causes affecting construction industry in Pakistan. A survey was conducted through mailed 200 questionnaires that were distributed in government, private and semi government organization out of which 120 were given response and in some organizations interviews were vocally taken by the labors or private firms. The delay factors are assessed by the critical assessment criteria such as mean delay factor range, mode and critical index. The survey results indicated that the majority of delay factors are relevant to client factor which must have strong economical ability and financial arrangement for project, correctly time decision. Most factors related to consultant are due to not understanding the client necessities, not having proper project information, absence of some detail in drawing. And due to contractor most delay factors occur because of deficient in obtaining up-to-date equipments, unwarranted material used in construction. Client must be mentally and financially strong for starting a new project due to which delays can be reduced in projects.

Hamzaha et al. [27] declared that the improvement of delay factors not only limited to technical factors, but also factors in project management perspective both from the aspect of processes involving and the influence of human attitudes, mentality, skills and behavior. With that spirit, study based on the same issue and problems but looking from a different angle had been conducted and delay framework has been proposed. The depth studies as to what extent these factors and variables can positively and negatively affect the construction project are suggested for future study. The reliability and criticality of framework are also required to validate the significance of the framework.

Wambeke et al. [59] examined the similarities and differences in perceptions between craft workers, foremen, and project managers in terms of starting time and task duration variation. The top eight causes of starting time variation and top nine causes of task duration variation were identified. Also quantitatively it was analyzed the underlying structure of the causes of variation using factor analysis. This was done by grouping the 50 individual causes into nine orthogonal factors that represent the underlying structure of the affecting causes.

Mahamid et al. [42] identified 52 delay causes affecting road construction projects in Palestine through a questionnaire survey, categorized them into eight groups. Then subjected to a questionnaire survey including 34 contractors and 30 consultants, owners are not included because the road construction projects are public projects and funded by the government and therefore only one client cannot be studied through a questionnaire. The suggested delay causes in road construction projects are ranked by the measurement of the severity index then the Spearman's rank correlation is used to measure the degree of correspondence between the two respondents. The survey concluded that the top five severe delay causes from the combined point of view of the contractor and the consultant are political situation, segmentation of the west bank and limited movement between areas, award project to lowest bid price, progress payment delay by owner, and shortage of equipment, approximately 75% of the participating contractors and 70% of the consultants indicated that the average time overrun for the projects they have experienced is between 10% and 30% of the original project duration, and approximately 20% of the contractors and 25% of the consultants indicated 30–50% time overrun compared with the origin specified duration, neither consultants nor contractors indicated any time delay greater than 100% of the original contract duration.

Kazaz et al. [35] examined the causes of time extensions in the Turkish construction industry and levels of their importance together. In total, 34 factors affecting project duration were taken into account. A questionnaire survey, including these factors, was then applied to 71 construction companies in Turkey, and the outcomes were evaluated by means of statistical analyses. According to the results, ''design and material changes'' was found to be the most predominant factor, followed by ''delay of payments'' and ''cash flow problems''. In terms of importance levels of factor groups, financial factors were found to be the first group, while environmental factors were the least effective group. It should be also noted that managerial causes of time extensions are encountered in developed and developing countries, whereas financial causes are experienced in developing countries only.

Niazai and Gidado [46] identified 83 delay causes affecting construction industry in Afghanistan categorized them into nine groups, through in-depth literature studies questionnaires were developed and sent to 60 carefully selected construction industry stakeholders including: 20 client, 25 contractor, and 15 consultant in Afghanistan. The importance index was used to analyze the data gathered and the agreement between each two parties in respect to the causes of delay was measured using Spearman's rank correlation coefficients. The findings show that the main critical factors that cause construction delays in Afghanistan are: security, corruption, poor qualification of the contractor's technical staff, payment delays by clients, and poor site management and supervision by contractor. The respondents reported that contract with less than 12 months highly contributes to delays and the most common time spent for the most delayed projects in Afghanistan is between 1 to 6 months.

Hamzah et al. [26] determined the causes of delay in Malaysian construction industries based on previous worldwide research. The field survey conducted includes the experienced developers, consultants and contractors in Malaysia. 34 causes of the construction delay have been determined and 24 have been selected. The analysis result will be used as the baseline for the next researches to find the causes of delay in the Malaysian construction industry taking place in Malaysian higher learning institutions.

Yang and Kao [60] used Windows-based delay analysis methods for identifying and measuring construction schedule delays. Based on a previous study identifying potential problems in available windows-based delay analysis methods, this study proposes an innovative windows-based delay analysis method, called the effect-based delay analysis method (EDAM). The EDAM performed delay analysis using extracted windows and determined delay impacts by

considering the effects of delays on the critical paths. According to its application to hypothetical cases and comparisons with other methods, EDAM is efficient in delay analysis and effective in solving concurrent delays and determining schedule shortened and is a good alternative for schedule delay analysis for construction projects.

Anastasopoulos et al. [9] used data from 1722 highway projects in Indiana, random-parameter statistical models are estimated to study the factors that contribute to the likelihood of encountering a project time delay and its duration. The model estimation results show that the likelihood and duration of project time delays are significantly influenced by factors such as project cost (contract bid amount), project type, planned project duration, and the likelihood of adverse weather.

Rahsid et al. [50] explored the causes of delay in construction projects. Data on the study variables have been collected through structured questionnaire from 37 construction firms located in Pakistan. Various statistical tools such as reliability test, factor analysis and regression have been applied for data analysis and inference. The results of the study reveal that the factors related to contractor, client, consultant, material and equipment have significant impact on delay in construction project whereas labor and general environment factors found to have no effects on delay. The findings of the study provide significant insights to construction industry so that they may formulate strategies in order to avoid delay and its consequences.

Aziz [12] identified relative importance indices and determined the influence ranks of ninety-nine (99) factors causing delay in construction projects in Egypt. It addressed the most significant factors and groups causing delays, especially after Egyptian revolution. The explored factors were classified under the following nine (9) primary classifications: (1) Consultant related delay factors; (2) Contractor related delay factors; (3) Design related delay factors; (4) Equipment related delay factors; (5) External related delay factors; (6) Labor related delay factors; (7) Material related delay factors; (8) Owner related delay factors; and (9) Project related delay factors. To study the effect of participants' experience on the obtained results, the results were grouped under experience based groups of the participants and professional cadre of respondents. The most and least important factors in groups were achieved through ranking results. Prediction model for estimating actual project duration was developed; a real case study was tested the accuracy of proposed model.

AlSehaimi et al. [7] aimed to demonstrate the root cause of delay in construction which is tended to be descriptive and explanatory, making it inadequate for solving persistent managerial problems in construction. It is contended that many problems in construction could be mitigated through alternative research approaches. Such prescriptive research methods can assist in the development and implementation of innovative tools tackling managerial problems of construction, including that of delay.

Ezeldin and Abdel-Ghany [16] focused on the causes of construction delays in the Egyptian construction industry. The first main objective of the research is to identify and rank the major causes of delays for engineering projects. The second main objective is to determine the party responsible for the main causes of delays. The research was conducted in three phases. The first phase included unstructured interviews with practitioners involved in the Egyptian construction industry. The second phase consisted of a survey for a sample of thirty-five (35) professional experts using a customized questionnaire. These experts represented the different parties of the construction industry; namely, the Contractor, the Employer, and the Consultant/ Project Manager. The third phase of the research covered the analysis of the data collected, in order to determine the frequency and ranking of the causes of delays. The analysis of the results also included the party responsible of the different causes. The results revealed that the causes of delays can be grouped into five (5) main categories: (1) Construction related causes; (2) Managerial related causes; (3) Political related causes; (4) Financial related causes; and (5) Technical related causes. The top 12 causes included 3 construction, 7 managerial, 1 political and 1 financial related causes. The contractor and the Employer were found to be responsible each of 5 of the top 12 causes. The remaining two were found to be the responsibility of a third party.

Hwang and Lim [31] aimed to identify CSFs in terms of the different project players and their objectives in the context of Singapore's construction industry. To achieve this objective, 32 CSFs were first identified and classified into four major categories: (1) project characteristics, (2) contractual arrangements, (3) project participants, and (4) interactive processes. Then the analytic hierarchy process (AHP) method was employed to establish a hierarchical model of the factors' relative importance. To facilitate systematic analysis on their importance, 12 experts with at least 10 years of industry experience were surveyed; then, through the use of the Expert Choice software, the CSFs addressing budget performance, schedule performance, quality performance, and overall project success were identified.

Arif and Morad [10] described "concurrent delays" as situation when more than one delay occurs simultaneously, either of which would alone delay the overall project. The responsibility of concurrent delays is usually attributable to opposing parties to the contract, such as owner and contractor. This often leads to disputes concerning the extent to which each of the parties is responsible for project delay. They overviewed and compared various approaches adopted by courts with respect to ruling on concurrent delay claims and apportionment under different legal system legal systems including the United States (U.S.), Canada, United Kingdom (U.K.), and Australia.

Bahadir and Mykhaylova [13] presented a simple two-sector model that incorporated housing supply which is subject to several types of delays. On average, it takes 6 months to get approved for a residential building permit and another 2–4 quarters to complete a construction project. These observations show the effect of these delays is not uniform: while they amplify the response of house prices to demand shocks, they dampen the effects of housing supply shocks. The results highlight the importance of capturing the nature and the persistence of the shocks when studying the effects of construction sector delays on housing market dynamics.

