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A Relational Database for Construction Delay

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Abstract
Construction projects are open to risks due to their multi-partied, environmentally dependent and complex nature. Unexpected situations generally lead to delays resulting considerable time and money losses. This makes delay and delay analysis to be the core subject matter during execution of construction projects. Therefore project participants should not only be focused on project control but also be able to clarify some project specific issues at the planning stage. At this point, past project data may be used to learn from previous projects and to take preventive actions in order to minimize delays. This study presents a relational database established to keep post project information about delays and to use the information for similar type of projects. The database may enable the user to access valuable information such as; most critical activities and parties in a specific kind of project, average cost and duration of the delay for that project, information on claim processes for delays, probable dispute issues, etc. In the literature, there exist some notable studies related to the use of computer support in delay and claim analysis; however easily accessible and manageable nature of the created database constitutes the originality of this study.

Keywords
Construction delay, Database, Delay analysis, Learning, Relational database

1. Introduction

Construction delay and its analysis have been one of the major considerations in construction projects. Besides risky and competitive characteristics of construction contracting, conflicting objectives of project participants also complicate the situation and make delays most common and costly problem of construction projects (Abudayyeh, 1997). Once delay occurs; it has the potential to lead further losses, unless it is properly analyzed and related claims are settled (Alkass *et al*., 1995). Nevertheless; delay in itself means a loss to a contracting party, so effort should be put in its prevention from the beginning.

Construction projects are unique, multi-partied and complex in nature, besides these contract administration leads complicated legal issues and requires voluminous data. These characteristics of the construction projects obstruct information collection and creation of a knowledge in the issue (Chong *et al*., 2013). For example, similar problems may be encountered in similar projects and the information may be fading with the close-out of the projects and their leaving personnel (Kim *et al*., 2008). This situation leads re-learning in recognizing and remedying mistakes with each delay occurring with its losses in terms of time, cost, labor and also safety. Thus, delay knowledge acquired during a project life should be accumulated, organized, and shared to prevent re-learning from the same mistakes (Yates, 1993).

Considering the information gathering; databases become prominent, by bridging a gap, namely by linking the data and the knowledge will be created through that data. However; capturing comprehensive data and creating broad knowledge require some cost and effort. Therefore, a practical database may be more useful and may reach its users to remediate a specific issue. In light of these, this study presents a practical database established to capture delay data and to increase knowledge in the issue. By this way; project participants may get some insight about the specific case in hand and use the knowledge in planning, decision making and execution processes of the project.

Within the context of the study; firstly information on data modeling together with the information of databases in construction sector and computer use in construction delay will be presented. Following data modeling, the details with the delay database will be laid out and the study will be concluded with possible use and advantages of the delay database.

2. Data Modeling

Data constitute the values of the facts, information is the interpretation of the captured data, and the knowledge is bringing an action through the decisions taken based on the provided information (Allen and Terry, 2005). In order to acquire sound knowledge, data should be organized in a way that it provides collection of useful information. Knowledge enables making estimations and reaching a conclusion in light of the information available (Allen and Terry, 2005). Data modeling provides the transition of data to knowledge. Accordingly, design and definition of the required structure is one of the most critical considerations in information systems. Relational database management systems are vast in use between all systems with known examples such as Oracle database, Microsoft SQL Server, and IBM D2 (Sideris, 2011). For diagramming of data models, Entity Relationship Diagrams (ERD) developed by Peter Chen in 1976 are generally used. ERDs not only provide valuable information for database developers, but are also capable of making nontechnical people get insight of the data model (Oppel, 2010; Sideris, 2011).

2.1 Database Management in Construction Industry

Database management has the potential to extend the use of scheduling, document management, and estimating software programs used in the construction industry. Thus, knowledge of database design and its manipulation have become one of the considerations of construction management professionals. Most of the used software programs in construction management are based on databases, and expanding construction volume and its complexity bring requirement of new technologies rather than traditional management practices. In order to meet this requirement; the companies that are not capable of using specialty software programs, establish their management systems on relational database management system software (Microsoft Access) or spreadsheet programs with limited database capabilities (Duvel and Schmidt, 2002; Tyszkiewicz, 2010). Use of databases in construction industry varies according to its aim and usage cost/effort ready to be expended. For example, Resident Management System (RMS) is a large database; which is operated by US Army Corps of Engineers to track construction contracts and progress information; requires program development, training, travel, software/hardware acquisition, and operating expenses and has an income from annual license fees (Kim *et al*., 2008; Barker, 2011).

