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RESEARCH ARTICLE

FUZZY MODEL TO PREDICT AMOUNT OF DELAY IN THE CONSTRUCTION OF PUBLIC UNIVERSITIES PROJECTS

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ABSTRACT

The kingdom of Saudi Arabia is one of the largest developing counties at the current time. Currently, a huge public construction work is running in the kingdom. It was observed that many of public construction projects are exposed to extensive delays especially in public universities construction projects. These delays will affect greatly the educational sector through: 1) Loss of benefits for all stakeholders, 2) Decrease of quality due to rapid execution in construction to recover the delayed time, 3) Delay of the start of related projects, and 4) Increase of claims and disputes between project parties. The main objectives of this research is to identify the main delay causes in public universities construction projects and to develop a fuzzy system to estimate the expected percentage of delay in the construction of public universities projects. This system will enable project owner and contractor to estimate the percentage of delay based on assumed construction related circumstances. The proposed system is implemented using *MATLAB* software. The research methodology will include identification of the most critical causes of delays through literature review and by conducting Delphi Technique with the help of a selected panel of domain experts. The main concept of Delphi technique is to achieve an agreement in different opinion of experts that will facilitate the determination of critical causes. Twelve critical causes of delay were identified. Those critical causes are used as input variables for the fuzzy system. Each critical cause will be identified in the form of membership functions. The relations between the critical causes are built by using a set of if then Rule. The proposed systemis validated using 14 actual cases collected from king Abdulaziz University and Taibah University projects. The validation results were satisfactory.

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INTRODUCTION

Saudi Arabia, as one of the largest developing country, is supporting many public projects with an amount of 78 billion SR in (2007) that increased to 121 billion SR in (2012) (SSCE (2012)). These amounts jumped to 248 billion SR in (2014) based on the 9th development plan (2013). As mentioned by SSCE (2012), delays in public construction projects were identified through a study conducted by principality of Makkah Al-Mukarrama. The study showed amount of delay in 294 projects out of 2262 project with percentage of 13% and total losses by 44 billion SR for years 2008 to 2012. Most of delayed projects were in health and educational sectors. This research work will focus on delay of public universities construction projects. This is because this sector constitute 16% of construction budget according to the 9th development plan (2013). Also, this plan showed that the estimated number of students in higher education is 1,206,000 (male & female) with yearly annual growth of 18.1%. The main objectives of this research are: 1) identifying the main delay causes in public universities construction projects, 2) develop a fuzzy system to estimate the expected amount of delay in such projects, 3) validate the fuzzy system using real life cases from King AbdulAziz University (KAU) and Taibah University (TU), and 4) suggest mitigation measures to minimize the effects of delay causes in the construction of public universities.

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Literature review

There are many studies that addressed the effect of delay in construction projects. Table 1 presents previous studies about delay effects and its causes.

Several research works were done to study the effect of delays on the success of construction operations. Table 2 summaries the findings of these researches.