Magdy et al. [41] analyzed delays in construction projects that initiated to investigate the level of awareness, frequency of usage, information needs, complexity of application, and success rate of each CPM DAM used in the Egyptian construction market. It was conducted through a triangulation approach for data collection that employed a quantitative questionnaire and a qualitative interview. Distribution of questionnaires followed a thorough analysis of the market

structure and size of organizations. Collected data were analyzed by SPSS software.

Braimah [14] reported (1) most contractors prefer to use linked bar chart format for their baseline programs over conventional critical path method (CPM) networks; (2) baseline programs are developed using planning software packages; (3) manpower loading graphs are not commonly developed as part of the main deliverables during preconstruction stage planning; and (4) baseline program development involves many different experts within construction organizations as expected.

González et al. [22] analyzed delay causes in activities that were not completed as scheduled and contributed a methodology to examine the qualitative (delay causes) and quantitative (time performance) dimensions of the delay issue. They proposed two indicators, as follows: (1) reason for noncompliance (RNC) as an indicator that characterizes scheduling failures, and (2) delay index (DI) as a time-performance indicator that described the impacts of delay on critical and noncritical activities.

Albogamy et al. [5] aimed to provide a new methodology for a client risk management model (CRMM) due to time delay. The study included the development of a framework by integrating the findings from the literature review and a construction industry survey. A client risk analysis system is developed by integrating the analytical hierarchy process and Monte Carlo simulation underpinned within Risk program. A case study was used to demonstrate the methodology and found that it was capable of managing the risks with a suitable risk mitigation strategy and supports the proactive actions at the design stage of a construction project from the client aspect.

Ruqaishi and Bashir [52] investigated the causes of delay in construction projects in oil and gas processing facilities in Oman and serves as a case study for the Gulf Cooperation Council (GCC) countries. Using a questionnaire, data were collected from 59 project managers employed in different organizations in the oil and gas industry in Oman. The survey results showed a high degree of agreement among the perceptions of project stakeholders, clients, contractors, and consultants on the causes of project delay, and there is no evidence to suggest that the causes of project delay differ significantly according to organization size or organizational ownership. Moreover, seven factors were identified as the major causes of project delay. Although six of these identified elements are general factors that can account for delay in any project in any industry, one of them poor interaction with vendors in the engineering and procurement stages was found to be unique to construction projects in the oil and gas industry.

Lopes et al. [40] reported that the increase in using equipment in various construction activities causing delay, planning the maintenance of this equipment has become extremely important as this aids meeting project deadlines.

Gunduz et al. [25] proposed a decision support tool for contractors before the bidding stage to quantify the probability of delay in construction projects in Turkey by using the Relative Importance Index (RII) method incorporated into fuzzy logic. 83 delay factors were identified, categorized into 9 major groups through a detailed literature review process as well as interviews with experts from the construction industry. The relative importance of these delay factors and groups was quantified by using the Relative Importance Index method. The ranking of the factors and groups was demonstrated according to their level of effect on delay. A delay assessment model was proposed using the fuzzy set theory by taking into account the delay factors characterized in construction projects.

Jung et al. [33] reported that it is very important to be able to estimate the delay that would result from such severe weather because construction contracts generally differentiate between weather delays that can be anticipated and those that cannot. A simulation model was developed by integrating the weather generation model and a construction schedule simulation model by using a discrete event simulation method, and a case study was conducted to validate the results of weather delay estimation and to analyze the degree to which vertical weather variations affect the schedule of building construction projects. The contribution of study is the proposal of a method based on analyzing the pattern of weather delays in building construction projects.

Larsen et al. [37] analyzed the factors that project managers experience as having the greatest effect on time, cost, and quality, and to discover whether the effects of these factors are significantly different from each other. A questionnaire with 26 factors identified from interviews was sent to employed project managers. Factors were ranked using the Relative Importance Index and tested for significant differences using Friedman's test. From the findings it was determined that the most influential factor for time is unsettled or lack of project funding; for cost, errors or omissions in consultant material; and for quality, errors or omissions in construction work.

Tumi et al. [58] mentioned the cause "indicative of experiences" while other researches mentioned a cause for contractor experience, owner experience, designer experience and consultants experience each at a time as a separate cause so each of the 4 causes " inadequate contractor experience work causing error", "inadequate experience of designers", "lack of experience of consultant in construction projects" and "lack of experience of owner in construction projects". Fallahnejad [17] mentioned the cause "labor injuries" as a part of a cause "accidents during construction – labor injuries – infectious disease". Marzouk and El-Rasas [43]mentioned the two causes "equipment availability and failure" as one cause while in the accumulated factors it was mentioned separately as "equipment failure (breakdown)" and "tool availability". Faridi and El-sayegh [18] mentioned the cause "changes in drawings" and "changes in specifications" as two separate cause while the accumulated cause is called "change in drawing and specifications". Fugar and Agyakwah-baah [20] mentioned the two causes "poor site management" and "poor supervision" as two separate causes while the accumulated cause is called "poor site management and supervision" as one cause. Ramanathan et al. [51] mentioned the cause "slowness of the owner decision making process" 3 times in the 113 causes. It was mentioned the cause "low speed of decision making" in the owner/client group and the cause "slowness of owners decision making process" in the contractual relationship group and the cause "supervision too late & slowness in making decision" in the consultant group and mentioned the cause "preparation and approval of shop drawings, samples" 3 times in the 113 causes. It was mentioned the cause "long waiting time for approval of drawings" in the owner/client group, the cause "preparations and approval of shop drawing" in the scheduling & controlling group.

The 290 causes of delay that have been collected from the literature review taking into account not to repeat any cause are analyzed and causes are ranked according to occurrence in each research. Often, the number of mentioning each cause in the overall researches is related to the importance of the factor, for example the factor "Weather conditions" is an important factor which is not related to the type of construction, location or cost; therefore, 88% of the studied researches mentioned this factor with researches ranked it as a major factor leading to unanticipated delays and has a direct effect on delay. "Shortage (availability) in construction materials" with percentage 71%, "Shortage in equipment/insufficient numbers" with percentage 54% support the view that construction industry problems in developing economies are problems of shortages or inadequacies in industry infrastructure (mainly supply of resources) as shown in Table 1.

The cause "Fraudulent practices" has an indirect and unimportant effect in the construction industry since the countries and project managers nowadays take strong legal actions against swindling and fraud. The causes "Global financial crisis" and "Hurricane" has almost no effect as it is a rare phenomenon that happens at mostly once in the projects lifetime. But it may have a big effect if it randomly happened during a project lifetime and it could have bad effects up to end of the project totally as shown in Table 2.

3. Research objective

This research aimed to: (1) Identify the most important and least important causes of delay that affects highway constructions in Egypt; (2) Identify the severity of the delay causes from contractor, consultant and site/design engineer's perspective; (3) Identify the possible ways to avoid the delay to highway constructions in Egypt; (4) Compare of the results from the questionnaire survey with a case of study on road project in Egypt; and (5) Make recommendations in order to minimize or control delays in road construction projects.

4. Research methodology

The methodology of this paper is listed as following items. (1) Gathering the causes: A number of 290 causes are gathered by thoroughness of the literature review taking into account the repetition of the causes in the different studies in the literature review and other 3 causes were added through discussions and interviews with experts, which are no adherence to contract conditions added to contract related group, nepotism added to external related group and time spent to find appropriate subcontractors for each task added to contractor related group to have a final number of 293 causes studied in this research. (2) Defining the causes into groups: Different numbers of groups were found in the literature review, and it was found that for a particular cause it can be placed in a research in a group different from the other research, the cause (preparation and approval of shop drawings, samples) was placed in the owners group in the study of Assaf and Al-Hejji [11] in Saudi Arabia, placed in the scheduling and control group in the study of Abd El-Razek et al. [1] in Egypt, placed in the consultant group in the study of Ramanathan et al. [51] in Malaysia, the study of Fallahnejad [17] in Iran, the study of Gunduz et al. [24] in Turkey, placed in the process related group in the study of Doloi et al. [15] in India. Defining the causes into 15 groups was the researchers view Proportional with the literature review. (3) The questionnaire survey: For the 293 different delay factors were identified, categorized into fifteen (15) groups, and Questionnaires were developed into two (2) major parts (A and B). Part (A): Personal information of the respondent was collected (e.g. work experience of construction projects, work position, etc.). Part (B): Aimed to obtain information about causes of time delays in construction projects, it

Table 1 Top twenty overall mentioned delay causes in the literature review.

Rank	Delay factor description	Related category item	Number of occurrence
01	Weather conditions	External	21
02	Shortage (availability) in construction materials	Material	17
03	Slowness of the owner decision making process	Owner	15
04	Poor site management and supervision by contractor	Contractor	15
05	Shortage of labor	Labor	14
06	Accidents/mistakes during construction	External	14
07	Slow delivery of materials	Material	14
08	Construction methods	Contractor	13
09	Shortage in equipment/insufficient numbers	Equipment	13
10	Financing by contractor during construction	Financing	12
11	Preparation and approval of shop drawings, samples	Owner	12
12	Inadequate contractor experience causing error	Contractor	12
13	Low productivity level work	Labor	12
14	Obtaining permits from municipality (government)	Rules & regulations	12
15	Ineffective planning and scheduling of project by contractor	Scheduling and controlling	12
16	Delays in contractors progress payment by owner	Financing	11
17	Unrealistic (unreasonable) contract time (duration) & requirements imposed	Contract	11
18	Owner financial problems/client finance/economic ability for the project	Financing	10
19	Change orders by owner during construction (variation)	Owner	10
20	Legal/industrial disputes between various parties in the construction project (claims)	Contractual relationships	10

Table 2 Least twenty overall mentioned delay causes in the literature review.