2.2 Computer Use in Construction Delay

As it is stated use of databases and computers in construction management literature varies. Its use with construction delay focus is also available in the literature. Some notable studies that handle construction delays with computer support can be presented as follow.

Yates (1993) created delay analysis system that is structured to be built in existing project management software. This system is capable of monitoring the project progress, analyzing possible causes of delays and suggesting possible actions to reduce delays and prevent further delays. The system compares some technical parameters, namely key controlling factors with the indicators of delays in the database; identifies activities in delay and reaches the expert knowledge database to extract the possible causes and corrective actions related to the delay in hand. Through its interactive environment, it provides acquirement of delay knowledge in its permanent databases and improves project control and analysis.

Alkass et al. (1995) presented a computerized approach to assist construction project control, claim (preparation and) analysis including delay analysis. The approach includes combination of project management software with its information export/import capabilities, database management system for stored project information and its utilization, and an expert system for expertise of construction claims to assist decision making in delay assessment (in terms of delay classification, action for its minimization, and legal course to be pursued). Thus; the system provides manipulation of exported project information in the database with the expert system's support and leads timely analysis of delays with considerable data readily available for claim preparation process.

Abudayyeh (1997) underlined the importance of use of multimedia information (pictures, videos, and audios) in construction project control and established a relational database that provides automated acquisition, storage, and retrieval of this information. The information system provided in the study associates multimedia information to project control data, and supports performance evaluation and delay management by processing and reporting this information.

Al-Sabah et al. (2003) created a relational database to document and analyze construction claims. The database not only assists analysis of construction claims (in terms of causes and underlying management issues) but also can be used in tracking of construction claims on live projects.

Li et al. (2006) studied tracking and control of construction activities for within budget and timely delivery of the projects. They developed an internet-based relational database that enables real-time analysis and reports the status of the activities in terms of cost and time with earned-value analysis.

Kim et al. (2008) focused on knowledge discovery in databases and proposed a methodology for delay factor selection. This methodology enables extraction of the factors that contribute most to the experienced delay through the acquired project data.

El-Omari and Moselhi (2009) also built a relational database for tracking and control of projects to base an automated data collection system from construction sites. The system includes tablet personal computer, barcoding, radio frequency identification, laser distance and ranging, digital images, and multi-media technologies to provide acquisition of data, generation of accurate reports, and timely response whenever it is required. Thus, the system provides controlling through execution of projects and supports document management required for claim preparation.

Zhu et al. (2010) developed a web-based data management framework to store portable document format based dispute review board reports into a database format that enables systematic search. This format brings functionality in retrieval of similar problems available in the reports, improves the efficiency and effectiveness of the dispute review board system.

Chong et al. (2013) remarked that although the use of information technology is accepted as a possible measure in mitigation of adversarial issues and disputes, its application in construction industry is very limited. With the aim of bridging this gap; they introduced the data warehousing concept, which is collection of data from different databases, to be able to extract valuable information from voluminous data required for analysis. They presented e-dispute resolution prototype with considerable benefits as support in decision making, mitigation, and prevention of disputes; and so improved contract administration.

3. Construction Delay Database

The database presented in this study has user interfaces in terms of forms; for data entry and edit, filter and report section. First of all, delay handled in the study means any schedule delay that is due to difference in planned duration and actual duration. Any case handled through mitigative actions is also recorded to support control mechanism. Within the methodology of the study, a conceptual and a relationship model are created to base the study. The model is implemented through Microsoft Excel and is validated through entering of delay data possible to be encountered in hypothetical projects.

