Analogy-Based Ranking of Delay Causes: An Outlook for Future Projects

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Abstract

Business competition has intensified in many world countries. With such increasingly competitive environment, companies –including those operating in the construction industry– need to seek opportunities outside their home market. Recent construction industry statistics show this trend to be on the rise, despite the increased level of uncertainty that comes along. With an aim to help Egyptian contractors expand their business, the paper presents a study on predicting the causes of schedule delay in potential out-of-country projects, especially in politically unstable and/or economically underdeveloped countries. Novelty of the research comes from developing a "ranked" project-specific list of schedule delay causes for any "future" project into consideration. Development of such list depends on partial analogies with past project cases, whether completed by the company or others working in the industry. For a new project in a given country/region, the list conveys the potentially significant causes of delay specific to the project under study, while taking into account the dominant country and project conditions. The paper provides an overview of the research methodology and study implementation. The research utilises a global list of schedule delay causes, created after scanning a large pool of completed projects in Africa, the Middle East, and the Far East. A process is then devised to handle both quantitative and qualitative data sources. The qualitative approach is adopted in case of incomplete, inaccessible, or unreliable past project records. In the latter case, knowledge of the experts who participated in these projects was used. Finally, means to merge the outcomes of both quantitative and qualitative analyses were sought. The paper also details the indexing system used for identifying the partial analogies between the new project and those past experiences contained in either the qualitative or the quantitative data sets.

Keywords: internationalization, risk, schedule delay, qualitative and quantitative analyses, analogy.

1. Introduction

Business competition has been on the rise in many world countries. With such increasingly competitive environment, companies –including those operating in the construction industry–

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are pressured to seek opportunities abroad. Despite the uncertainties, statistics clearly show an upward trend for the internationalization of construction.

In 2010, the top 225 international contractors generated US$383.7 billion in revenue from construction projects outside their home countries (ENR 2011). Twenty two of these top contractors were from the US. The total international revenue generated by those US contractors was US$44.9 billion, up from US$24.9 billion only five years earlier (ENR 2006, ENR 2011). What may come as a surprise is that out of this US$44.9 billion, 36% associates with projects in the Middle East and Africa. Such market remains attractive despite the political situation in some countries (ENR 2011). A more interesting example concerns Egyptian contractors. Only three showed up on the top 225 international contractors list, with total international revenue of US$1.95 billion in 2010. However, their international revenue jumped eight folds from a mere revenue of US$245 million back in 2005 (ENR 2006).

Diversification into new markets still comes with a hefty price. Companies simply have to learn how to deal with a different set of uncertainties and risks, which are not common in the company's home market (Artidi and Gutierrez 1991, Ramcharran 1998, Hastak and Shaked 2000, Shore and Cross 2003, Gunhan and Artidi 2005, Ozorhon et al. 2007).

To shed more light on the subject, this paper presents a study on schedule-related project risks in politically unstable and/or economically underdeveloped countries. Study was initiated to help Egyptian contractors better understand the causes of schedule delay encountered in projects abroad, especially those in countries of the latter types.

2. Literature Review and Study Contribution

Causes of schedule delay have been a topic for interest for a long time. Some studies focused on identifying the main causes of delay in certain project types while others were specific to the country of execution. Other researchers discussed the delay analysis methods and proposed ways to mitigate the prospective delay. For instance, Wang et al. (2004) utilised feedback from 31 industry professionals to develop a framework for construction risk mitigation in developing countries. Other studies which made use of a larger sample size such as the ones conducted by Abd El-Razek et al. (2008) and Lo et al. (2006) were limited to their home countries, Egypt and Hong Kong, respectively. Yet, with the myriad of studies in literature, none managed to develop a comprehensive approach for ranking delay causes in prospective future projects, while addressing both quantitative and qualitative data sources in an integrated manner. This paper attempts to fill such gap.

The main contribution of the study stems from how a "ranked" list of potential delay causes specific to a "future" project into consideration is developed, figure 1. Utilising a generic list of delay causes, partial analogies with past project cases, e.g., projects 1 through 12, are used to deliver a ranked list of delay causes specific to projects into consideration, e.g., projects KLM and PQR. As per figure 1, projects 1, 2 and 3 are irrelevant to target project PQR, whereas projects 10, 11 and 12 are irrelevant to target project KLM. In other words, no partial analogies can be drawn from these source projects to the target project into consideration. The resulting list of delay causes then becomes available to the contractor prior to project execution. It gives insight on what should be watched for in that particular project. Risk mitigation strategies can be decided upon in accordance with the significance of delay causes.