Rank	Delay factor description	Related category item	Number of occurrence
01	Fraudulent practices	External	1
02	Delay in honoring payment certificates	Financing	1
03	Global financial crisis	Financing	1
04	Late payment to subcontractor by the main contractor	Financing	1
05	Issues regarding client approval	Owner	1
06	Improper selection of subsequent consultants	Owner	1
07	Frequent change of client managers	Owner	1
08	Non-adherence of material specifications provided by client	Contractor	1
09	Low ability of contractor to provide imported material	Contractor	1
10	Absenteeism of laborers	Labor	1
11	Staffing problems	Labor	1
12	Disagreement on design specifications	Design	1
13	Geological problems on site	Site	1
14	Disturbance to public activity	Site	1
15	Previous working relationships of consultant	Contractual relationship	1
16	Unrealistic contract price	Contract	1
17	Delay in finalization of rates for extra items	Project	1
18	Hurricane	External	1
19	Public holidays	External	1
20	No planning before project starts	Scheduling and controlling	1

was asked to rate those initially identified two hundred ninety-three causes according to their importance. A five-point Likert scale ranging from 1 (not important) to 5 (extremely important) was used to categorize the importance of the causes. Participants were asked to add any further causes. (4) Data are gathered and analyzed by using an importance index, taking in view of contractors, consultants and site/design engineers. Agreement on the ranking of the importance of the causes of delay between the three parties is analyzed. (5) Develop proposed model for predicting actual road construction project duration within a real case study to test the accuracy of proposed model.

5. Project delay causes and groups

There are two hundred ninety-three (293) causes categorized into fifteen (15) major groups as shown in Table 3 that causes delay in construction project, which are used in this paper, as follows: (1) Owner financial problems/client finance/economic ability for the project; (2) Payment of completed work; (3) Delays in contractors progress payment by owner; (4) Partial payments during construction/financing; (5) Delay in honoring payment certificates; (6) Difficulty in accessing bank credit; (7) Financing by contractor during construction; (8) Exchange rate (price) fluctuation/economic; (9) Changing of bankers policy; (10) Cash- flow problems during construction; (11) Global financial crisis; (12) Material and labor wage escalation (inflation); (13) Financial instability in markets; (14) Difficulty in obtaining materials at official current prices; (15) Late payment to subcontractor by the main contractor; (16) The unavailability of financial incentives for contractor to finish ahead of schedule; (17) Slowness of the owner decision making process; (18) Indication of suspension, postponement or delay of project by owner; (19) Design changes by owner or his agent

Table 3 Categorized groups that cause delay in construction projects.

S/N	Category group item	Related cause ID	Total number of causes
01	Financing related cause group	01: 15	15
02	Owner related cause group	16: 38	24
03	Contractor related cause group	39: 58	20
04	Labor related cause group	59: 73	15
05	Design related cause group	74: 99	26
06	Site related factors category	100: 126	27
07	Contractual relationships related cause group	127: 154	28
08	Contract related cause group	155: 167	13
09	Project related cause group	168: 181	14
10	External related cause group	182: 205	24
11	Equipment related cause group	206: 215	10
12	Rules & regulations related cause group	216: 234	19
13	Consultant related cause group	235: 248	13
14	Scheduling and controlling related cause group	249: 278	30
15	Material related cause group	279: 293	15
Total		01: 293	293

during construction; (20) Change orders by owner during construction (variation); (21) Issues regarding client approval; (22) Late issuing of approval of design documents by owner; (23) Preparation and approval of shop drawings, samples; (24) Waiting for sample material approval; (25) Delay in approval of completed work by client/CM; (26) Not definite about material; (27) Main concern construction type; (28) Poor scope definition; (29) Improper selection of subsequent consultants; (30) Lack of experience of owner in construction projects; (31) Delay in material to be supplied by the owner; (32) Unclear perception of demand; (33) Changes in clients requirements; (34) Slow land expropriation due to resistance from occupants; (35) Unfinished client – furnished item; (36) Complicated administration process of client; (37) Frequent change of client managers; (38) Specified sequence of completion; (39) Controlling subcontractors by general contractors in the execution of work; (40) Poor subcontractor performance/delays; (41) Often change of subcontractors; (42) Construction methods; (43) Rework because of errors during construction; (44) Unreliable subcontractors; (45) Poor site management and supervision by contractor; (46) Delay in site mobilization by contractor; (47) Poor resource management; (48) Incompetent project team; (49) Inadequate contractor experience (work) causing error; (50) Non-adherence of material specifications provided by client; (51) low ability of contractor to provide imported material; (52) Delay in commencement; (53) Poor qualification of the contractors technical staff; (54) Obsolete technology; (55) Unstable management structure and leadership style of contractor; (56) Lack of trade's skill; (57) Defective work; (58) Time spent to find appropriate subcontractors for each task; (59) Shortage of labor; (60) Labor skill; (61) Nationality of laborers; (62) Labor injuries; (63) Labor disputes and strikes; (64) Absenteeism of laborers; (65) Low motivation and morale of labor; (66) Slow mobilization of labor; (67) Staffing problems; (68) Shortage of unskilled labors; (69) Shortage of technical personnel/staff; (70) Insufficient (un qualified - inadequate experienced) laborers; (71) Low productivity level work; (72) Foreman incompetence; (73) Severe overtime; (74) Design errors made by designers (due to unfamiliarity with local conditions and environment); (75) Lack of database in estimating activity duration and resources; (76) Variation order in extra quantities; (77) Design details unclear & inadequate; (78) Complexity of project design; (79) Slow response of designer; (80) Build ability of design; (81) Incomplete/conflicts of design drawings details and specifications; (82) Unrealistic design duration imposed; (83) Incompletely understanding of clients requirements; (84) Wrong or improper (poor) (inappropriate) design; (85) Slow decision making by designers; (86) Inadequate experience of designers; (87) Disagreement on design specifications; (88) Insufficient training of designers; (89) Change orders by deficiency design; (90) Rework due to change of design or deviation order; (91) Late design work; (92) Unclear authority among designers; (93) Slow information delivery between designers; (94) Poor use of advanced engineering design software; (95) Mistakes and delays in producing design documents; (96) Insufficient or ill-integrated basic project data and survey; (97) Non availability of drawing/design on time; (98) Inadequate path design; (99) Change in drawings & specifications; (100) Foundation conditions encountered in the field; (101) Mistakes in soil investigation; (102) Errors committed during field construction at job site; (103) Effects of subsurface conditions (e.g., soil . High water table, etc.); (104) Geological problems on site; (105) Unexpected underground condition; (106) Insufficient available utilities on site (water, electricity, telephone, etc.); (107) Different – unfavorable site conditions; (108) Overcrowded work areas/confined site; (109) Disturbance to public activity; (110) Limited construction area; (111) Inconvenient site area; (112) Poor ground condition; (113) Poor soil quality; (114) Poor terrain condition; (115) Traffic control regulation practiced in the site of the project; (116) Statutory undertakers (gas, water, etc.); (117) Delay in providing services from utilities (water, electricity, etc.); (118) Inaccurate site investigation; (119) Restricted access at site; (120) Site accidents due to negligence; (121) Site accidents due to lack of safety measures; (122) Inaccurate specification of site condition; (123) Faulty soil investigation paper; (124) Unsatisfactory site compensation; (125) Late land handover by owner/slow site clearance; (126) Poor site layout; (127) The relationship between different subcontractors schedules in the execution of the project; (128) The conflict between contractor and other parties (consultant & owner); (129) Conflicts between consultant and design engineer; (130) Poor organization of the contractor or consultant/inappropriate overall organizational structure linking to the project); (131) Difficulty of coordination between various parties (contractor, subcontractor, owner, consultant) working on the project; (132) No utilization of professional construction/-contractual management; (133) Poor communication by consultant with other parties; (134) Poor communication by contractor with other parties; (135) Insufficient communication between the owner and designer or other parties in design phases; (136) Legal/industrial disputes between various parties in the construction project (claims); (137) Conflicts between joint – ownership; (138) Poor communication between designers; (139) Laborers personal conflict; (140) Unfair subcontractor relationships with employees; (141) Previous working relationships of consultant; (142) Personal conflict between laborers and management team; (143) Conflict between owners and other parties; (144) Deficiencies in organization; (145) Deficiencies in coordination; (146) Crew interfacing; (147) Provision for ease of communication; (148) Inadequate integration on project interfaces (involvement); (149) Insufficient communication between parties; (150) Poor documentation; (151) Uncooperative owners; (152) Foundation conditions encountered in the field; (153) Previous working relationship of owner; (154) Lack of responsibilities; (155) Poor contract management; (156) Mistakes and discrepancies in contract documents; (157) Negotiations and obtaining of contracts; (158) Contract modification/excessive contracts and subcontracts; (159) Change orders of contract; (160) Unrealistic contract price; (161) Unrealistic (unreasonable) contract time (duration) & requirements imposed; (162) Unclear contract conditions; (163) Use of standard form of contract; (164) Suitability of contract to project time; (165) Inadequate and inconsistent contract terms; (166) Unfavorable/inadequate contract clauses; (167) No adherence to contract conditions; (168) Project delivery systems used (design – build, general contracting, turnkey, etc.); (169) Category (public, private); (170) Complexity of project; (171) Location of project; (172) Unreasonable project time frame; (173) Function or end use (office, residential, industrial); (174) Inadequate definition of substantial completion; (175) Ineffective delay penalties; (176) Improper project feasibility study; (177) Type of project bidding and award (negotiation, lowest bidder); (178) Delay in