3.1 Data Structure

The data structure in form of entity-relationship model depicts the logical background of the study. The following conceptual model improved with attributes depicts reason of existence of each entity (Figure 1). The "project" entity with its characteristic attributes is required to investigate similar projects to the one in hand and extraction of information through its attributes. The core entity "delay", which is followed by "mitigation" entity to handle mitigative actions undertaken; "claim" entity for claims issued; and the "dispute" entity to reflect claims turned into dispute are represented in the following diagram (Figure 1).

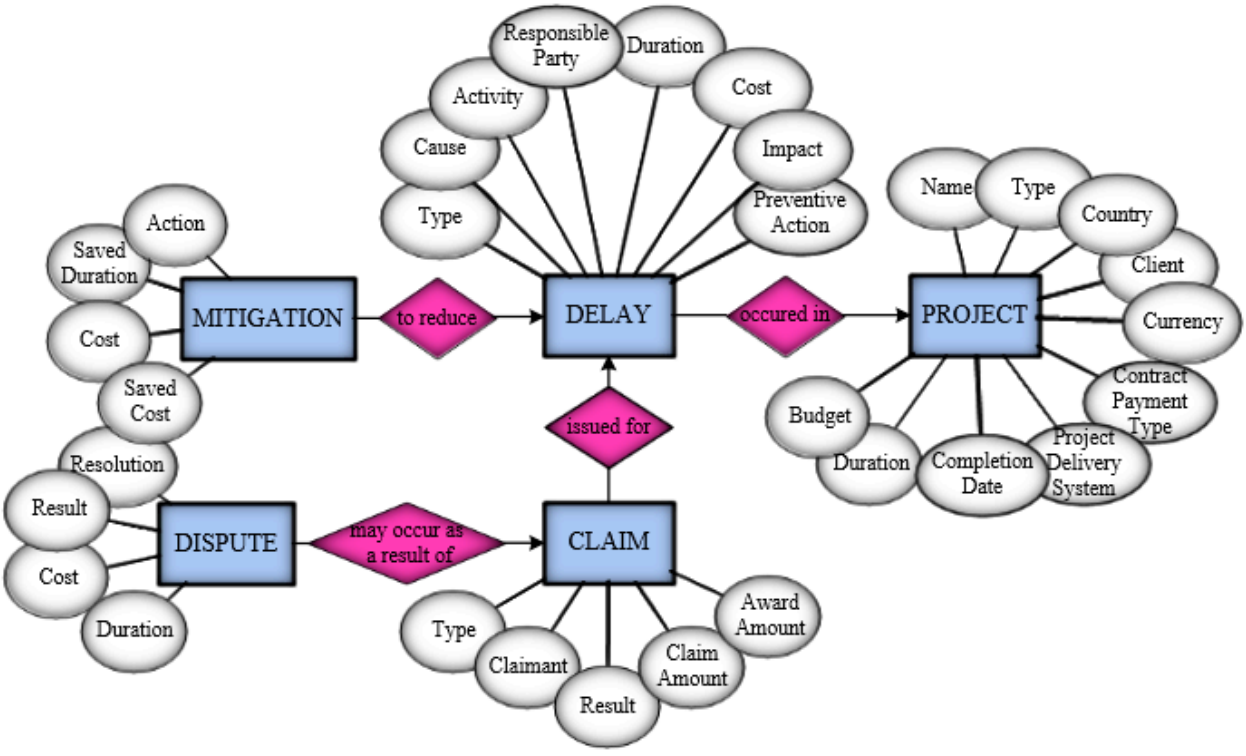

Figure 1: Entity-Relationship Diagram of the Conceptual Model

The relational database is designed with five tables and attributes specific to each table. Primary keys of each table are provided. The details of the tables can be given as follow:

1. **Project:** This table includes descriptive project attributes to manipulate the results according to the case in hand. Retrieval of the information may be on the user selected attributes like client, project delivery system, completion date, etc. (Menassa and Mora, 2010). Additionally budget and duration information is kept to calculate total effects of delays.
2. **Delay:** Attributes of delay are identified in order to investigate individual effects of delays and possible preventive actions.
3. **Mitigation:** Mitigative actions and effectiveness of these actions are handled through mitigation attributes.
4. **Claim:** Claims and success of these claims are investigated through claim attributes.
5. **Dispute:** The claims that are leaded to disputes and effectiveness of dispute resolution processes are handled through dispute attributes.

