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Root Delay Causes for Construction Projects

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Abstract: Many research works were conducted worldwide to measure the sources of construction project delays. Most of these research works dealt with the actual delays or the occurred delays that actually recorded or noticed on completed or in-progress construction projects but there is limited research was conducted to search for the root of delay causes in construction projects. The presented research in this paper aims at extracting the root delay causes of construction projects.

Design/methodology/approach: Fifty-three delay causes were gathered from previous research work conducted globally, then using cause-effect analysis to extract root delay causes. The resulted root delay causes were verified using a field interview questionnaire with thirty experts in the construction industry. Statistical analysis contains descriptive, factor analysis and check of independency to check the legitimacy of the resulted root delay causes.

Findings: Fourteen root delay causes were resulted from cause-effect technique analysis. These root delay causes include project parties' management efficiency, inter-relationship work environment and specific project characteristic.

Originality/value: Although construction delays have been globally investigated in previous studies relating to construction management, few have attempted to analyze and search for the root delay causes. The existing research is aiming to analyze in deep the recorded delays and attempting to get their root causes. These root delay causes are the underpinning of project delay, so prior evaluation of these root delay causes before project starts can predict the prone of project to delay. The evaluation of these root delay causes can help project planners to put in their mined the possibility of project delays and the areas to be focused to mitigate the effect of proposed delays in case of occurrence. This step can be used a step of project risk analysis to enhance the delay management mitigation strategy.

Keywords: Construction projects, Delay causes, Root delay, Verification, Cause-effect.

I. INTRODUCTION

A construction project delay is defined as the time during which part of the construction project has been extended beyond what was originally planned due to unanticipated circumstances [1] or the time overrun beyond project delivery date [2]. Kaming et al. defined delay as the extension of time beyond planned completion dates traceable to the contractors [3].

In the UK, the construction industry has had a significantly poor record with respect to the completion of projects on time over a long period of time [4]. A report published by the UK's National Audit Office and edited by John Bourn, exposed that 70% of the construction projects carried out by public departments and agencies were completed late. Moreover, recent research by the Building Cost Information Service [5] found that nearly 40% of all studied construction projects had overrun the contract period [6].

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In the developing countries, the problem may be worse; Arditi et al. survey of 258 public projects in Turkey showed that 44% overran from the original duration. Al-Ghafly found that the percentage of delayed projects in Saudi Arabia varied from 35% to 84% [7,8].

Not only are the traditional projects exposed to delay, even green buildings. 32.29% of the green construction projects were completed behind schedule [9].

As described above, the problem of delays in construction projects is significant and an international problem. Therefore, researching for causes of delays and attempts to mitigate their effects is a valid and worthwhile effort. It is essential to predict major delay sources before constructing a project so that project parties can manage these delay sources and apply proactive procedures to prevent these delays [10]. Many of previous globally research work conducted to measure and rank the delay causes in construction projects. This previous research work concentrated on ranking delay causes for completed project or from construction personnel experience.

Delay causes in construction can be defined as those events that happen during the project life and lead to either (individually or combined) the project, or any part of it, taking more time to finish than the original estimate [11]. This delay can recognized, recorded by one or more parties in the construction project during the normal management process. This type of delay is a direct delay that can be used a basis for claims from any party. There are underpinning problems that can encourage the delay to occur. These problems are the root causes of project delay causes.

Study Objective

This study has three objectives; first is intensive search for the previous research works in the field of construction project delays to gather the used delay causes. The second objective is to extract root delay causes or the underpinning delay causes for a construction project. The third objective is to validate the research findings.

Background

Many efforts have been made to define the causes of construction delays and evaluate their effects on total project delay. These studies are on a global scale. Most of this previous research work used questionnaire based approach to collect information related to construction delays. This approach used questionnaires by either post or interview with respondents. The respondents were asked to either rank causes of delays or assess their level of influence on project delay.

Previous research used several different of similar terminologies related to delay causes. They used "delay factors", "delay source", "delay reasons" and "project problems" to state delay causes.

Many studies were recorded during the past three decades. Most of the previous research work was conducted to determine the causes of delay based upon gathering subjective data from construction industry personnel by asking

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them to use their own judgment about the causes of delays. Discussion of these researches is allocated in detail in Soliman and Chidambaram et al. [12,13].

More than fifty researches have been conducted as shown in Table 1. Table 1 shows summary for this research work. This research work conducted globally. Table 1 shows the place where is the research was conducted, year of publication, method of data gathering and analysis technique used to get the delay causes and delay causes ranking.

Table 2 shows the frequency of researches per country. In previous research work, the participants were also asked to rank or assess the importance of a set of predefined causes of delay. The previous research work categorized participants in main groups as following:

1. Contractors or constructors group, which contains the participants who are working as a contractor or represented as one of the constructor party.
2. Owners group, which contains the participants who are working as an owner, owner, or public agencies.
3. Consultant or designer group, which contains participants who are working in a consulting office, design firm or architectural/ engineering office.

Many drawbacks have been noticed of this type of research work such as:

a) It is obvious that the three groups of participants have different objectives, and when they were asked to determine the responsible for delays, they often blame the other group. This statement was proven from most of the previous studies. Many of these studies focused in determining the level of agreement of the participants' group in ranking the delay causes. A certain consensus between owners and consultants is noticed because of closeness of their objectives, while there is little consensus between contractor and owner.

b) None of the research distinguished between the delay consequences and delay makers. For example, material shortage can be resulted from improper supply chain strategy or late delivery of material, while all of them are presented as delay causes.