finalization of rates for extra items; (179) Increase in scope of work/notification of extra work; (180) Poor means of contracting; (181) Interfering of other projects; (182) Rain effect on construction activities; (183) Wind damage; (184) Fire; (185) Social, religions and cultural factors; (186) Accidents/mistakes during construction; (187) Problems with neighbors; (188) Infectious disease; (189) Segmentation of the west bank and limited movement between areas; (190) Natural disasters (earthquake, flood, etc.); (191) Hurricane; (192) Weather conditions; (193) Political situation; (194) Physical obstructions; (195) Conflict, war, revolution, riot, and public enemy; (196) Public holidays; (197) Vandalism – robbery (security); (198) Monopoly; (199) Necessary variations; (200) Unavoidable changes in construction/execution methods; (201) Bribes (kickbacks) & personal interest (prejudices) "corruption"; (202) Fraudulent practices; (203) Poor government judicial system for construction dispute settlement; (204) Warlords influence; (205) Nepotism; (206) Shortage in equipment/insufficient numbers; (207) Lack of skilled operators for specialized equipment; (208) Equipment productivity (efficiency); (209) Equipment failure (breakdown); (210) Slow delivery (mobilization) of equipment; (211) Lack of high-technology mechanical equipment; (212) Equipment allocation problems; (213) Tool availability; (214) Improper equipment; (215) Inadequate modern equipment; (216) Obtaining permits from municipality (government); (217) Excessive bureaucracy in project owned operation; (218) Building permits approval process; (219) Changes in laws and regulations; (220) Safety rules; (221) Occupational safety & health administration (OSHA) regulations; (222) Building regulations in coastal regions; (223) Coastal construction control line permit; (224) Florida administrative code; (225) Failure of RIBA plan of work application; (226) National flood insurance program; (227) Obtaining permits for laborers; (228) Building codes used in the design of the projects; (229) Permits (urban planning bureau & order of engineers) and access facilities; (230) Change orders by code change; (231) Regulations; (232) Discrepancy between design specification and building codes; (233) Environmental concerns and restrictions; (234) Issues regarding permissions/approval from other stakeholders; (235) Waiting instructions from consultant; (236) Delay of design submittal from consultant; (237) Incapable inspectors; (238) Insufficient inspectors; (239) Inflexibility of consultant; (240) Uncompromising attitude of inspector; (241) Inspection and testing procedures used in the project; (242) Waiting time for approval of tests and inspection; (243) Inspection delays (delay in performing inspection and testing by consultant); (244) Late in reviewing and approving design documents; (245) Delay in approving major changes in the scope of work by consultant; (246) Lack of experience of consultant in construction projects; (247) Inadequate project management assistance; (248) Consultant or architect's reluctance for change; (249) Lack of training personnel and management support to model the construction operation; (250) Judgment and experience of the involved people in estimating time and resources; (251) Overestimation/underestimation of the productivity; (252) Inadequate early planning of the project; (253) Preparation of scheduling networks and revisions by consultant while construction is in progress; (254) Quality assurance/control; (255) Unreasonable or unpractical initial plan; (256) Incompetence of planning and control from contractor staff; (257) Priority on construction time; (258) Ineffective planning and scheduling of project by contractor; (259) No planning before project starts; (260) Damage to structure/liquated damage; (261) Transportation delays; (262) Inadequate progress review; (263) Completeness & timeliness of project information; (264) Not property time decision; (265) Application of quality control based on foreign specifications; (266) U Improper or wrong cost estimation; (267) Delay in performing final inspection and certification by a third party; (268) Lack of program of works; (269) Poor professional construction management; (270) Date of notice to proceed; (271) Ambiguity in specifications & conflicting interpretation by parties; (272) Inconsistence of technical specifications; (273) Inadequate geotechnical investigations; (274) Customer/end-user related issues; (275) High turnover of skilled staff; (276) Inappropriate owner's capable representative management style; (277) Inefficient capability of contractor staff management; (278) Inadequate control procedures; (279) Shortage (availability) in construction materials; (280) Materials changes in types and specifications during construction; (281) Slow delivery of materials; (282) Damage of materials in storage; (283) Imported materials and plant items; (284) Low quality of construction materials; (285) Materials management problem; (286) Reworks due to defects in construction materials; (287) Delay in manufacturing special materials; (288) Unreliable suppliers; (289) Poor procurement of material; (290) Lack of water for hydrostatic test; (291) Poor material handling on site; (292) late in selection of finishing materials due to availability of many types in market; and (293) Inappropriate/misuse of material.

6. Questionnaire survey

A number of 500 questionnaires were distributed and were filled out by three hundred eighty-nine (389) highly experienced construction professionals including technical consultants, main contractors and sub-contractors, and site/design engineers with a response rate of 78 %. One hundred eighty-six (186) valid responses were obtained. The collected data were analyzed through Relative Importance Index (RII) method. The analysis included ranking the different causes according to the relative importance indices. The analysis revealed the most contributing factors and categories causing delays.

Road projects in Egypt have four participants: (1) The government as the owner; (2) A consultant team usually from the faculty of engineering as the consultant; (3) Directorate of road and transportation as the supervisor on the implementation; and (4) Contractors of road projects as the real implement. The respondents samples had the three last participants excluding the owner (the government) with the one point of view.

Respondents profiles are included in the following tables. Table 4 shows the profession of the respondents, consultants, contractors or site/design engineers. Table 5 shows the gender of the respondents. Table 6 shows the years of experience of the respondents.

6.1. Analysis and discussions

The causes of delay in road construction projects in Egypt will be looked at from different perspectives. It will examine the data provided by respondents and that will be the basis for case selection.

Table 4 Profession of respondent.

S/N	Professional cadre of respondents	No of respondents	Percentage (%)
01	Consultants	36	19.35
02	Site/design engineers	19	10.20
03	Contractors	131	70.45
Total		186	100%

Table 5 Gender of respondent.

S/N	Professional cadre of Respondents	Male	Female
01	Consultants	33	3
02	Site/design engineers	102	29
03	Contractors	14	5
Total		149	37
Percentage (%)		80.10	19.90

Table 6 Respondents years of experience.

S/N	Years of experience	No of respondents	Percentage (%)
01	Less than 5 Years	38	20
02	5:10 Years	41	22
03	10:20 Years	57	31
04	20:30 Years	32	17
05	Above 30 Years	18	10
Total		186	100%

6.1.1. Ranking of delay causes

To provide a degree of importance for each delay cause, an important index was calculated in the same way as shown in Eq. (1). This formula was used by Aibinu and Odeyinka [4] and Doloi et al. [15].

$$\mathbf{RII}_{\mathbf{k}}^{\mathbf{i}} = \frac{\sum_{i=1}^{5} W}{A \times N} \tag{1}$$

where $\mathbf{RII}_{\mathbf{k}}^{\mathbf{i}}$ is the yearly experience of **R**elative **I**mportance **I**ndex of each factor for each group of respondents; W is the weighting given to each factor by the respondents (ranging from 1 to 5); A is the highest weight (i.e. 5 in this case); and N is the total number of respondents.

Overall **R**elative **I**mportance **I**ndex "**ORII**" for each factor of all respondents representing can be calculated by Eq. (2) This formula was used by Aziz [12] and the formulation consists of three groups as follows: "Consultants group ($i = 3$)"; "Site/design Engineers group ($i = 2$)"; and "Contractors group ($i = 1$)" considering all years of experiences of respondents together; which is calculated as a weighted average by RII from Eq. (1).

$$\mathbf{ORII} = \sum_{i=1}^{i=3} \frac{i}{6} \times \left[\frac{\sum_{k=1}^{k=K} (k \times \mathrm{RII}_{k}^{i})}{\sum_{k=1}^{k=K} (k)} \right] \tag{2}$$

where **ORII** is the weighted **O**verall **R**elative **I**mportance **I**ndex for each factor; which is calculated based upon total years of experiences of all grouped respondents together; k is the number that represents' years of experience of grouped respondents (from first year of experience $k = 1$ to last year of experience $k = K$); i is the type of grouped respondents; and RII_{k}^{i} is the yearly experience percentage of Relative Importance Index of each factor; which is calculated separately for corresponding year (k) of grouped respondents experience and calculated by Eq. (1). The causes are arranged in ascending order of ranks, and causes with highest ORII or rank 1 indicate that it has the maximum impact on the delay while the least rank indicates that it has the least impact on delay.

6.1.1.1. Analysis of overall results. Financial problems, shortages in equipment, construction materials, skilled operators, inadequate experiences, reworks, changes or errors in design, delays in design submittal, soil and underground problems in investigation or management or expropriation, physical obstructions are the reasons for delay according to the questionnaire results. The cause (conflict, war, revolution, riot and public enemy) with revolution as in the 25 January revolution in Egypt made it to be from the top twenty causes of delay unlike the majority of the researches which have no weight. Showing these causes to be the most important 20 causes of all 293 causes in Table 7.