The table-relationship model constructed in Microsoft Access environment is provided in Figure 2 to transform conceptual model to a logical model that is more akin to the data structure to be implemented (Ryu *et al*., 2003).

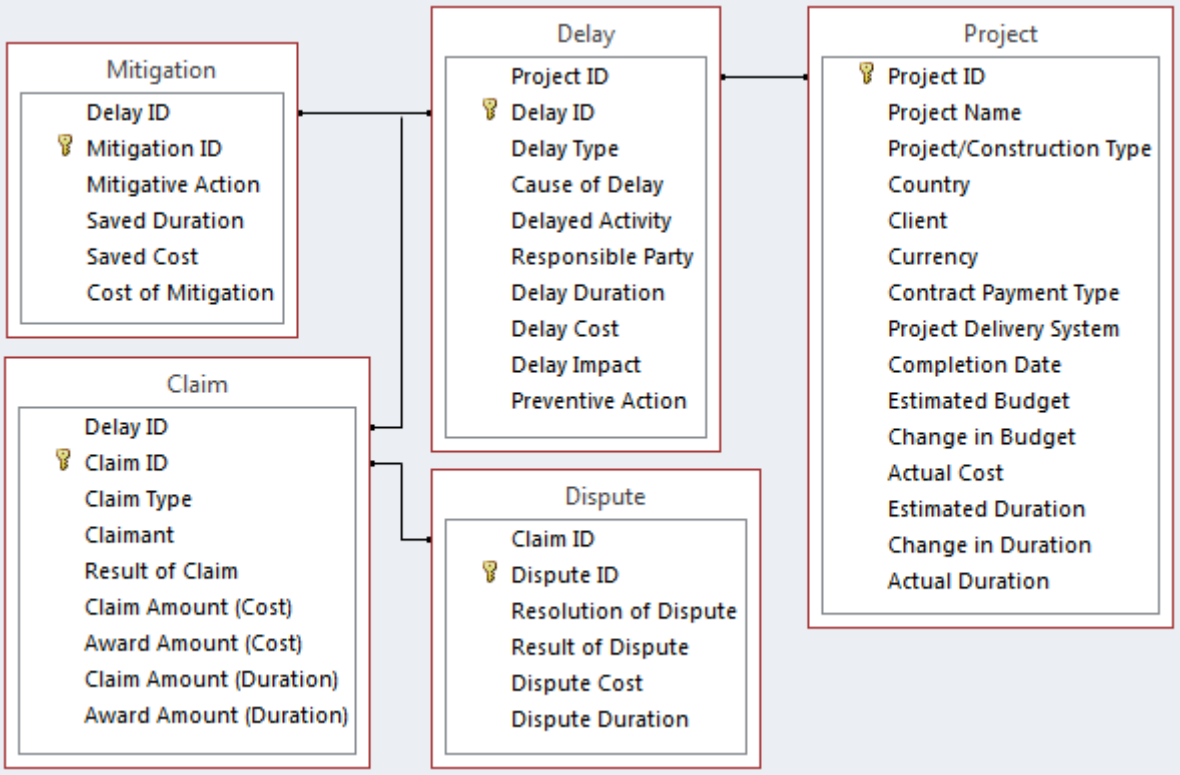

Figure 2: Relationships between Tables

3.2 Implementation

Microsoft Access database is generally used in establishment of relational databases due to its capability of storing everything in a single physical file, availability, inexpensiveness, and user friendliness (Al-Sabah *et al*., 2003; Chong *et al*., 2013). However, Microsoft Excel is selected for implementation of the database in this study due to its higher capability in manipulation/calculation of data and higher accessibility; even if it may require higher effort for implementation of a relational database. The tables, queries, forms, reports, macros, and modules that would be created with Microsoft Access environment is created through Microsoft Excel by using macros behind forms created for data entry and retrieval (Al-

Sabah *et al*., 2003). Two report sheets are set aside to display and to print-out the results to be obtained by filtering.