It is worth mentioning that analogies can be made, whether the source data is qualitative or quantitative in nature. The paper particularly elaborates on the way each type of data sources is dealt with.

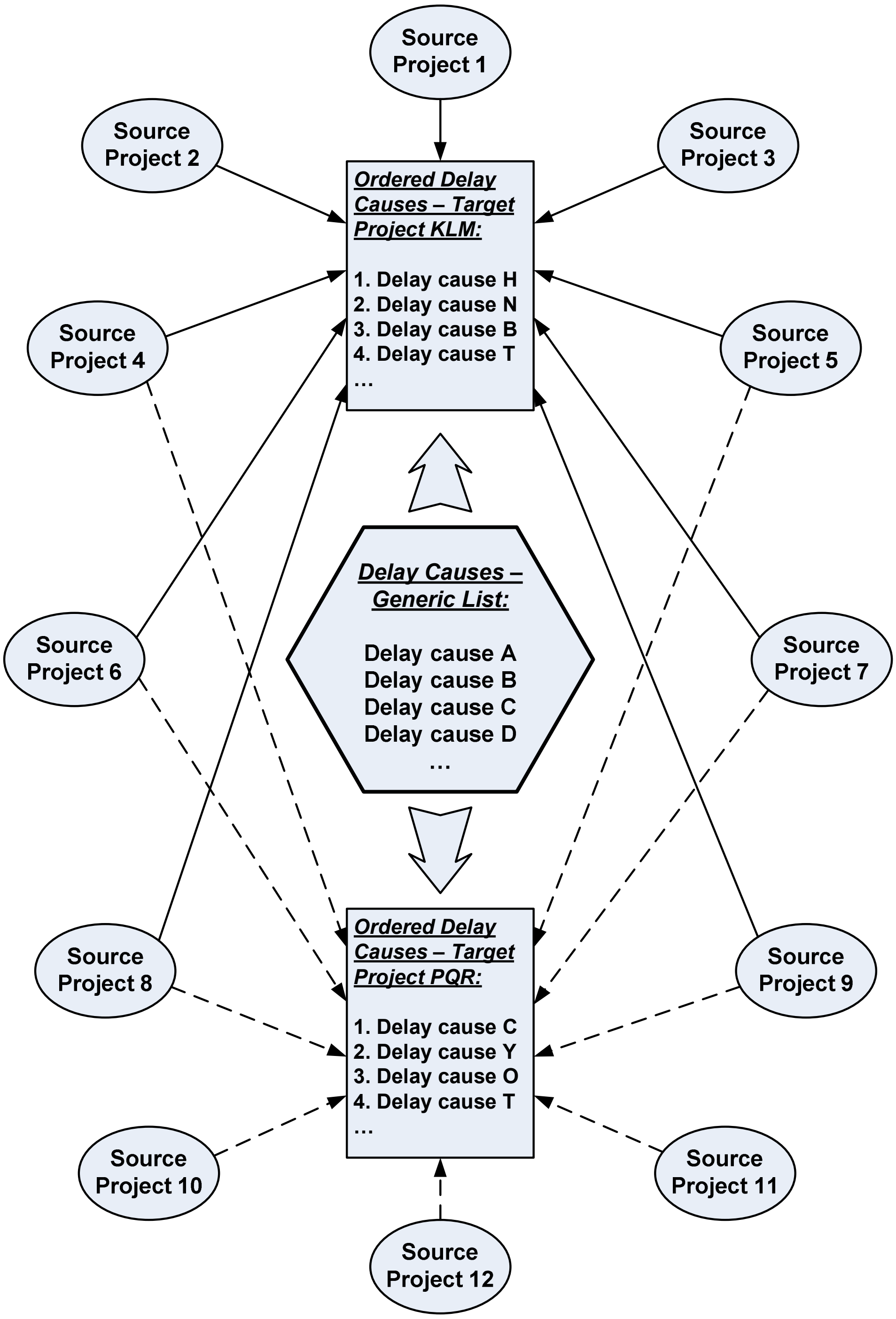

Figure 1: Ranking of delay causes according to partial analogies with past projects

3. Research Methodology

A five stage generic process was adopted to implement the research idea, figure 2. This same process can also be applied by interested construction companies for their own international operations.