Therefore, there is a need to understand the science of how delay occur not only measure the relative weight of these delays. There is a need to search for what are the root delay causes of construction projects. Root delay causes defined as earlier events or the triggers that develop to become direct delay. These root delay causes may be due to managerial, financial or specific project related factors.

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Table 1: Summary of past research work of delay causes globally.

No	Authors	Country	Year of Publ.	Project Owner	Project Type	Method of Data Gathering	Participants	No of Participants	No of Used Delay Causes	No of Delay Causes Groups	What Asked for Participants	Technique Used to Delay Cause Rank	Technique Used to Get Rank Agreement for Groups
1	Baldwin et al.	USA	1971	N/A	N/A	Mailed OR Questionnaire	contractors& architects& engineers	contractors& (101) architects (100) &engineers (99)	17	1	severity in 5 levels	Severity Index	Rank Agreement Factor
2	Arditi et al.	Turkey	1985	Public	Building & Civil	Mailed Questionnaire	public clients and contractors	public clients (44) and contractors (34)	23	1	define the most 5 importance causes	Average score for each delay cause	NO
3	Sullivan et al.	UK	1986	N/A	Big Civil Projects	Interview Questionnaire	contractors, clients and consultant	contractors (12), clients (3) and consultant (4)	16	1	Define the frequency	Average frequency	NO
4	Okpala et al.	Nigeria	1988	N/A	N/A	interview then mailed Questionnaire	engineers, architects and quantity sprvinre	engineers (58), architects (52) and quantity serviors (401	20	1	Importance in 5 levels	severity index	Rank Agreement Factor
5	Dlakwa	Nigeria	1990	Public	N/A	Mailed Questionnaire	Owners, Consultants & Contractors	not defined	17	1	Importance in 5 levels	Mean value for each delay cause	NO
6	Waheed	Egypt	1994	Public & Private	Building & Civil	Interview Questionnaire	owners and contractors	not defined	16	1	Importance in 5 levels	Severity Index	NO
7	Assaf et al.	Saudi Arabia	1995	Public	Building	Interview Questionnaire	Owners, Consultants & Contractors	Owners (20), Consultants (40) & Contractors (100)	56	9	Importance in 5 levels	Importance Index	rank correlation coefficient

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8	AI-Khalil et al.	Saudi Arabia	1999	Public	Water and Sewage Projects Sewage Projects	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (10), Consultants (12) & Contractors (23)	60	6	Importance in 5 levels	Severity Index, Frequency Index and Importance Index	coefficient of concordance
9	Ogunlana et al.	Thailand	1996	Private	High rise buildings	Interview Questionnaire	contractors, consultants, owners and ennstrnetinn	12 project sites- not defined numbers for each respondents	25	6	define the existed delay cause from the list	percentage from total sample size (Sample is 12 nrnipets1	NO
10	Cumaraswamy and Chan	Hong Kong	1998	Public & Private	Civil and Building Projects	Mailed Questionnaire	Owners, Consultants & Contractors	Owner (50), consultants (49) and contractors (48)	83	8	Importance in 5 levels	RII relative importance index	Rank Agreement Factor
11	Odeh and Battaineh	Jordon	2002	Public	Buildings, Roads & Water-sewage projects	Mailed Questionnaire	Contractors & Consultants	Contractors (63) & Consultants (19)	28	8	Importance in 5 levels	RII relative importance index	Spearman Correlation Coefficient
12	Frimpong et al.	Ghana	2003	Public	Ground water Projects	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (28), Consultants (19) & Contractors (25)	26	1	Importance in 5 levels	Relative Importance Weight (RIW)	The Kendall's Coefficient of Concordance
13	Zayed and Kalavagunta	Canada	2005	N/A	Industrial, Heavy, Residential And Building Construction	Questionnaire IRE (Not Defined, Mailed Or Interview)	Experts - Not defined categories	not defined	22	4	Pair comparison for groups, and delay cause	AHP	NO

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14	Alaghbari et al.	Malaysia	2007	N/A	N/A	Mailed Questionnaire	Contractors, consultants and governmental and developers	Contractors (29), consultants (31) and governmental and developers (19)	31	4	Importance in 5 levels	Mean Values	NO
15	Soliman	Kuwait	2010	*N/A*	N/A	Interview Questionnaire	Owners, Consultants & Contractors	Owners (5), Consultants (16) & Contractors (9)	30	6	Importance is 5 levels	Importance Index	Rank Agreement
16	Abdel-Razek et al.	Egypt	2008	N/A	Buildings	Interview then Questionnaire	Owners, Consultants & Contractors	Owners (22), Consultants (23) & Contractors (29)	32	4	Importance in 5 levels	Importance Index	Spearman Correlation Coefficient
17	Shebob et al.	Libya	2012	N/A	Buildings	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (28), Consultants (20) & Contractors (24)	75	8	Importance in 5 levels	Severity Index, Frequency Ind. and Importance Inriax	NO
18	Shebob et al.	UK	2013	N/A	Buildings	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (12), Consultants (19) & Contractors (13)	75	8	Importance in 5 levels	Severity Index, Frequency Ind. and Importance Molex	NO
19	Koushki et al.	Kuwait	2005	private	residential	Mailed Questionnaire	Owners	owners (450)	8	1	effect on project delay in (0.0..,0	months	NO
20	Haseeb et al.	Pakistan	2011	N/A	large projects	Questionnaire	Defined classification.	120 participants	37	7	grade then significant in 4 levels	Mean then critical index	NO