Table 1. List of previous Studies about delay causes in construction

Author (Year)	Brief description of the study	Important factors/ group causing delay
Assaf, Al-Khalil and Al-Hazmi (1995)	Conducted a survey to identify causes of delay in large building construction projects. 56 causes of delay were identified.	Preparation and approval of shop drawings by contractor, progress payment by owner, cash problems during construction for A/E, schedule between contractor and subcontractor, slowness indecision making by owner, design error, excessive bureaucracy in project owner organization, labor shortage and inadequate labor skills.
Al-Khalil and Al-Ghafly (1999) A	Studied important Causes of delay in public utility projects; as a result, 60 potential delay causes were identified and grouped into 6 major categories of delay.	Shortage of man power, contractor's poor coordination, delay in mobilization, poor qualification of contractor, improper technical study, ineffective planning and scheduling, ineffective control, delay in submissions, contractor's cash flow problem, delay in contractor claims by owner, slow decision making by owner, owner's poor communication, owner failure to coordinate with authorities, excessive bureaucracy by owner, change in project scope, ineffective delay penalty, difficulties in obtaining work permits, government tendering system problem and effect of subsurface condition.
	Brief description of the study	Important factors/ group causing delay
Al-khalil and Al-Ghafly (1999) B	Conducted a survey to investigate three components of delay in public utility projects. (1) the frequency of delayed projects which was 37% as an average.(2) the extent of delay which was 39% as an average.(3) the responsibility of delay which assigned 30% by contractor to owner. While owner and consultant assigned 57% and 52% respectively to contractor.	Cash flow and financial difficulties, delay in work permits, government assigning contractor to the lowest bidder without regards of qualification, no systematic approach or procedure for setting contract duration by owner.
Abd El-Razek et al. (2008)	Identified the main causes of delay in construction projects in Egypt. 32 causes of delay were obtained.	Financing by contractor during construction, delays in contractor's payment by the owner, design change by the owner or his agent during construction, partial payments during construction, nonutilization of professional construction/contractual management.
Al-Kharashi and Sketmore (2009)	Carried out a survey to identify delay causes and located 112 factors that are causing delays in public construction projects and grouped them into 6 categories.	lack of qualified, lack of experienced personnel, innovative, construction projects, associated current undersupply of manpower in the industry
Mahamid et al. (2012)	Conducted a study to investigate delays in road construction projects. 52 causes of delay were identified.	Political situation, segmentation and limited movement between areas, award project to the lowest bid price, progress payment delay by the owner, shortage of equipment.
Venkatesh et al. (2012)	Investigated the causes of delays in Indian construction projects. 45 causes of delay were identified.	Shortage of labor and shortage of material.

Table 2. List of previous Studies about fuzzy set theory

Author (Year)	Important factors/ group causing delay
Oliveros and Fayek (2005)	Listed causes of delay, categories delay, estimating delay durations by fuzzy logic, procedure for updating schedule, procedure to evaluate effecting consequence of delay and As-built data base integration with schedule.
Moselhi and Al-Kass (2006)	Addressed the effects of a number of factors that indicates cost overruns and schedule delays by using fuzzy logic.
Gunduz, Nielsen and Ozdemir (2015)	Identified 83 delay factors to make a decision support tool. Delay assessment is done by using fuzzy set theory. The model is developed using commercial software product.

Table 3. Domain experts details

Party	Title	Experience (Years)	No. of experts
Owner	Project Manager	15	1
	SeniorEngineer	12 &13	2
	Project Supervisor	5-8	3
Consultant	Project Manager	22 & 27	2
	Contract Manager	25	1
	Senior Engineer	21	1

Table 4. Classification of delay causes in surveys

Class	Range
Very High	81-100
High	61-80
Medium	41-60
Low	21-40
Very Low	0-20

Table 5. Summary of locating most critical causes of delay using Delphi Technique