3.3 Data Entry and Evaluation

Main menu consists of sections for data entry, viewing, editing and reporting all of which are established through forms. The following figure is a screenshot of data edit form for "Claim" information (Figure 3).

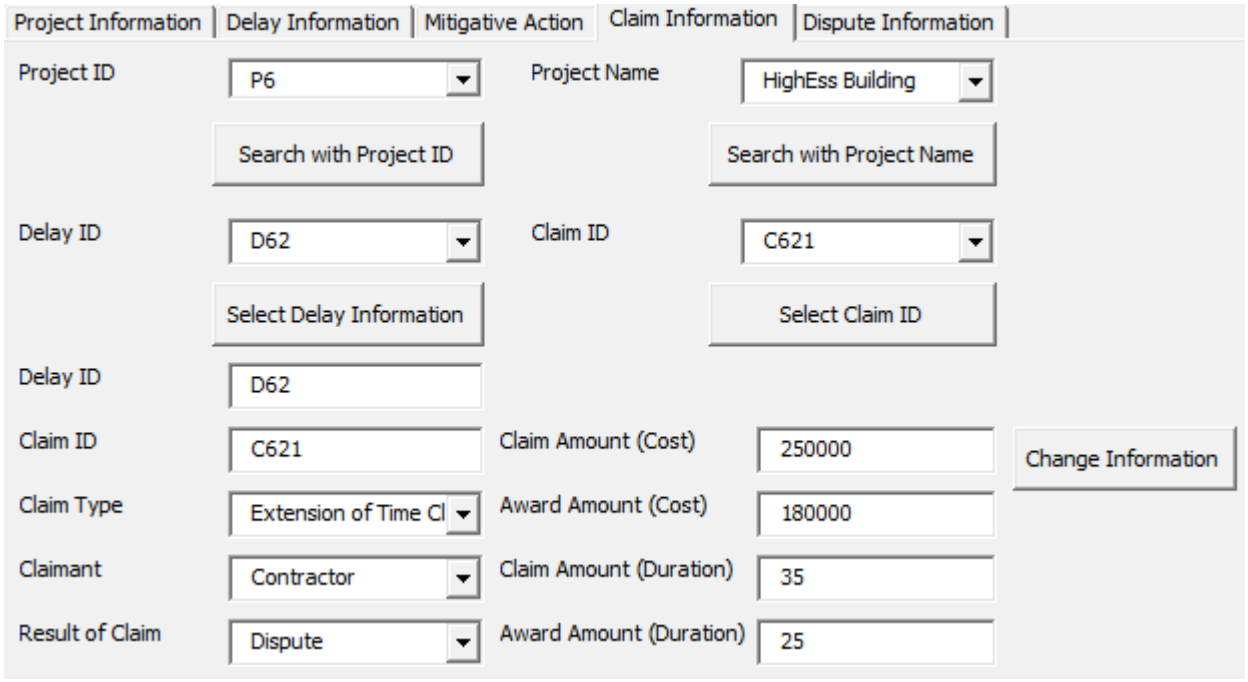

Figure 3: Data Edit Form for Claim Information

Some default data lists are provided for delay types, causes, responsible parties, preventive and mitigative actions and such, that are structured through a delay analysis ontology constructed with the aim of sharing delay information (Bilgin, 2011). The new data can be added through forms available in the database or directly be manipulated from the sheets set aside to keep scroll down data. The database requires manual ID assignment and it informs if there exists conflicting IDs identified previously or missing data in the entry. Queries are formed for search of the results through the form providing filtering. User can reach information through filtering by concurrent selection of at most 3 different categories between "Project Type", "Country", "Client", "Contract Payment Type", "Project Delivery System", and "Completion Date". Finally the results are obtained as deviations in budget and durations of the projects, with the list of causes of delays, delayed activities, responsible parties, possible preventive actions, number of claims and disputes in the projects. Mitigative actions; resolution types of disputes; and success rates for mitigation, claims, and dispute resolution processes can be obtained in the report sheet as a result of the filtering option.