Working relationships have almost no effect on delay, and workers personal health, culture, religion or nationality, segmentation of lands, flood program, coastal control line permit, bankers policy, holidays are causes which do not exist or do not have a presence in the real road project in Egypt which is Consistent with road project circumstances in Egypt as shown in Table 8 for the least 20 time delay causes.

6.1.1.2. Analysis of delay groups according to overall results. The groups of delay causes were analyzed based on the overall results. The group importance index was calculated as the average of the importance indices for the delay causes in the groups. The ranked groups of delay causes and their corresponding importance index are shown in Table 9 showing the equipment related group to be the first group affecting the delay and the rules and regulations group to be the last affecting delay.

6.1.1.3. Analysis of delay causes according to each parties result. In order to analyze the delay causes by each party independently. The 19 contractors, 36 consultants and 131 site/design engineer data were separated and analyzed individually by calculating the importance index. The most important 20 causes organized by each party is shown in Tables 10 and 11 showing the importance index of each cause and the rank of the top ten causes and the least ten causes in the overall results .

6.1.1.4. Analysis of groups according to each parties results. The groups of delay causes were analyzed based on each parties response. The group importance index was calculated for each party separately. Table 12 shows the ranking of the three parties view for the groups importance index.

6.1.1.5. Ranking of delay causes under each group for overall results.

- *Equipment group*

Equipment group is ranked the first group affecting delay for the overall results as shown in Table 9. Under the equip-

Table 7 Overall RII and ranking of top 20 time delay causes.

Rank	Group ID	Delay cause description	Related group item	Overall Relative Importance Index (ORII)
01	F1	Owner financial problems/client finance/economic ability for the project	Financing	0.886
02	E1	Shortage in equipment/insufficient numbers	Equipment	0.824
03	C11	Inadequate contractor experience (work) causing error	Contractor	0.816
04	M1	Shortage (availability) in construction materials	Material	0.814
05	E4	Equipment failure (breakdown)	Equipment	0.813
06	D1	Design errors made by designers (due to unfamiliarity with local conditions and environment)	Design	0.810
07	S2	Mistakes in soil investigation	Site	0.808
08	C2	Poor subcontractor performance/delays	Contractor	0.805
09	D17	Rework due to change of design or deviation order	Design	0.804
10	C7	Poor site management and supervision by contractor	Contractor	0.797
11	D11	Wrong or improper (poor) (inappropriate) design	Design	0.797
12	S24	Faulty soil investigation paper	Site	0.795
13	E2	Lack of skilled operators for specialized equipment	Equipment	0.794
14	O20	Slow land expropriation due to resistance from occupants	Owner	0.791
15	E14	Conflict, war, revolution, riot, and public enemy	External	0.791
16	M8	Reworks due to defects in construction materials	Material	0.788
17	O4	Design changes by owner or his agent during construction	Owner	0.783
18	E13	Physical obstructions	External	0.781
19	C2	Delay of design submittal from consultant	Consultant	0.781
20	S6	Unexpected underground condition	Site	0.780

Table 8 Overall RII and ranking of least 20 time delay causes.

Rank	Group ID	Delay cause description	Related group item	Overall Relative Importance Index (ORII)
274	E18	Necessary variations	External	0.597
275	C27	Previous working relationship of owner	Contractual relationship	0.596
276	C14	Unfair subcontractor relationships with employees	Contractual relationship	0.591
277	C15	Previous working relationships of consultant	Contractual relationship	0.591
278	R8	Coastal construction control line permit	Rules & Regulations	0.590
279	E6	Problems with neighbors	External	0.584
280	P6	Function or end use (office, residential, industrial)	Project	0.580
281	L9	Staffing problems	Labor	0.578
282	O1	The unavailability of financial incentives for contractor to finish ahead of schedule	Owner	0.573
283	F9	Changing of bankers policy	Financing	0.572
284	L4	Labor injuries	Labor	0.563
285	C13	Laborers personal conflict	Contractual relationship	0.560
286	E15	Public holidays	External	0.542
287	E7	Infectious disease	External	0.514
288	E8	Segmentation of the west bank and limited movement between areas	External	0.481
289	R11	National flood insurance program	Rules & Regulations	0.472
290	E4	Social, religions and cultural factors	External	0.462
291	L3	Nationality of laborers	Labor	0.447
292	R10	Failure of RIBA plan of work application	Rules & Regulations	0.443
293	R9	Florida administrative code	Rules & Regulations	0.431

Table 9 Groups importance index for overall results.

Rank	Delay group	Group importance index
01	Equipment related group	0.752
02	Design related group	0.739
03	Contractor related group	0.728
04	Material related group	0.723
05	Contract related group	0.718
06	Consultant related group	0.707
07	Financing related group	0.699
08	Site related group	0.698
09	Scheduling and Controlling related group	0.686
10	Owner related group	0.680
11	Contractual relationship related group	0.668
12	Labor related group	0.665
13	Project related group	0.660
14	External related group	0.641
15	Rules & regulations related group	0.633

Table 10 Ten most important causes by project parties.

Rank	Consultant	ORII	Contractor	ORII	Site/design engineer	ORII
01	Owner financial problems/client finance/ economic ability for the project	0.839	Owner financial problems/client finance/ economic ability for the project	0.947	Owner financial problems/client finance/economic ability for the project	0.890
02	Conflict, war, revolution, riot, and public enemy	0.817	Cash- flow problems during construction	0.884	Shortage in equipment/insufficient numbers	0.837
03	Slow land expropriation due to resistance from occupants	0.800	Unexpected underground condition	0.853	Inadequate contractor experience (work) causing error	0.834
04	Mistakes in soil investigation	0.794	Faulty soil investigation paper	0.853	Equipment failure (breakdown)	0.831
05	Difficulty of coordination between various parties (contractor, subcontractor, owner, consultant) working on the project	0.794	Mistakes in soil investigation	0.842	Rework due to change of design or deviation order	0.829
06	Poor subcontractor performance/delays	0.789	Poor subcontractor performance/delays	0.832	Design errors made by designers (due to unfamiliarity with local conditions and environment	0.826
07	Unexpected underground condition	0.789	Lack of experience of consultant in construction projects	0.832	Shortage (availability) in construction materials	0.823
08	Shortage in equipment/insufficient numbers	0.789	Physical obstructions	0.821	Wrong or improper (poor) (inappropriate) design	0.811
09	Design changes by owner or his agent during construction	0.778	Obtaining permits from municipality (government)	0.821	Poor site management and supervision by contractor	0.809
10	Changes in clients requirements	0.778	Excessive bureaucracy in project owned operation	0.821	Lack of skilled operators for specialized equipment	0.809

ment group, 10 causes are listed. Table 13 shows the top five affecting causes on delay in the equipment group.

- *Design group*

Design group is ranked the second group affecting delay for the overall results as shown in Table 9. Under the design group, 26 causes are listed. Table 14 shows the top five affecting causes on delay in the design group.

- *Contractor group*

Contractor group is ranked the third group affecting delay for the overall results as shown in Table 9. Under the contractor group, 20 causes are listed. Table 15 shows the top five affecting causes on delay in the contractor group.

- *Material group*

Material group is ranked the fourth group affecting delay for the overall results as shown in Table 9. Under the material group, 15 causes are listed. Table 16 shows the top five affecting causes on delay in the material group.

- *Contract group*

Contract group is ranked the fifth group affecting delay for the overall results as shown in Table 9. Under the contract

Table 11 Ten least important causes by project parties.

Rank	Consultant	ORII	Contractor	ORII	Site/design engineer	ORII
284	Inadequate progress review	0.561	Previous working relationship of owner (275)	0.505	Laborers personal conflict (285)	0.557
285	Lack of trade's skill	0.556	Necessary variations	0.505	Labor injuries	0.550
286	Infectious disease	0.544	National flood insurance program	0.484	Public holidays	0.533
287	Coastal construction control line permit	0.528	Public holidays	0.474	Infectious disease	0.516
288	National flood insurance program	0.494	Failure of RIBA plan of work application	0.453	Segmentation of the west bank and limited movement between areas	0.496
289	Failure of RIBA plan of work application	0.489	Infectious disease	0.442	Social, religions and cultural factors	0.476
290	Segmentation of the west bank and limited movement between areas	0.478	Nationality of laborers	0.421	National flood insurance program	0.464
291	Nationality of laborers	0.472	Social, religions and cultural factors	0.421	Nationality of laborers	0.444
292	Florida administrative code	0.450	Florida administrative code	0.389	Florida administrative code	0.432
293	Social, religions and cultural factors	0.433	Segmentation of the west bank and limited movement between areas	0.379	Failure of RIBA plan of work application	0.429

Table 12 The ranking of the groups according to each party.