Stage 1 involves the establishment of the project pool (or in other words, the source data to use for the research method implementation). When project data is properly archived, a review of the relevant documents is performed with the aim of highlighting delay cases/scenarios. To prepare for the following steps of the methodology, the schedule impacts and number of instances a given delay cause occurs are meticulously recorded. Another approach has to be adopted when only incomplete, inaccessible, or unreliable project records exist. In the latter case, semi-structured interviews and/or questionnaire forms are employed to solicit the knowledge of those who participated in managing the source projects. It is important to include such data pool, in order not to exclude a significant source of data for study implementation. Stage 1 ends with the categorization of projects according to the country/region and type of work.

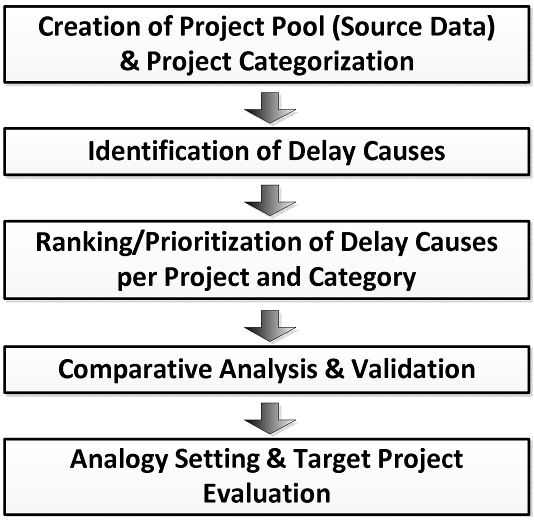

Figure 2: Research methodology

Stage 2 involves identifying and listing the delay causes for each project, whether the source of data is qualitative or quantitative. For standardization purposes, a global list of schedule delay causes is devised and each project is annotated with the delay causes specific to it.

Stage 3 proceeds with ranking the delay causes for each project. It then utilises the categorization of projects to identify and rank risks per each category. Besides identifying commonalities in delay causes within the category, differences from one category to another could be pointed out. With such knowledge, a comparative analysis is conducted to signify the similarities and differences, stage 4. Validation of the results using test cases is necessary to assure the quality of outcomes.

Last step utilises the delay causes that have already been identified, categorized, and ranked, as per the previous steps, to evaluate any target project into consideration. Using partial analogies with past project cases, an outcome in the form of a project-specific ranked list of schedule delay causes for the target project is produced. Research specifically adopts case-based reasoning (CBR) as the computational platform of choice to prioritize the list of delay cause for future projects.

Implementation of the research methodology, for both quantitative and qualitative data sets, is elaborated on in the next sections. Emphasis is on the identification, categorization, and ranking of delay causes.

4. Quantitative Approach

This approach requires full access to archived files of past out-of-country projects. To be able to detect the delay scenarios/causes, and measure their impacts and how frequent they occur in numerical terms, several companies were approached with a request to access their completed project databases. Due to restrictions on the proprietary information and the poor record keeping by some, the implementation by authors had to be limited to data from few companies with the majority of projects from one well-known international contractor. Thus, the results obtained, part of which will be presented at the end of this section, cannot be considered conclusive of the Egyptian construction industry. Moreover, this led to emphasizing the qualitative approach as complementary to the quantitative counterpart.

For each candidate project, the delay scenarios were identified. To streamline the identification process, a global register for schedule delay causes was developed as the identification progressed from one project to another. This register includes all schedule delay causes possible, where each project exhibits some of these causes. This guarantees a common reference in study implementation. Also projects were organised in categories according to project region/country and/or type of work, e.g., Roads in Sub-Saharan Africa.

Review of project baseline and update reports was fundamental in measuring the delay impact factor, DIF_{ijk}, for each delay scenario, eq. (1).

$$DIF_{ijk} = D_{ijk} \,/\, T_{jk} \qquad (1)$$

Where, DIF_{ijk} is the impact factor for delay cause i in project j under category k, D_{ijk} is the delay (in time units) resulting from delay cause i in project j under category k, whereas T_{jk} is the total time/duration for project j under category k. Unlike many studies in literature, the measurement of D_{ijk} made extensive use and comparisons of actual project plans and baselines, critical path and update reports, etc. This also led to the exclusion of many projects that did not fare the bill, or in other words, had to be analysed qualitatively.