Number	Delay Causes	1st Round % of Opinion	2nd Round % of Opinion	3rd Round % of Opinion	Difference Between 2nd& 3rdRounds (%)
1	Delay in Change order approval by client	64 (H)	65 (H)	66 (H)	2%
2	Government Tendering system problem (award to lowest bidder only…)	53 (M)	53 (M)	-	-
3	Change in project scope & specification	47 (M)	47 (M)	-	-
4	Changes in government regulation and laws	12 (L)	-	-	-
5	Delay in Change order prepared by contractor	47 (M)	47 (M)	-	-
6	Complexity level of the project	21 (L)	-	-	-
7	Scope is not well defined	20 (VL)	-	-	-
8	Improper technical study during bidding stage	56 (M)	56 (M)	-	-
9	Unforeseen subsurface condition on site	29 (L)	-	-	-
10	Ineffective delay penalty	49 (M)	65 (H)	73 (H)	11%
11	Contract duration is too short	26 (L)	-	-	-
12	Not applying engineering method to estimate project duration	45 (M)	45 (M)	-	-
13	Ineffective planning and scheduling by contractor	63 (H)	72 (H)	83 (VH)	13%
14	Low incentive to be ahead of schedule by contractor	48 (M)	48 (M)	-	-
15	Late in approving design documents by owner	30 (L)	-	-	-
Number	Delay Causes	1st Round % of Opinion	2nd Round % of Opinion	3rd Round % of Opinion	Difference Between 2nd& 3rdRounds (%)
16	Incompetent design	33 (L)	-	-	-
17	Conflict between design specification and building code	27 (L)	-	-	-
18	Frequent design changes	57 (M)	57 (M)	-	-
19	Mistakes by designers due to unfamiliarity with local conditions & environment	40 (L)	-	-	-
20	Late of selection finishing materials	21 (L)	-	-	-
21	Mistakes on specifications and project documents	43 (M)	43 (M)	-	-
22	Poor design	49 (M)	49 (M)	-	-
23	Variations in quantities	48 (M)	48 (M)	-	-
24	Conflicts between consultant and designer	28 (L)	-	-	-
25	Conflict between contract documents	31 (L)	-	-	-
26	Difficulties in obtaining work permits from owner	15 (VL)	-	-	-
27	Delay in work approval by owner	35 (L)	-	-	-
28	Delay in contractor claims by owner	20 (VL)	-	-	-
29	Suspension of works by owner	36 (L)	-	-	-
30	Slow decision making by owner	43 (M)	43 (M)	-	-
31	Delay in progress payments by owner	25 (L)	-	-	-
32	Delay in approving submittals by owner	27 (L)	-	-	-
33	Documents not issued on time	29 (L)	-	-	-
34	Delay in solving major disputes and negotiations	28 (L)	-	-	-
35	Nonpayment of contractor claims	16 (VL)	-	-	-
36	Delay in work approval by consultant	40 (L)	-	-	-
37	Delay in instructions from consultant	34 (L)	-	-	-
38	Delay in approving changes by consultant	37 (L)	-	-	-
39	Inflexibility(rigidity) of consultant to finalize works	43 (M)	43 (M)	-	-
40	Difficulties in obtaining work permits from consultant	27 (L)	-	-	-
41	Delay in approving of shop drawings	44 (M)	44 (M)	-	-
Number	Delay Causes	1st Round % of Opinion	2nd Round % of Opinion	3rd Round % of Opinion	Difference Between 2nd& 3rd Rounds (%)
42	Difficulties in obtaining permits from authorities	35 (L)	-	-	-
43	Delay in preparation of contractor submissions	64 (H)	60 (H)	62 (H)	3%
44	Interference by owner in construction operation	21 (L)	-	-	-
45	Shortage of materials on site or market	29 (L)	-	-	-

Continue……….

46	Low skill of manpower	63 (H)	61 (H)	65 (H)	6%
47	Fraud and cheating in execution	33 (L)	-	-	-
48	Rework due to errors of construction	38 (L)	-	-	-
49	Improper construction method by contractor	36 (L)	-	-	-
50	Inefficient quality control by contractor	55 (M)	55 (M)	-	-
51	Material quality problem	37 (L)	-	-	-
52	Nationality of labor	23 (L)	-	-	-
53	Shortage of shoring for excavation	22 (L)	-	-	-
54	Damage of stored materials	17 (VL)	-	-	-
55	Government Tendering system problem (award to lowest bidder only…)	51 (M)	51 (M)	-	-
56	Owner’s poor communication	12 (VL)	-	-	-
57	Poor qualification of Owner key personnel	39 (L)	-	-	-
58	Monthly payments difficulties	32 (L)	-	-	-
59	Complicating contract administration by owner	30 (L)	-	-	-
60	Owner poor coordination with government authorities	20 (VL)	-	-	-
61	Excessive bureaucracy in owner's administration	34 (L)	-	-	-
62	Type of project bidding and award	13 (VL)	-	-	-
63	Inadequate Owner experience.	17 (VL)	-	-	-
64	Breach/modification of the contract by owner	28 (L)	-	-	-
65	Work interference between various contractors	35 (L)	-	-	-
66	Owner’s personality problem	16 (VL)	-	-	-