Rank	Consultant	ORII	Contractor	ORII	Site/design engineer	ORII
1	Equipment related cause	0.716	Financing related cause	0.716	Equipment related cause	0.760
2	Contract related cause	0.716	Equipment related cause	0.765	Design related cause	0.752
3	Material related cause	0.707	Consultant related cause	0.756	Contractor related cause	0.740
4	Design related cause	0.702	Site related cause	0.724	Material related cause	0.731
5	Contractor related cause	0.701	Design related cause	0.717	Contract related cause	0.721
6	Contractual relationships related cause	0.680	Contract related cause	0.704	Consultant related cause	0.708
7	Consultant related cause	0.679	Material related cause	0.700	Financing related cause	0.705
8	Site related cause	0.676	Contractor related cause	0.696	Site related cause	0.701
9	Owner related cause	0.675	Scheduling and controlling	0.678	Scheduling and controlling	0.690
10	Scheduling and controlling	0.675	Owner related cause	0.645	Owner related cause	0.686
11	Financing related cause	0.668	Labor related cause	0.637	Labor related cause	0.671
12	Labor related cause	0.661	Contractual relationships related cause	0.635	Contractual relationships related cause	0.669
13	Project related cause	0.658	Rules & regulations related cause	0.633	Project related cause	0.666
14	External related cause	0.634	Project related cause	0.625	External related cause	0.646
15	Rules & regulations related cause	0.624	External related cause	0.618	Rules & regulations related cause	0.636

Table 13 Top 5 ranking of causes under equipment group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
2	Equipment	E1	Shortage in equipment/insufficient numbers	0.824
5	Equipment	E4	Equipment failure (breakdown)	0.813
13	Equipment	E2	Lack of skilled operators for specialized equipment	0.794
24	Equipment	E3	Equipment productivity (efficiency)	0.776
56	Equipment	E9	Improper equipment	0.746

Table 14 Top 5 ranking of causes under design group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
6	Design	D1	Design errors made by designers (due to unfamiliarity with local conditions and environment)	0.810
9	Design	D17	Rework due to change of design or deviation order	0.804
11	Design	D11	Wrong or improper (poor) (inappropriate) design	0.797
21	Design	D26	Change in drawings & specifications	0.778
27	Design	D13	Inadequate experience of designers	0.772

Table 15 Top 5 ranking of causes under contractor group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
3	Contractor	C11	Inadequate contractor experience (work) causing error	0.816
8	Contractor	C2	Poor subcontractor performance/delays	0.805
10	Contractor	C7	Poor site management and supervision by contractor	0.797
22	Contractor	C5	Rework because of errors during construction	0.777
45	Contractor	C12	Non-adherence of material specifications provided by client	0.757

Table 16 Top 5 ranking of causes under material group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
4	Material	M1	Shortage (availability) in construction materials	0.814
16	Material	M8	Reworks due to defects in construction materials	0.788
31	Material	M2	Materials changes in types and specifications during construction	0.769
40	Material	M6	Low quality of construction materials	0.760
43	Material	M3	Slow delivery of materials	0.759

group, 13 causes are listed. Table 17 shows the top five affecting causes on delay in the contract group.

- *Consultant group*

Consultant group is ranked the sixth group affecting delay for the overall results as shown in Table 9. Under the consultant group, 14 causes are listed. Table 18 shows the top five affecting causes on delay in the consultant group.

- *Financing group*

Financing group is ranked the seventh group affecting delay for the overall results as shown in Table 9. Under the financing group, 15 causes are listed. Table 19 shows the top five affecting causes on delay in the financing group.

- *Site group*

Site group is ranked the eighth group affecting delay for the overall results as shown in Table 9. Under the site group, 27 causes are listed. Table 20 shows the top five affecting causes on delay in the site group.

- *Scheduling and controlling group*

Scheduling and controlling group is ranked the ninth group affecting delay for the overall results as shown in Table 9. Under the scheduling and controlling group, 30 causes are listed. Table 21 shows the top five affecting causes on delay in the scheduling and controlling group.

- *Owner group*

Owner group is ranked the tenth group affecting delay for the overall results as shown in Table 9. Under the owner group, 23 causes are listed. Table 22 shows the top five affecting causes on delay in the owner group.

- *Contractual relationships group*

Contractual relationships group is ranked the eleventh group affecting delay for the overall results as shown in Table 9. Under the contractual relationships group, 28 causes are listed. Table 23 shows the top five affecting causes on delay in the contractual relationships group.

- *Labor group*

Labor group is ranked the twelfths group affecting delay for the overall results as shown in Table 9. Under the labor group, 15 causes are listed. Table 24 shows the top five affecting causes on delay in the labor group.

- *Project group*

Project group is ranked the thirteenth group affecting delay for the overall results as shown in Table 9. Under the project group, 14 causes are listed. Table 25 shows the top five affecting causes on delay in the project group.

- *External group*

External group is ranked the fourteenth group affecting delay for the overall results as shown in Table 9. Under the external group, 24 causes are listed. Table 26 shows the top five affecting causes on delay in the external group.

- *Rules and regulations group*

Rules and regulations group is ranked the fifteenth (last) group affecting delay for the overall results as shown in Table 9. Under the rules and regulations group, 19 causes are listed. Table 27 shows the top five affecting causes on delay in the rules and regulations group.

6.1.2. Ranking of correlation

Two approaches are used to find the agreement between parties: Pearsons correlation coefficient among values of importance indices and Spearman's rank correlation coefficient among ranks, Abd El-Razek et al. [1], and the agreement

Table 17 Top 5 ranking of causes under contract group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
23	Contract	C13	No adherence to contract conditions	0.776
25	Contract	C7	Unrealistic (unreasonable) contract time (duration) & requirements imposed	0.774
37	Contract	C6	Unrealistic contract price	0.763
92	Contract	C2	Mistakes and discrepancies in contract documents	0.728
99	Contract	C1	Poor contract management	0.724

Table 18 Top 5 ranking of causes under consultant group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
19	Consultant	C2	Delay of design submittal from consultant	0.781
52	Consultant	C12	Lack of experience of consultant in construction projects	0.753
54	Consultant	C11	Delay in approving major changes in the scope of work by consultant	0.749
57	Consultant	C1	Waiting instructions from consultant	0.746
75	Consultant	C14	Consultant or architect's reluctance for change	0.737

Table 19 Top 5 ranking of causes under financing group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
1	Financing	F1	Owner financial problems/client finance/economic ability for the project	0.886
28	Financing	F2	Payment of completed work	0.771
50	Financing	F15	Late payment to subcontractor by the main contractor	0.754
60	Financing	F12	Material and labor wage escalation (inflation)	0.744
66	Financing	F7	Financing by contractor during construction	0.742

Table 20 Top 5 ranking of causes under site group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
7	Site	S2	Mistakes in soil investigation	0.808
12	Site	S24	Faulty soil investigation paper	0.795
20	Site	S6	Unexpected underground condition	0.780
41	Site	S4	Effects of subsurface conditions (e.g., soil. High water table, etc.)	0.759
42	Site	S27	Poor site layout	0.759

Table 21 Top 5 ranking of causes under scheduling and controlling group.

Overall rank	Delay group	No in group	Cause	ORII
30	Scheduling and Controlling	S11	No planning before project starts	0.769
59	Scheduling and Controlling	S20	Lack of program of works	0.745
77	Scheduling and Controlling	S18	Improper or wrong cost estimation	0.735
89	Scheduling and Controlling	S21	Poor professional construction management	0.729
90	Scheduling and Controlling	S29	Inefficient capability of contractor staff management	0.729

Table 22 Top 5 ranking of causes under owner group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
14	Owner	O20	Slow land expropriation due to resistance from occupants	0.791
17	Owner	O4	Design changes by owner or his agent during construction	0.783
29	Owner	O15	Improper selection of subsequent consultants	0.770
33	Owner	O5	Change orders by owner during construction (variation)	0.767
46	Owner	O17	Delay in material to be supplied by the owner	0.756

Table 23 Top 5 ranking of causes under contractual relationships group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
49	Contractual relationships	C5	Difficulty of coordination between various parties (contractor, subcontractor, owner, consultant) working on the project	0.755
82	Contractual relationships	C2	The conflict between contractor and other parties (consultant & owner)	0.731
84	Contractual relationships	C4	Poor organization of the contractor or consultant/inappropriate overall organizational structure linking to the project)	0.730
85	Contractual relationships	C28	Lack of responsibilities	0.730
108	Contractual relationships	C9	Insufficient communication between the owner and designer or other parties in design phases	0.718

Table 24 Top 5 ranking of causes under labor group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
39	Labor	L2	Labor skill	0.760
44	Labor	L14	Foreman incompetence	0.758
64	Labor	L1	Shortage of labor	0.743
68	Labor	L13	Low productivity level work	0.741
135	Labor	L11	Shortage of technical personnel/staff	0.704

Table 25 Top 5 ranking of causes under project group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
72	Project	P9	Improper project feasibility study	0.739
81	Project	P5	Unreasonable project time frame	0.732
112	Project	P3	Complexity of project	0.716
165	Project	P8	Ineffective delay penalties	0.689
192	Project	P10	Type of project bidding and award (negotiation, lowest bidder)	0.673

Table 26 Top 5 ranking of causes under external group for the overall results.

Overall rank	Delay group	No in group	Cause	ORII
15	External	E14	Conflict, war, revolution, riot, and public enemy	0.791
18	External	E13	Physical obstructions	0.781
62	External	E20	Bribes (kickbacks) & personal interest (prejudices) "corruption"	0.744
121	External	E22	Poor government judicial system for construction dispute settlement	0.711
146	External	E16	Vandalism – robbery (security)	0.699

Table 27 Top 5 ranking of causes under rules and regulations group.

Overall rank	No in group	Cause	ORII
26	R1	Obtaining permits from municipality (government)	0.774
35	R3	Building permits approval process	0.765
104	R2	Excessive bureaucracy in project owned operation	0.723
129	R17	Discrepancy between design specification and building codes	0.708
138	R4	Changes in laws and regulations	0.703

was calculated in a manner similar to that in the study of Abd El-Razek et al. [1].