A combined list for each category k was developed to showcase the delay causes detected in the source projects under this category. The DIF_{ijk} values were then summed up to estimate a collective impact factor for each delay cause at the category level, CIF_{ik}.

The frequency of occurrence, and thus the probability, P_{ik}, for each delay causes was further tracked as per eq. (2).

$$P_{ik} = Q_{ik} \,/\, N_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where P_{ik} is the probability of occurrence of delay cause *i* under category *k*, Q_{ik} is the frequency or number of projects under category *k* where delay cause *i* occurred, and finally N_k is the total number of projects under category *k*.

An expected value index, EV_{ik}, for each delay cause *i* under category *k* can be estimated as the multiplication product of P_{ik} and CIF_{ik}, according to eq. (3) as follows:

$$EV_{ik} = P_{ik} * CIF_{ik} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Outcome of the above methodology was a prioritized list of schedule delay causes per category, a sample of which is illustrated in table 1.

Table 1: Prioritized causes of delay for Airport Aprons in Afghanistan

R_{ik}	Cause of Delay	EV_{ik}
1	Change orders	2.64
2	Removal of debris	2.11
3	Demining	1.90
4	Theft at harbor	0.50
5	Unavailability of mobilization area	0.40
6	Unclear scope of work	0.25
7	Lack of coordination	0.25
8	Lack of sufficient data	0.14
9	Lack of access to batch plant site	0.10
10	Lack of good documentation	0.10
11	Unavailability of permanent power connection by government	0.09
12	Occupation of site by client	0.09
13	Gate access delays	0.05
14	Regulatory issues at harbor	0.02
15	Strike	0.02
16	Bad weather	0.01

5. Qualitative Approach

The qualitative approach allowed a much more diverse group of projects in Africa, the Middle East, and the Far East, to be investigated. Semi-structured interviews were conducted with 19 experts who participated in 38 projects that took place in the target regions. With schedule impacts in mind, experts were asked to rank the causes of delay in each international project they participated in. Estimation of CIF_{ik} in this approach is based on the ranking of delay causes in projects under any targeted category *k*. An average rank, R_{ik}, for each delay cause *i* under category *k* is based on 1) the number of times this delay cause was associated with a project under this category, Q_{ik}, and 2) The relative impact of the delay cause as indicated by its ranking in the list. This average rank is calculated as per eq. (4).

$$R_{ik} = \sum_{j=1}^{N_k} R_{ij} \;/\; Q_{ik} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where R_{ij} is the rank for delay cause *i* in project *j* (R=1 being the top-rank delay cause). Finally, CIF_{ik}, which represents the relative impact of the delay cause *i* under category *k*, is taken as the reciprocal of R_{ij}. Table 2 shows an example of a prioritized list of causes of delay categorized according to project region. In this context, CIF_{ik} is utilised to calculate EV_{ik} as per the generic eq. (3).

Table 2: Prioritized causes of delay list in Sub-Saharan Africa

R_{ik}	Cause of Delay	EV_{ik}
1	Cash flow problems	0.5
2	Regulatory issues at the customs	0.375
3	Lack of equipment with reasonable rental prices	0.31
4	Bad weather	0.25
5	Unclear scope of work	0.125
6	Lack of qualified subcontractors	0.125
7	Change orders	0.1
8	Strikes	0.08
9	Site obstructions	0.08
10	Delays in site possession	0.08
11	Re-routing	0.06
12	Lack of co-ordination	0.06
13	Poor planning/Estimating	0.06
14	Bribery/Corruption	0.05
15	Lack of supply of primary resources	0.05
16	Delay in shipment	0.05
17	Fluctuation in prices/exchange rates leading to work stoppages	0.05
18	Re-work	0.04
19	Procurement administrative issues	0.04
20	Security issues	0.03

It is to be noted that the rank of a delay cause *i* under category *k*, that is R_{ik}, is recorded and used for merging the quantitative and qualitative analysis results. The same eq. (4) was applied for quantitative data to unify the method of measurement. Table 3 shows the exact same example used in table 1 organized using eq. (4). EV_{ik} is again calculated using the generic eq. (3). Further details are presented in the following section.