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21	Le-Huai et al.	Vietnam	2008	N/A	building and industrial construction mini •-t	INTERVIEW QUESTIONNAIRE	Owner, consultant and contractor).	Owners (29), consultant (20) and contractor (38).	21	6	Ikert Scale in 4 level	Severity Index, Frequency Index and Importance Index	Spearman Correlation Coefficient
22	EI-Sayegh	UAE	2008	N/A	N/A	Mailed Questionnaire	Owners, Consultants, Contractors & nnnct, ctinn	Owners (13), Consultants (10), Contractors	42	1	Importance in 4 levels	RII relative importance index	Spearman Correlation Coefficient
23	Kartam and Kartam	Kuwait	2001	N/A	N/A	Mailed Questionnaire	Contractors	Contractors (35)	26	1	Significant in three levels and 10 points rank	weight score	NO
24	Tommy et al.	Hong Kong	2006	Public	N/A	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (55), Consultants (48) & Contractors (48)	30	7	Importance in 5 levels	RII relative importance index	Rank Agreement Factor
25	Kaliba et al.	Zambia	2009	Public	Road	Mailed Questionnaire	Owners, Consultants & Contractors	total number of 60 - not drfinrf cote • nixes	14	1	Importance in 5 levels	weighted average	NO
26	Tumi et al.	Libya	2009	N/A	N/A	Mailed Questionnaire	Contractors	not defined	43	1	not defined	&Vera • El	NO
27	Kaming et al.	Indonesia	1997	N/A	high due building •Is	Mailed Questionnaire	sro'ect mana•ers	31 • ro'ect mana•er	11	1	Importance in 5 levels	Severity Index, Frequency Ind. and Importance Index	NO
28	Fallahnejacl	Iran	2013	Public	Gas pipe line project	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (10), Consultants (8) & Contractors (7)	43	9	Importance in 5 levels	Severity Index, Frequency Index and Importance Index	Spearman Correlation Coefficient

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29	Pourrostam and Ismail	Iran	2011	N/A	N/A	Mailed Questionnaire	Contractors & Consultants	not defined	27	1	Importance in 5 levels	RII relative importance index	Spearman Correlation Coefficient
30	Ariz	Egypt	2013	Public &	Buildings	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (27), Consultants (196) & Contractors (2277)	99	9	Importance in 5 levels	RII relative importance index	NO
31	Marzouk and El-Rases	Egypt	2014	N/A	N/A	Interview Questionnaire	Owners, Consultants & Contractors	Owners (11), Consultants (11) & Contractors (11)	43	7	Importance in 5 levels	Severity Index, Importance Index - no use for *freupnev in..,*	NO
32	Doloi et al.	India	2012	N/A	N/A	Interview Questionnaire	Owners, Consultants & Contractors	Owners (21), Consultants (13) & Contractors (33)	45	6	Importance in 5 levels	RII relative importance index	NO
33	Sweis et al.	Jordon	2008	N/A	N/A	Interview Questionnaire	Owners, Consultants & Contractors	Owners (26), Consultants (29) & Contractors (36)	40	8	Importance in 5 levels	average values	NO
34	Aibinu and Odeyin	Nigeria	2006	N/A	N/A	Mailed Questionnaire	construction managers	construction manager.. (100)	44	8	Importance in 5 levels	RII relative importance index	The Kendall's
35	Albogamy et al.	Saudi Arabia	2012	N/A	N/A	Mailed Questionnaire	Not defined classifications	98 Questionnaire	63	4	Importance in 5 levels	Severity Index, Importnace Index - no use for *freupnev in..,*	NO

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36	Faridi and E4 Sayegh	UAE	2006	N/A	N/A	Mailed Questionnaire	Contractors & Consultants	Contractors (52) & Consultants (46)	44	7	Importance in 5 levels	RII relative importance index	Spearman Spearman Correlation
37	Al-Kharashi a and Skitmon Saudi	Arabia	2009	N/A	N/A	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (20) , Consultants (31) & Contractors (35)	112	6	Importance in 5 levels	weighted average	Spearman Spearman Correlation
38	Ayudhya	Singapore	2011	N/A	building & residential	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (14), Consultants (20) & Contractors (40)	35	1	severity in 5 levels	Severity Index	Spearman Spearman Correlation
39	Salome et al.	UAE	2008	Public	Oil and gas projects	Interview & Questionnaire	Not defined classifications	37 respondents	35	1	Importance in 5 levels	RII relative importance index	NO
40	Motolob sod Kfahk	UAE	2010	N/A	N/A	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (8) , Consultants (15) & Contractors (12)	42	5	Importance in 5 levels	RII relative importance index	Spearman Correlation Coefficient
41	Tabtabl	Kuwait	2002	Public	hotel. ballet.	Mailed Questionnaire	Cerie., Consultants & Contractors	Owners (23) , cooffoltooto (8) & Contractors (17)	53	8	Importance in 5 levels	RII relative importance index	Rgo. Agreement Factor
42	Sambasivan and Soon	Malaysia	2007	Public & Private	N/A	Mailed Questionnaire	Owners, Consultants & Contractors	Owners (67) , Consultants (48) & Contractors (35)	28	8	Importance in 5 levels	RII relative importance index	Spearman
43	Fuger *8.* Agyakwah-Baah	Ghanna	2010	Public	N/A	interview 8 CI ire	Owners, Consultants & Contractors	Owners (37), Consultants (54) & Contractors (39)	32	9	importance in 5 levels	Relative importance Weight (RIW)	Spearman