Spearman's rank correlation coefficient is a nonparametric measure of statistical dependence between two variables. It assesses how well the relationship between two variables can be described using a monotonic function. If there are no repeated data values, a perfect Spearman's correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. The value of the Spearman's rank correlation coefficient ranges from +1 (perfect positive correlation), to 0 (no correlation), to −1 (perfect negative correlation). The Eq. (3) is used in the analysis.

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)} \tag{3}$$

where ρ = Spearman's rank correlation coefficient; d = difference between the ranks indicated by two parties; and n = number of records as shown in Table 28.

Results show the agreement between the three parties to be a high agreement between consultant and site/design engineer with a coefficient (0.838) followed with a coefficient (0.783) for the agreement between the contractors and the engineers and last a coefficient (0.666) for the agreement between the contractor and the consultant, as shown in Table 29.

7. Proposed model

It might be noted that all these factors are originated by its category group, and this is expected since each party is trying to blame the other for causing delays. It was desired to compare the strength or the importance of each category; the weighted average value of category causes was calculated. The results are tabulated in Table 30 by using priority rule formula as shown in Eq. (4) which used by Aziz [12] is as follows:

$$\mathbf{ERII} = \left(\frac{\sum_{n=1}^{n=N} (P_n \times \mathrm{ORII}_n)}{\sum_{n=1}^{n=N} (P_n)} \right) \tag{4}$$

where **ERII** is the weighted **E**quivalent **R**elative **I**mportance **I**ndex per category; ORII_n is the weighted **O**verall **R**elative **I**mportance **I**ndex per factor of specific category; which is calculated based upon total years of experiences of all respondents; n is the number represents the factor number in the related category (from first factor of category $n = 1$ to last factor of category $n = N$); and P_n is the priority weight of the studied factor.

It is clear that the results of the 15 categories are almost consistent, where the categories are ranked from top to bottom as shown in Table 30. From previous analysis of collected data

Table 28 An example for calculations of Spearman's coefficient.

No	*Cause*	*Rank of site/design engineer*	*Rank of contractor*	*d*	d^2
1	Owner financial problems / client finance /economic ability for the project	1	1	0	0
2	Payment of completed work	24	20	4	16
3	Delays in contractors progress payment by owner	163	21	142	20164
4	Partial payments during construction / financing	199	112	87	7569
5	Delay in honoring payment certificates	273	263	10	100
↓	↓	↓	↓	↓	↓
289	Poor procurement of material	142	182	-40	1600
290	Lack of water for hydrostatic test	214	208	6	36
291	Poor material handling on site	190	183	7	49
292	Late in selection of finishing materials due to availability of many types in market	222	244	-22	484
293	Inappropriate / misuse of material	98	94	4	16
$\sum d^2$					910988
$6\sum d^2$					5465928
Since n = 293					
n^3 =					25153757
n^3 - n =					25153464
$6\sum d^2 / (n^3 - n)$ =					0.2173032
$1 - (6\sum d^2 / (n3 - n))$ =					0.7826968

Table 29 The Spearman's coefficient of agreement on delay causes and groups from results.

Parties	Spearman's coefficient of agreement on delay causes	Spearman's coefficient of agreement on delay groups
Consultants and site/design engineers	0.838	0.868
Contractors and site/design engineers	0.783	0.800
Contractors and consultants.	0.666	0.607

Table 30 Equivalent average Relative Importance Index of category.

Rank	Category Item	Equivalent Relative Importance Index Eq. (4)
01	Equipment related group	0.851
02	Design related group	0.838
03	Contractor related group	0.827
04	Material related group	0.822
05	Contract related group	0.817
06	Consultant related group	0.806
07	Financing related group	0.798
08	Site related group	0.797
09	Scheduling and Controlling related group	0.785
10	Owner related group	0.779
11	Contractual relationship related group	0.767
12	Labor related group	0.764
13	Project related group	0.759
14	External related group	0.740
15	Rules & Regulations related group	0.732

from road construction projects field, it will be predicted approximately the road construction actual duration of any new construction project before construction using Eqs. (5) and (6) as follows:

$$\mathbf{PDC} = 1 + \left(\frac{\sum_{j=1}^{j=4} (d_j \times \mathbf{ERII_j})}{\sum_{j=1}^{j=4} (\mathbf{ERII_j})} \right) \quad (5)$$

$$\mathbf{PAD} = \mathbf{PDC} \times \mathbf{PSD} \quad (6)$$

where **PDC** is the **P**redicted **D**elay **C**oefficient; $\mathbf{ERII_j}$ is the weighted **E**quivalent **R**elative **I**mportance **I**ndex per category; d_j is the each category impact according to the studied road construction project and it ranged between 0.00 and 1.00; **PAD** is the **P**redicted **A**ctual **D**uration of the studied road construction project; and **PSD** is the total **P**lanned **S**cheduled **D**uration before constructing the studied road construction project.

8. Case study

8.1. Basic information

Within the framework of the development taking place in the Governorate of Alexandria, implementation of the first phase of project development through Mahmudiya is an important hub and necessary to resolve the dense traffic jams in the governorate. Information about the project is mentioned as follows. (1) Project description: The first stage of the development of Mahmudiya canal road from Moharram Bey Bridge to Awayed Bridge with a length of 10 km. (2) Project information: (A) The project is working so that the seaside of the road will be the direction of traffic with one component of 4-lane so that it is the downward trend from the Bridge Awayed in the direction of Bridge Moharram Bey and the wild side direction of traffic one component of 4-lane to be the trend-fated from the Bridge Moharram Bey until Bridge Awayed. (B) The road transmits traffic from the Maritime direction to the other direction by 11 Bridge back to back to facilitate the traffic. The project consists of different lengths of bridges on the width of the waterway of Mahmudiya canal starting from 19.5 m to 46.56 m and width 22.05 m. (3) Aim of the project: The project aims to the re-planning and development of hub Canal Mahmudiya to turn it into a hub arterial major distributor with high efficiency and without any intersections and a width of 4 lanes of traffic in each direction to accommodate 20% of the traffic on the Corniche Road and Alhurria road and service population density in Smouha and the city center and reduce loads on the axes entry and exit to and from the Corniche (the Suez Canal – 15 May – Victor Emmanuel). It also leads to the development of a comprehensive urban for Alexandria interface on Canal Mahmudiya and bordering urban areas. (4) Project Details: (A) The owner: Alexandria Governorate; (B) The consultant: Engineering Center – Alexandria University – Faculty of Engineering; (C) The contractor: Arab Contractors administration of internal roads; (D) The supervision authority: Directorate of road and transportation in Alexandria; (E) The contract: An assigning order was Released for Arab Contractors in date 15/11/2009. A contract was signed between Alexandria Governorate and Arab Contractors administration of internal roads in 14/12/2009; (F) The project duration: The Expected project duration was 18 months, the expected end date was 14/6/2011 and actual end date was 14/6/2012; and (G) The value of the project: The estimated value of the project was 120 million pounds while the actual value of the project was 187.04 million pounds.

This project consists of several types of works: (1) Surveying works, (2) Sanitary works, (3) Road works, (4) Electrical works, (5) Agricultural works and (6) Bridge works. In this paper road works only were studied as the paper is concerned with causes affecting delays in road construction projects.

8.2. Reasons for delays

The duration of the contract was 18 months and the Business volume port-to-date is 116 million pounds with 55 million for road works only. The project was delayed 12 months over estimated period for the following reasons: (1) The Signal Corps stopping work until the establishment of a new path for cables of Signal Corps; (2) Stopped working in more than one area because of the gas projects, water projects and electricity projects; (3) Getting started in extension of international cables, which led to stopping of work in one side totally; (4) Business

interruption as a result of the events of the January 25 revolution; (5) Frequent attacks on workers by the people; and (6) Waste placed on both sides of the axis of Mahmudiya canal and along the path from the outlaws because of the lack of security presence.

8.3. Equivalent causes

The cause owner financial problems/client finance/economic ability for the project which is ranked the first from the research's result has almost no effect in this case because the government contracted for this project with an assigning order contract which finance is present before making the assigning order.

If the 293 causes are divided into 5 zones as in the five-point Likert scale ranging from 1 (not important) to 5 (extremely important) so it could be considered that each 58.6 causes are a different zone ranging from not important to extremely important. Based on that the ranking of the cause is as follows in the Table 31.

As for the first three causes referring to stop working because of establishment of a new path for cables of Signal Corps or stop working because of gas or water or electricity projects these reasons are consistent with the delay cause (**Interfering of other projects**) ranked no 231 for overall causes, 217 from consultants view, 231 from contractors view and 229 from site/design engineers view. The results of the questionnaire indicate that this cause is in the zone of Somewhat important causes which cannot be applied to the case of study that was considered from the top causes affecting the delay.

As for the cause no 4 regarding 25 January revolution and interruption of work due to it this reason is consistent with the delay cause (**Conflict, war, revolution, riot, and public enemy**) ranked no 15 from overall causes, 2 from consultants view, 41 from contractors view and 23 from site/design engineers view. This result is somehow consistent with the questionnaires result as it is from the top twenty causes of delay from the overall results.

As for the reason number 5 about frequent attack on workers and the reason number 6 regarding waste placed on both sides of the axis of Mahmudiya canal and along the path of the outlaws which was referred to the lack of security presence. These two reasons can be analyzed into more than the security presence. These reasons can be referred to culture of people throwing there wastes in the public roads, Poor site management and supervision by contractor banning any one from throwing things in their site but that can be explained as the site is almost 10 km which can be so hard to monitor and manage but is still the contractor's responsibility, Inconvenient site area which is too big in this case, and environmental concerns and restrictions which do not apply fines for throwing wastes in the street. Besides absence of security, in the following Table the equivalent causes and there rankings for overall and each parties view are shown and there place in the importance zone.