Table 3: Table 1 causes of delay for Airport Aprons in Afghanistan prioritized using Eq.4

R_{ik}	Cause of Delay	EV_{ik}
1	Change orders	1.0
2	Removal of debris	0.5
3	Demining	0.33
4	Theft at harbor	0.14
5	Unavailability of mobilization area	0.125
6	Unclear scope of work	0.1
7	Lack of coordination	0.08
8	Lack of sufficient data	0.06
9	Lack of access to batch plant site	0.05
10	Lack of good documentation	0.05
11	Unavailability of permanent power connection by government	0.04
12	Occupation of site by client	0.04
13	Gate access delays	0.04
14	Regulatory issues at harbor	0.03
15	Strike	0.03
16	Bad weather	0.03

6. Merging Qualitative and Quantitative Data

In order to benefit from the enhanced quality of the quantitative data and the large coverage of the qualitative data, a merging approach is proposed. The merging enables knowledge to be leveraged from both approaches, thereby enhancing accuracy and coverage of the prediction, figure 3.

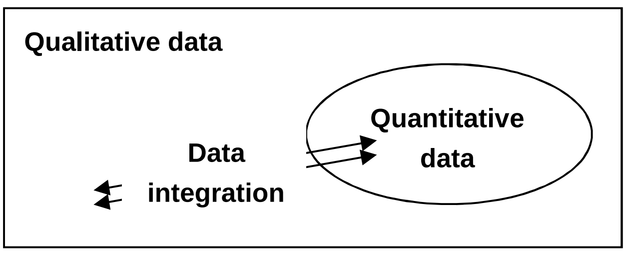

Figure 3: Qualitative and quantitative data merging

In study implementation, projects were generally categorized according to the project region/country (R) and type of work (W). This classification reflects on earlier studies in delay analysis and risk classification, e.g., Hastak and Shaked (2000) and Wang et al. (2004). The adopted categorization and outcomes of both quantitative and qualitative analyses were used to develop a common/global index, GEV_{ik}, for delay causes under category *k*. This index can be calculated according to eq. (5).

$$GEV_{iRW} = EV_{iR} * EV_{iW} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where EV_{iR} is the expected value index for delay cause *i* in region *R* (i.e., category *k* is equivalent to region *R*), and EV_{iW} is the expected value index for delay cause *i* in work type *W* (i.e., category *k* is equivalent to work type *W*).

When the merging approach is utilized, EV_{iR} is calculated based on the rank value reciprocal similar to the qualitative approach methodology (eq. (4)).

To exemplify, let us assume a construction company is considering an Apron Project located in Sub-Saharan Africa. Table 2 provides information for the sought type of work (*W*), which is Apron Projects, whereas table 3 is reflective of project region/country (*R*), which is Sub-Saharan Africa. Thus, the value of GEV_{ik} for delay cause “change orders” – based on Tables 2 and 3 – shall be equal to EV_{iR} * EV_{iW} = 1 * 0.1 = 0.1. Obviously, in merging the qualitative and quantitative data, all needs to be in sync. That is why the calculated EV_{ik} values of table 1 was not utilised. Table 3 was used instead.

Finally, the research took into consideration that quantitative data is more reliable; therefore a multiplier is used to augment the weight of results derived from quantitative analysis. Another used multiplier accounts for the level of confidence in qualitative data/interviewer for more results precision

7. On-Going Research

Further works include estimating a multiplier to account for own company circumstances. This can contribute to the re-prioritization of delay causes as defined by eq. (4). Such multiplier can be derived from semi-structured interviews with high profile experts within the companies in concern. Further works also includes introducing a case-based reasoning (CBR) model to enhance estimating the similarity between the contractors’ upcoming projects and the projects available in the case base.

8. Conclusions and Recommendations

This paper presents three distinct yet complementary approaches to quantify the expected delay causes on construction projects. The quantitative approach was based on actual delay durations calculated from an in-depth assessment of delay causes from construction schedules and narratives. This approach can be used when the company has a large number of well-documented construction schedules. The qualitative approach is based on interviews with 19 experts and covered 38 projects in Africa, the Middle East, and the Far East. Based on the ranking of delay causes from these data sets, expected values of delays were calculated for various project types and regions. This approach can be utilized when companies do not have reliable construction schedules, but have access to experts with sufficient knowledge on delay causes. For companies that can capitalize on both types of data (qualitative and quantitative), a data merging approach is proposed. This technique is able to leverage the advantages of both approaches (accuracy and coverage) to enable construction companies to better predict the expected causes of delay on international construction projects. This improved prediction can result in 1) the development of more effective risk response plans, 2) more reliable estimation of contingencies, and 3) establishment of more efficient project control procedures.

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