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44	Assaf and Al-Hejji	Saudi Arabia	2005	Public	N/A	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (15). Consultant. (10) & Contractors (23)	73	9	Importance in 5 levels	Severity index, Frequency index and importnace inf..	Spearman Correlation CoeMcient
45	Faiqi	Saudi Arabia	2004	N/A	Buildings	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (5). Consultants (24) & Contractors (18)	57	10	Frequency & Severity in 4 levels	Fequency index, severity index and important index	NO
46	Faiqi	UK	2004	N/A	Buildings	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (5). Consultant. (10) & Contractors (11)	57	10	Frequency 8. Severity in 4 levels	Fequency index, severity index and important index	NO
47	Ahmed et al.	USA	2003	N/A	N/A	PAalled Questionnaire	contractors	contractors (35)	50	5	chance of occurance In 5 levels	weighted average	NO
48	Akinsiku and Akinsulire	Nigeria	2012	N/A	N/A	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (5). Consultants (17) end contractor. (15)	33	1	importance in 5 levels	weighted average	NO
49	KAZAE et al.	Turkey	2.2	N/A	N/A	CI ire In two rounds	Contractors	Contractors (71)	34	7	Importance in 5 levels	relative importance index	NO
50	PAahamid et al.	Paiestain	2012	Public	Road		Contractors & Consultants	Contractors (34) 8. Consultants (30)	52	8	Severity in 5 levels	Severity index	Spearman Spearman Correlation
51	Kikwasi	Tanzania	2012	N/A	N/A	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (7). Consultant. (13) end contractor. (20)	21	1	Importance in 4 levels	Ril relative importance index	NO

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52	Niazal and Gidado	Afghanistan	2012	N/A	N/A	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (7). consultants (5) and contractors (I)	83	9	Importance in 5 levels	Ril relative importance index	Spearman Spearman Correlation
53	Renw et al.	UAE	2008	N/A	Large projects	PAalled Questionnaire	Contractors in two rounds	Controators (52) in first round, 10 in second round	53	3	severity in 5 levels	average based on (100% for 5,, 85% for , 85% for 3, 4SIX, fnr 2 *and* VS%	NO
54	PAnzher Towel	Lebanon	1998	Public & Private	large projects	PAalled Questionnaire	Owners, Consultants & Contractors	Owners (11), Consultants (10) & Contractors (1S)	54	10	Importance in 4 levels	RII relative Importance index	Spearman Correlation CoeMcient

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Table 2: Frequency of researches in countries.

Country	No of researches
Afghanistan	1
Canada	1
Egypt	4
Ghana	2
Hong Kong	2
India	1
Indonesia	1
Iran	2
Jordon	2
Kuwait	4
Lebanon	1
Libya	2
Malaysia	2
Nigeria	4
Pakistan	1
Palestine	1
Saudi Arabia	6
Singapore	1
Tanzania	1
Thailand	1
Turkey	2
UAE	5
UK	3
USA	2
Vietnam	1
Zambia	1
Total	54

Ellis and Thomas searched for the root delay causes of highway project through interviews with industry personnel. This work was limited for the highway projects [14]. Majid and McCaffer defined the root delay causes for only non-excusable delay causes. In this research, the root delay causes for building projects that were used in previous research work will be analyzed to search for their root delay causes [15].

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In this study, fifty-three delay causes were gathered from previous research work. These causes will be exposed to more deep analysis to get there root delay causes. The delay causes that are due to external or force-major were excluded from this study. The delay causes are categorized in nine groups of delay causes. Table 3 shows the used delay causes and their categories.

Table 3: Delay causes used.

Group	Delay cause	Group	Delay cause
Preconstruction related delays	Owner's failure to co-ordinate with government authorities in pre-construction stage	Designer related delays	Design changes and modification by consultants
			Ambiguities, mistakes and inconsistencies in design specification and drawings
			Design complexity
			Delay in taking actions regarding material, shop drawing approval and providing design information
	Unrealistic contract tender price	Client related delays	Delay in contractors progress payments
			Owner financial problems
			Design changes by owner
			Owners' poor communication with the construction parties and government
			Deficiencies in owners organisation
			Interference by the owner in the construction operations
			Slow decision making by the owner
			Excessive bureaucracy in the owners administration
	Improper technical study by the contactor during the bidding stage	Project related delays	Site possession
			Difficulties in obtaining work permit from public authorities
			Mistakes and discrepancy of contract clauses
			Inefficient delay penalty
			Weather delay conditions
			Unrealistic contract price or time
			Effects of subsurface site conditions materially differing from contract documents
			Project Delivery System
	Delay in mobilisation from contractor	External related delays	High inflation
			Strikes
			Changes in government regulation and laws
	Delay of shop drawing approval		
	Original contact duration is too short		
	Preparation and approval of planning and network schedule before or short after		
	Problems due to project delivery system		
	Delay to furnish and deliver the site to the contractor by the owner		
Material related delays	Unavailability of required materials		