3.4 Validation

For the validation of the database, possible delays that may be encountered in 10 hypothetical projects with 34 delays in total are entered in the database and the results for a privately owned high-rise building project in Russia is searched within the database by filtering for "Project Type", "Country", and "Client" categories. Delay causes as "Inclement weather causes" and "Unforeseen ground conditions" need attention with their relatively high occurrence and causation to disputes. Most critical activity seems to be

"Foundation", and responsible party in most of the delays is "Owner". The related preventive measure is obtained as "Owners must make sure that sufficient time, money and effort are allocated to the feasibility study and design process" due to unforeseen ground conditions delays. The claims that lead to disputes has lower success rates and the "Litigation" is not a favorable resolution process due to its long duration and costs incurred when it is compared with "Negotiation". Contractor caused delay due to "Unavailability of materials" has notable mitigation success rates with acceleration by "Increased manpower". Partial list of the obtained results is shown in the following table (Table 1).

Table 1: Partial List of Results

Project Name	Cause of Delay	Delayed Activity	Respons. Party	Delay Duration (%)	Result of Claim	Success of Claim (Dur.)	Resolution of Dispute	Dispute Duration (%)
Alpha Office Buildings	Unforeseen ground conditions (rock, acid, sediment basin)	Foundation	Owner	4,10%	Dispute	80,00%	Negotiation	3,61%
	Inclement weather causes	Excavation	Nobody	2,41%	Settlement	100,00%		
	Difficulty in site acquisition/Failure to provide property	Mobilization	Owner	2,41%	Settlement	100,00%		
	Delay in performing inspection and testing by consultant	Flooring Systems	Owner's Consultant	0,72%	Settlement	100,00%		
HighEss Building	Change orders by owner during construction/Owner initiated variations	Door Window Framing	Owner	1,94%	Settlement	100,00%		
	Inclement weather causes	Excavation	Nobody	3,40%	Dispute	72,00%	Negotiation	2,43%
	Delays in contractor's progress payments (of completed work) by owner	Foundation	Owner	0,97%	Settlement	100,00%		
	Delay in performing inspection and testing by consultant	Door Window Framing	Owner's Consultant	0,97%	Settlement	100,00%		
Welders Building	Inclement weather causes	Foundation	Contractor	1,71%	Settlement	0,00%		
	Unforeseen ground conditions (rock, acid, sediment basin)	Foundation	Owner	3,08%	Dispute	68,75%	Litigation	44,52%
	Unavailability of materials on site on time	Door Window Framing	Sub-contractor	1,28%				
	Unavailability of site labors	Facing Systems	Sub-contractor	0,86%				

4. Concluding Remarks

A user-friendly, inexpensive, easily accessible database is created to establish a delay knowledge and timely handling of the delays occurred in a project. The established database may be used in planning process to get insight of some project specific risky activities or actors, namely provide learning from previous problems encountered, and take this information into consideration. Additionally, the database may also be used while project tracking to keep delay data as it happens and may provide on-going delay analysis to foresee possible immediate actions and claim success rates and effective dispute resolution mechanisms. Thus the database may serve for both planning and decision making processes of a project and act in use of the knowledge created. The database may not only provide the information on procedures followed before, namely the link between procedures for the cases and the decisions made, but also keep delay information ready for claim analysis and reduce time and cost required for claim analysis. Default data in forms of dropdown lists also provide some level of guidance and can be easily adapted for user-defined lists.

Major limitations of the study can be summarized as; the database provides filtering options to the user, whereas it does not provide user defined results to be obtained. In addition to that, it is not capable of ranking the results. Manual assignment of IDs may also create some difficulty and complexity. Since the database is spreadsheet-based, more user is assumed to be capable of using it; however, a web-based version of the database may provide its concurrent use. It works according to the contractor's point of

view, therefore an improved version of the database with capture of more controlling data and including other claims may serve for owners as well. Finally, validation of the study is based on hypothetical projects with a limited number, which ensures its verification more than its validation. Actual validation can be done with real project data and its active usage by a construction company in planning and control processes.

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