From Table 32 the cause equivalent to the case study within the top 20 causes is Poor site management and supervision by contractor.

Figs. 2 and 3 are examples for the delay because of interfering from the electrical projects and the signal corp projects and wastes thrown on the sides of the canal making obstructions to work causing delay.

Table 31 Importance zone for the delay causes.

Ranks of causes	Zone
From ranking 1–59	Extremely important
From ranking 59–117	Important
From ranking 117–176	Moderate
From ranking 176–234	Somewhat important
From ranking 234–293	Not important

8.4. Case study discussion and conclusion

From studying this project and analyzing the data, it was found that total planned project duration before start date was 18 working months, and total actual project duration after completion was 30 months, while total actual project duration is before constructing the studied project and after knowing the delay causes to calculate the predicted project duration from the following formulas:

$$\mathbf{PDC} = 1.7098 \tag{5*}$$

$$\mathbf{PAD} = 18 * 1.7098 \approx 30.77\,\text{Months} \tag{6*}$$

From analyzing and studying the studied road construction project, it was found that there is a variation between actual project duration increased than planned project duration by 66.67% and predicted actual project duration increased than

Table 32 Causes convenient to the case of study and their ranks.

N/S	Cause	Ranking				Zone of importance
		Overall results	Consultant view	Contractor view	Site/design engineer view	
1	Vandalism-robbery (security)	146	147	166	145	Moderate important
2	Social, religions and cultural factors	290	293	291	289	Not important
3	Poor site management and supervision by contractor	10	24	22	9	Extremely important
4	Inconvenient site area	222	247	237	210	Somewhat important
5	Environmental concerns and restrictions	241	239	252	230	Not important

Figure 2 Example of electricity projects causing delays.

Figure 3 Example of wastes on Mahmudiya canal sides.

planned project duration by 70.94% with accepted variance +0.77 months or +2.57%. Reasons of such increase, which are found the analyzing forms in questionnaires, are the same.

9. Conclusion

A study in palestine by Mahamid et al. [42] highlighted the following causes to be the top 5 causes from total 52 causes affecting delays in road construction projects: (1) Political situations; (2) Segmentation of the west bank and limited movements between areas; (3) Award project to lowest bid price; (4) Progress payment delay by owner; and (5) Shortage of equipment. These top causes identified for delay of road projects in palestine are ranked 195, 288, 192, 152 and 2 respectively from the total 293 cause that were studied in this research, and only the shortage of equipment is ranked to be from the top 5 causes in the two studies, meaning that for the same type of construction the top delay causes differ from a country to another.

The ranking of the top five groups from total 8 groups was as follows: (1) Project group; (2) Owner group; (3) Contractors group; (4) Consultants group; and (5) Design group.

These groups are ranked 13, 10, 3, 6, 2 from total 15 group which have only contractors group and design group to be from the first groups affecting delays. Questionnaire surveys using randomly sampled responses and analysis of data obtained from the responses is the approach taking by most researches.

Each study has different causes with different numbers and different groups with different numbers causing different ranking for causes and groups. Causes and groups causing delays are country, location and project specific and there are no root causes that can be taking for granted to be the most effective or the least effective delay causes.

The review findings show that the group and cause ranking differs based on the location between Egypt and Palestine. Sambasivan and Soon [53], Głuszak and Leśniak [21] stated that ''The effects of delays in construction projects can be country specific" whereas other studies has proven that project characteristics may even be region-specific and that none of the studies is comparable to any other and each study has different rankings for the causes and the groups which is this research's finding too.

The first step in reducing delays in road construction is to understand the root causes of the delay. The objective of this

research was to identify the main causes of delay that affect road projects in Egypt. A literature review and expert interviews were conducted to identify the causes of delay. A compiled list of 293 causes given the combination of causes and groups in almost every construction project, was obtained and subjected to further quantitative evaluation in a questionnaire survey to confirm the causes and identify the most important causes of project delay. The most important causes affecting delay identified by the survey by using questionnaire that was conducted and the results were analyzed for the overall view and for each of the three parties who participated in the questionnaire (consultants, contractors, site/design engineers) separately to make an overall view of the causes of delay in road projects in Egypt.

From overall results it was found the owner financial problems was considered the first cause affecting delay in road projects in Egypt which in this case is considered the government, in comparison this cause was not included in the causes affecting delay in the case of study because in assigning contracts the funds of the project is already presence for that project. Generally large road projects are assigned to large contractors but the daily road projects with low funds face the problems of finance. Shortage in equipment, inadequate contractor experience, shortage in materials, equipment failure, design errors, mistakes in soil investigations, poor subcontractor performance, rework due to change of design, poor site management and supervision by contractor which was considered from the delay cases in the case of study are the most prominent delay causes for overall results.

From consultants view it was found the consultants ranked the owner financial problems to be the first cause affecting delay following it with conflict, war, revolution, riot and public enemy and this cause was ranked high only by the consultant which is a real fact going on in Egypt nowadays and has a big effect. Difficulty in coordination between different parties was ranked high only by the consultant who is a neutral party with no interest showing the compatibility between parties to be a difficult thing to happen. Also the cause of changes in clients requirements was given a high rank from consultants view.

From contractors view it was found that contractors also ranked the owner financial problems to be the first cause affecting delay following it by cash-flow problems during construction and the cause payment of completed work ranked from the top delay causes, confirming the issue of funds that affect the contractor. Lack of experience of consultant in construction projects was given a high rank from the contractors view blaming consultants for delays. From the top ranks are obtaining permits from municipality, excessive bureaucracy in project owned operation and building permits approval process which is the case of Egypt as the government has a routine which causes delay.

From site/design engineer's view: Site/design engineers like the two other parties ranked the owner financial projects to be the first cause affecting delay. Engineers gave the causes that appear in site a high rank like shortages in equipment, materials and skilled operators, site management and supervision, contractors experience or subcontractors performance, mistakes in soil investigation or faulty soil report. And the causes connected to design like rework due to change of design, design errors made by designers, wrong or improper design, delay of design submittal from consultant, design changes by owner or his agent during construction was within the top delay causes from site/design engineers view.

Site/design engineers who were a new participant in the questionnaire respondents none of the reviewed literature took their view in the questionnaire conducted in the research the previous findings confirm the expression giving to those engineer's (site/design) as those engineer's are either in site as supervisors or in office as designer and there view was neglected.

From the overall results found in the questionnaire the equipment group was ranked the first group affecting delays in the road projects in Egypt since the equipment used in road pavements are heavy equipment and pricey so they are not available to most contractors or subcontractors who eventually do the work so insufficient numbers or failure there (breakdown) with no maintenance is a real problem facing road projects in Egypt followed by the design group which is repeated in some cases because of designer's error, followed by contractors group as the first responsible parties group of the three common parties (owner, consultant and contractor), then materials group with its own problems of fluctuation prices or availability or quality, and contract group with non-adherence to contract condition or type in Egypt and the awarding of the project to the lowest bid price.

It appears to be a great agreement on delay causes between consultants and site/design engineer with the Spearman's correlation coefficient equals (0.838) almost reaching the total agreement (1). The same with a big degree of agreement (0.783) between contractors and site/design engineer and finally a somehow low agreement between contractors and consultants with a coefficient (0.666) on the overall results. The correlation between research's result and other results.

Finally, It was concluded that: (1) The Questionnaire surveys were used in the research and feasible method is taken into consideration for getting best results by using random samples and is the approach taken by most researches; (2) There are no root causes that can be taken for granted to be the most effective or the least effective delay causes; (3) None of the studies is comparable to another; and (4) Delay causes are specified according to country or location of the project or the type of the project.

10. Recommendations

An overview of the work of this paper can be accessed with the following recommendations based on the top results: (1) The owner financial problems make it important to pay the contractor's dues on time to make it easy the contractors ability to finance the work; (2) Shortage in equipment makes it important to study the availability of the construction equipment needed whether it is for road construction or any other type of construction; (3) Inadequate contractor experience (work) causing error makes it necessary to Choose a contractor with a good reputation and sufficient experience in the field of work; (4) Shortage in construction materials like Bitumen in the road constructions can cause a big delay especially when the shortage is because of the prices fluctuation. Prices differences should be considered in the contracts; (5) Equipment failure (breakdown) that can due to lack of maintenance, insufficient workers or high prices of the equipment which make contractors depend on a certain equipment for a long

time. Qualified workers should be assigned for dealing with equipments, having a regular maintenance (rare in Egypt) and assigning contractors with sufficient equipments; (6) Design errors made by designers due to unfamiliarity with local conditions and environment make it important for owner to employ experienced designers capable of adjusting all conditions with there design; (7) Soil investigation is the first step in decision of the design of road with traffic capacity, loads on road, number of layers of pavement. An appropriate Laboratory should be chosen; (8) Poor subcontractor performance delays so choosing experienced subcontractors with good reputation is necessary; (9) Rework due to change of design or deviation order makes it helpful to settle on the design and have the final approval of achieving the owner's demand and the contractors capability of work; and (10) Poor site management and supervision by contractor There is a need for contractor to employ experts in management or improving the abilities of engineers responsible of management and supervision of site by Training courses.

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