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	Delay in material delivery	
	Damage material in store	
Labour related delays	Unavailability of manpower (skilled, semi-skilled and unskilled)	
	Low skill of manpower	
	Low labour productivity	
Equipment related delays	Unavailability of required equipment	
	Failure of equipment	
	Unskilled equipment operator	
	Equipment productivity	
Contractor related delays	Shortage of technical professionals in the contactors organisation	
	Ineffective planning and scheduling of the project by the contractor	
	Improper construction method implemented by the contractor	
	Difficulties in financing the project by the contractor	
	Problems between the contractor and suppliers, subcontractors	
	Accidents during construction period	
	Unsuitable leadership of contractors construction manager	
	Inefficient contractor site management	
	Delay in taking action	
	Contractors poor co-ordinator with the parties involved in the project	

II. Research Methodology

More than fifty researches were globally conducted to define delay causes in construction projects. From this huge number of researches, fifty-three delay causes were collected and all of them were used in most of previous research work. These delay causes are categorized into nine groups of delay causes. These categorizes were based on internal project contributors and external causes. Cause and effect technique was applied to extract root delay causes for the delay causes groups. A group of root delay causes was resulted from cause-effect analysis.

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To validate the resulted root delay causes, a questionnaire was designed and distributed for selected construction projects experts. A sample of personal experts that participated in this study was selected from the Kuwaiti construction industry where the author is living and working in. Kuwait state as a gulf country is featured by multinational construction personnel. More than 100 nationalities are working in construction industry in Kuwait. All of these people gained their experience in their home construction industry and enhanced during their professional work in Kuwait. So Kuwait construction industry can be seen as a repetitive for globally construction industry.

Fifty-eight experts were contacted to participate in this study, thirty of them agreed. First, a phone call was conducted with the participant to illustrate the purpose of study. A copy of questionnaire was sent (faxed or emailed) to the participant before conducting the questionnaire interview session. The participant is asked to make an appointment to conduct the interview questionnaire session. Thirty interview sessions with industry personnel have been held with the participants. A structured questionnaire interview was held between the author and the participant. The interview questionnaire session took about 1.5 hours. The interview was held mainly in project site. The participant is asked to evaluate the level of importance of the listed root delay causes. Statistical analysis such as mean value and standard division were conducted for the interview questionnaire results. Factor analysis is used to test if there is any possibility to reduce the number of resulted root delay causes. Correlation analysis is used to check the independency of resulted root delay causes.

Extract Root Delay Causes for Construction Projects

Kaoru Ishikawa developed the cause-effect diagram in 1943, who pioneered quality management processes in the Kawasaki shipyards [16]. Both researchers and industry personnel used to use cause-effect technique to derive derive the root causes of a predefined problem. In construction industry, Tah and Carr used cause and effect technique to identify the relationships between risk factors and their consequences [17]. Sambasivan and Soon studied causes and effects of delays in Malaysian construction industry [18]. Manavizha and Adhikarib linked the material-related causes to the probable cost overruns in construction projects in Nepal [19]. Assaf and Al-Hejji linked the contractor-related and labor-related causes to the probable time overruns in construction projects in Saudi Arabia [20]. Chan and

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Kumaraswamy linked the consultant- related and client-related causes to the probable time overruns in construction projects in Hong Kong [21].

In cause and effect analysis technique, a diagram is used to identify the possible causes for a defined problem. The problem or the effect is drawn as a trunk or the back bone for a fish and the possible causes are drawn the branches or the bones for the fish.

Each one of the delay causes that were collected from previous research, which listed in Table 3, will be analyzed to extract its root delay causes by the cause-effect diagram technique.

The causes of delays are categorized into nine main groups based on the time of delay occurrence or the responsibility for delays as shown in Table 3. These groups are:

1) Preconstruction related delays
2) Material related delays
3) Labor related delays
4) Equipment related delays
5) Contractor related delays
6) Designer related delays
7) Owner related delays
8) Project related delays
9) External related delays

The cause-effect technique will be applied for each group of delay causes except the external related delays. External delay causes were excluded because external delay causes cannot be controlled or assessed before project start. Most of external delay causes are covered in usual forms of contract.

As examples, Fig. 1 shows the cause-effect application for equipment related causes of delays and Fig. 2 shows Cause-effect application for contractor related causes of delay. Cause-effect technique is used for all of the other of eight groups of delay causes.

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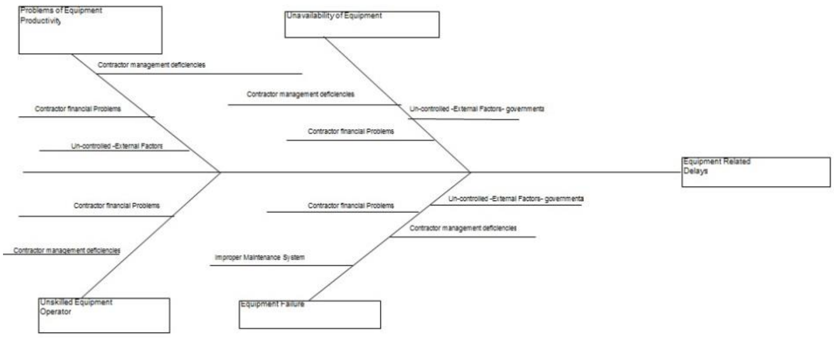

Fig. 1: Cause-effect diagram for equipment related delay causes.

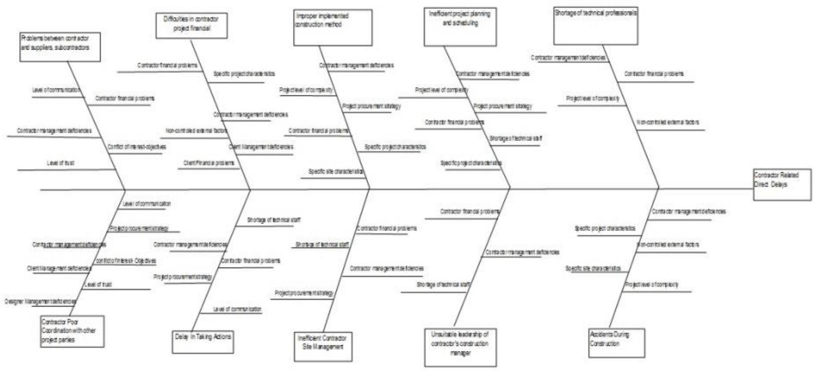

Fig. 2: Cause-effect diagram for contractor related delays.

In Fig. 1, the equipment related delays causes that are found from previous studies as shown in Table 3 are:

- Unavailability of required equipment
- Failure of equipment
- Unskilled equipment operator
- Low equipment productivity

To get the root delay causes for equipment related direct delays, as an example equipment unavailability can result from the inefficiency of the contractor's management efficiency to plan the requirements of equipment, orient the equipment when it is required, and make the required maintenance system that ensures the equipment is ready when it is required. On the other hand, it can result from the contractor's financial problems that do not enable the

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contractor to fund the equipment purchasing or leasing when it is required. Equipment unavailability may also result from many unexpected or uncontrolled causes.

Applying the same technique for the rest of branches, the root delay causes for equipment related direct delays as shown in Fig. 1 are:

1. Contractor management deficiencies
2. Contractor financial problems
3. Uncontrolled external factors

In Fig. 2, another example for the contractor related direct delays that are found in past research work, as shown in Table 3, are:

- Shortage of technical professionals in the contractor's organization
- Ineffective planning and scheduling of the project by the contractor
- Improper construction method implemented by the contractor
- Difficulties in financing the project by the contractor
- Problems between the contractor and suppliers, subcontractors
- Accidents during construction period
- Unsuitable leadership of contractor's construction manger
- Inefficient contractor site management
- Delay in taking action
- Contractor's poor co-ordination with the parties involved in the project

To apply the cause-effect technique diagram for contractor direct delays, the root delay causes for ineffective planning and scheduling of the project by the contractor will be studied.

The contractor's plan should contain the logical sequence of project tasks, estimated duration's for tasks, the financial and labor plan requirements [22]. Any delay or failure of the contractor to prepare or submit this plan in the proper way

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and in time will expose the project to lose the control tool to manage project time performance. Using inadequate planning techniques can affect the time performance of the project [23]. Problems of planning and scheduling can be resulted by any one of the followings:

- Contractor management deficiencies either it has not the sufficient experience or has unqualified technical staff.
- Contractor's financial problems that prevent contractor from using the proper staff and/or techniques to properly plan in the proper time.
- Unfamiliarity with the procurement strategy and contracts that the project is using.
- Level of project complexity and required technology that the contractor is not familiar with or does not have.
- Specific project characteristics such as time pressures i.e. there is not enough time to use the proper planning techniques.

All the other causes of delays for contractor related group will be analyzed by the same way. Fig. 2 shows the cause and effect diagram for contractor related direct delays. The following is the list of root delay causes for contractor related direct delays:

1) Contractor management deficiencies
2) Contractor financial problems
3) Level of communication
4) Lack of trust between project parties
5) Owner management deficiencies
6) Designer management deficiencies
7) Changes of objectives between project parties
8) Specific project characteristics
9) Project level of complexity
10) Familiarity with project procurement strategy
11) Uncontrolled external factors

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List of Root Delay Causes

The cause-effect technique has been applied to obtain the root delay causes for all the causes of delays obtained from past research work which grouped into nine groups as shown in Table 3. These root delay causes can be categorized into three main categories:

(1) Root delay causes due to the project parties management efficiency for designer(s), contractor(s) and owner.

(2) Root delay causes from the inter-relationship work environment: communication, trust and agreement of project objectives.

(3) Root delay causes related to the specific project: design documents, site characteristics, project characteristics, project procurement strategy, interaction before project start and the level of project complexity.

As can be noticed from the above diagrams many of these root delay causes influence more than one delay cause. The resulted root delay causes can be listed as:

1) *Level of designer's management efficiency:* Describes the level of consultant and designer management efficiency in design and/or construction supervision work.

2) *Quality of design work documents:* Measures the level of accuracy and matching of design work documents such as drawings, specifications, documents, calculations….etc.

3) *Level of contractor's management efficiency:* Defines the level of contractor(s) technical and managerial capabilities to execute and finish project in contractual time.

4) *Contractor's financial problems:* This measures the ability of contractor(s) to fund the project and not to stop the project due to contractor financial problems.

5) *Level of owner's management efficiency:* This is the efficiency level of owner and/or owner representative(s) to provide the required information and support to finish project as scheduled.

6) *Owner's financial problems:* This measures the ability of owner(s) to fund the project and provide contractor(s) payments when required.

7) *Efficiency level of communication between project parts:* This measures the level of communication efficiency between project parties during construction phase.

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8) *Level of interactions between project parties in pre-construction phase:* Measures level of interaction between project parties before project start to union project objectives and discuss project risks.

9) *Level of trust between project parties:* Measures the level of trust between project parties to complete project as contracted.

10) *Level of project complexity and required technology:* This measures level of project complexity and required technology.

11) *Level of objectives harmony between project parties:* This measures level of matching between owner and other project parties goals.

12) *Specific site characteristics:* This measures the level of specific site characteristics in terms of location, weather, underground, environmental conditions.

13) *Specific project characteristics:* This measures the level of specific project characteristics in terms of time, cost and quality.

14) *Project contract and procurement strategy:* This measures the level of familiarity of the contract used and of the project procurement techniques.

All of these root delay causes can be assessed, measured or judged before project start and in this case, a mitigation strategy can be suggested to dilute occurrence of project delay.

Root Delay Causes Verification

The list of root delay causes extracted using cause-effect technique is verified by an interview questionnaire with construction industry personnel.

Questionnaire and Questionnaire Design

The questionnaire consists of many parts. The first part deals with general information regarding the participant such as to which type of construction entities he works, no of years' experience and in which management level he belongs.

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The second part asked the participant to estimate the level of effect of the listed root delay causes in the project time performance and project delay. The level of effect is ranged in five levels from very highly effect to no effect.

Participants Description and Sampling

The resulted of thirty experts who participated in this study was analyzed. Table 4 shows the numbers of each employer type. The experts sample is consist of: 8 experts working for client, 9 working for consultant and 13 experts working for contracting companies. Table 5 shows the years of experience for the sample participants. All the sample experts had more than 10 years of experience and eight of them have more than 20 years of experience in construction industry. Table 6 shows the participants' level of management. All of participants came from middle and top management levels.

Table 4: Participants employer type.

Employer Type	Frequency	percentage
client	8	27%
consultant	9	30%
contractor	13	43%
Total	30	100%

Table 5: Participants years of experience.

Years of Experience	Frequency	percentage
10-15 years	5	17%
15-20 years	17	57%
bigger than 20 years	8	26%
Total	30	100%

Table 6: Participants level of management.

Management level	Frequency	percentage
Site Management level	0	0.00%
Middle Management Level	18	60.00%
Top Management Level	12	40.00%
Total	30	100.00%

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Statistical Analysis

Descriptive analysis: The participant is asked to evaluate the level of effect of construction project root delay causes. The participant is asked to evaluate this level in five Likert scale varying from very high effect to no effect. The respondent's answers for each one of the root delay causes are statistically analysed. Table 7 shows the mean and standard deviation for the sample data regarding root delay causes effect on project delay. Mean value is calculated as per Equation 1

$$Mean\ Value = \frac{Wi*Ni}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

Wi is the weight for each level. The level is ranged from 5 to very high effect to 1 for no effect. *Ni* frequency for each respondents' level of effect. *N* total respondent numbers.

Table 7: Sample mean and standard deviation for root delay causes.

Root Delay Cause	Root delay cause code	Mean	Std. Deviation
Designer management deficiencies	DM	3.433	1.224
Quality of design work documents	DD	3.4	1.037
Contractor management deficiencies	CM	4.3	0.75
Contractor financial problems	CF	4.233	1.006
Client management deficiencies	OM	3.633	0.765
Client financial problems	OF	4.167	1.117
Efficiency level of communication	MM	3.8	0.805
Level of interactions in preconstruction stage	NT	2.9	1.094
Trust between project parties	TR	2.667	1.093
Level of project complexity and required technology	CT	2.867	1.196
Level of objectives harmony	OB	3.133	1.137
Site characteristics	SC	3.533	0.973
Project characteristics	PP	3.5	1.414
Project contract and procurement strategy	PS	3.833	1.02

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Benjamin and Cornell 1970 suggested that, to accept a criteria or proposed variable, it should meet two conditions:

1. Respondents' mean value is equal to or more than the average as defined in the Likert scale.

2. Experts' response standard deviation is less than 1.

Any root delay cause satisfies the above two conditions will be accepted as a root delay cause and verify the analysis technique that is used to extract the root delay causes.

The respondent's answers for each one of the root delay causes are statistically analysed. Table 7 shows the mean and standard deviation values for the sample data regarding root delay causes effect on project delay. There are four-root delay causes satisfy the above-mentioned conditions, which are:

- Contractor management deficiencies
- Client management deficiencies
- Efficiency level of communication
- Site characteristics

While there are three additional root delay causes are near to satisfy the conditions, which are:

- Quality of design work documents
- Contractor financial problems
- Project contract and procurement strategy

There are three delay causes have mean value less than 3, which is mean value and standard deviation more than 1, which are:

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- Level of interactions in preconstruction stage
- Trust between project parties
- Level of project complexity and required technology

The other four root delay causes have mean values more than the average of the sample.

The statistical analysis verifying the method of analysis to get root delay causes.

So the question arises that "is any possibility to reduce the number of root delay causes based on the participants' answers. Factor analysis will be used to test if there is any possibility to reduce the number of variables.

Factor Analysis for Root Delay Causes

Factor analysis is used to explore the possibility of an under lying structure in a set of interrelated variables without imposing any preconceived structure on the outcome [24]. Factor analysis is a statistical technique widely used in psychology and social science. In some branches of psychology, it is necessary to use it in questionnaire analysis. Factor analysis is defined generally as a method for simplifying a complex set of data [25].

Factor analysis is a statistical approach that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors). The statistical approach involves finding a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with a minimum loss of information.

(Benjamin and Cornell 1970) suggested the factor analysis value of extraction less than 0.5 should be excluded from the list of variables. Factor analysis can be applied to any set of variables, but most often between 10 and 100. The factor analysis based on correlation analysis and extraction of principal components amounts to a *variance maximizing (varimax)* rotation.

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To check if the root delay causes can be reduced causes. A factor analysis using SPSS 18 software is used to test the sample. Table 8 describes the results. Table 8 shows the extraction values of factor analysis.

Table 8: Extraction values for factor analysis of root delay causes.

Root Delay Cause	**Initial**	**Extraction**
Designer management deficiencies	1	0.907
Quality of design work documents	1	0.651
Contractor management deficiencies	1	0.787
Contractor financial problems	1	0.671
Client management deficiencies	1	0.708
Client financial problems	1	0.731
Efficiency level of communication	1	0.756
Level of interactions in preconstruction stage	1	0.971
Trust between project parties	1	0.855
Level of project complexity and required technology	1	0.971
Level of objectives harmony	1	0.749
Site characteristics	1	0.809
Project characteristics	1	0.819
Project contract and procurement strategy	1	0.633

All the initial values should be 1.00 for correlation, extraction are estimates of the variance in each variable accounted for by the components. The extraction in this Table 8 is more than 0.5, which indicates that the extracted components represent the variables well. The possibility to reduce variables is not supported.

Check the Independency of Root Delay Causes Variables

Table 9: Root delay causes correlations coefficients.

	DM	**DD**	**CM**	**CF**	**OM**	**OF**	**MM**	**NT**	**TR**	**CT**	**OB**	**SC**	**PP**	**PS**
DM	1	0.717	0.18	-0.231	0.152	0.597	0.588	0.5	0.661	0.468	0.524	-0.1	-0.1	-0.046
DD	0.717	1	0.284	0.073	0.061	0.744	0.347	0.462	0.639	0.573	0.392	0.123	0.123	0.098
CM	0.18	0.284	1	0.315	0.559	0.309	0.446	0.584	0.421	0.431	0.235	0.198	0.198	0.609
CF	-0.231	0.073	0.315	1	0.249	0.118	-0.068	0.241	0.167	-0.145	-0.119	-0.167	-0.167	0.308
OM	0.152	0.061	0.559	0.249	1	0.195	0.213	0.697	0.509	0.02	0.375	0.225	0.225	0.582
OF	0.597	0.744	0.309	0.118	0.195	1	0.345	0.466	0.668	0.482	0.607	-0.053	-0.053	-0.005
MM	0.588	0.347	0.446	-0.068	0.213	0.345	1	0.525	0.313	0.473	0.219	0.009	0.009	0.378
NT	0.5	0.462	0.584	0.241	0.697	0.466	0.525	1	0.721	0.385	0.566	0.149	0.149	0.541
TR	0.661	0.639	0.421	0.167	0.509	0.668	0.313	0.721	1	0.413		4022	0.	0.166
CT	0.468	0.573	0.431	-0.145	0.02	0.482	0.473	0.385	0.413	1	0.521	0.034	0.034	0.179
OB	0.524	0.392	0.235	-0.119	0.375	0.607	0.219	0.566	0.786	0.521	1	0.027	0.027	0.05
SC	-0.1	0.123	0.198	-0.167	0.225	-0.053	0.009	0.149	-0.022	0.034	0.027	1	1	0.475
PP	-0.1	0.123	0.198	-0.167	0.225	-0.053	0.009	0.149	-0.022	0.034	0.027	1	1	0.475
PS	-0.046	0.098	0.609	0.308	0.582	-0.005	0.378	0.541	0.165	0.179	0.05	0.475	0.475	1

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Table 9 represents the correlation coefficient between root delay causes as resulted from SPSS 20 software. Coding for each root delay cause is used as serial for the fourteen root delay causes. As can be noticed from Table 9, all the coefficients are not high (to be taken into consideration as a close correlation, they should not be less than 0.75). This means that all the root delay causes are independent and the assumption that all the root delay causes are independent variables is correct can be interpreted the factor analysis result.

III. CONCLUSION

In spite of intensive globally research work in defining and ranking construction project delays, limited effort has been conducted to extract their root delay causes. Cause-effect technique was used to extract root delay causes for the used researched delay causes gathered from previous work. Fifty-three delay causes are gathered and grouped into nine delay causes groups based on the causative. Fourteen root delay causes were resulted. These root delay causes can be categorized into three main categories:

1. Root delay causes due to the project parties management efficiency for designer(s), contractor(s) and owner.
2. Root delay causes from the inter-relationship work environment: communication, trust and agreement of project objectives.
3. Root delay causes related to the specific project: design documents, site characteristics, project characteristics, project procurement strategy, interaction before project start and the level of project complexity.

All the fourteen root delay causes were verified through a semi-structured interview questionnaire with thirty of construction management experts. Questionnaire results revealed that the resulted root delay causes are verified and statistically confirmed. These root delay causes can be measured or evaluated either before the project start or during the project life. By using these measures or evaluation, the project prone to delay can be anticipated. Further research work will be conducted to test and measure the resulted root delay causes and how to be used as a warning signal of project delay. Any effort to control root delay causes will enhance the construction project time performance.

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