Number	Delay Causes	1st Round % of Opinion	2nd Round % of Opinion	3rd Round % of Opinion	Difference Between 2nd& 3rd Rounds (%)
67	Lack of finance by owner	49 (M)	49 (M)	-	-
68	Holding other work	27 (L)	-	-	-
69	Increase in contractor’s overheads	30 (L)	-	-	-
70	Uncooperative owner with consultant & contractor	18 (VL)	-	-	-
71	Poor qualification of Consultant	50 (M)	50 (M)	-	-
72	Delay in inspection and testing works	33 (L)	-	-	-
73	Inadequate Consultant experience	38 (L)	-	-	-
74	Internal company problems (Consultant)	26 (L)	-	-	-
75	Slow response from consultant to contractor inquiries	41 (M)	41 (M)	-	-
76	Absence of consultant’s site staff	27 (L)	-	-	-
77	Shortage of Manpower	71 (H)	73 (H)	77 (H)	5%
78	Shortage of qualified engineers.	65 (H)	71 (H)	73 (H)	3%
79	Delay in mobilization	37 (L)	-	-	-
80	Cash flow& financial problem	75 (H)	74 (H)	76 (H)	3%
81	Delay in materials delivery	69 (H)	69 (H)	-	-
82	Poor qualification of Contractor	50 (M)	50 (M)	-	-
83	Shortage of equipment	35 (L)	-	-	-
84	Failure of equipment	22 (L)	-	-	-
85	Increased number of projects by the same contractor	70 (H)	75 (H)	83 (VH)	10%
86	Missing of contractor administrative personnel	31 (L)	-	-	-
87	Poor implementation of safety rules and regulations	48 (M)	48 (M)	-	-
88	Accidents during construction	24 (L)	-	-	-
89	Shortage of technical professionals persons of contractor	52 (M)	52 (M)	-	-
90	Ineffective control of progress by contractor	56 (M)	62 (H)	70 (H)	11%
91	Financing difficulties by contractor	75 (H)	74 (H)	76 (H)	3%
92	Problems between contractor and subcontractors (payments, quality, time…)	65 (H)	66 (H)	70 (H)	6%

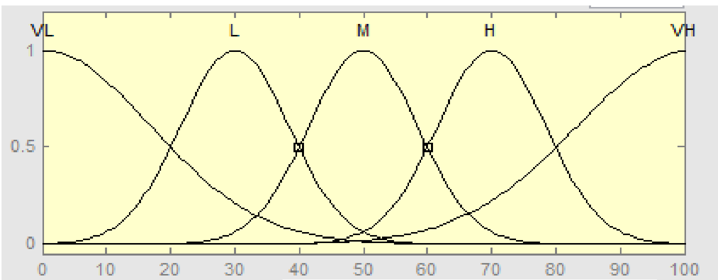
Number	Delay Causes	1st Round % of Opinion	2nd Round % of Opinion	3rd Round % of Opinion	Difference Between 2nd& 3rd Rounds (%)
93	Delay in shop drawings preparation	63 (H)	63 (H)	-	-
94	Late of procurement/ supplying materials	58 (M)	58 (M)	-	-
95	Low productivity level of labors	49 (M)	49 (M)	-	-
96	Low productivity level of equipment	29 (L)	-	-	-
97	Technical problems in project site	47 (M)	47 (M)	-	-
98	Missing information on shop drawings	34 (L)	-	-	-
99	Mistake in soil investigation	24 (L)	-	-	-
100	Breach of the contract by contractor	35 (L)	-	-	-

Continue……….

101	Ineffective contractor head office involvement in the project	64 (H)	64 (H)	-	-
102	Inefficient work break down structure	48 (M)	48 (M)	-	-
103	Poor site layout	48 (M)	48 (M)	-	-
104	Inadequate Contractor experience	41 (M)	41 (M)	-	-
105	Internal company problems (Contractor)	44 (M)	44 (M)	-	-
106	Key personal replaced	42 (M)	42 (M)	-	-
107	Rise in material prices	29 (L)	-	-	-
108	Adverse Weather conditions	17 (VL)	-	-	-
109	Poor communication between project parties	29 (L)	-	-	-
110	Poor coordination with project parties	39 (L)	-	-	-
111	Legal disputes between various parties	27 (L)	-	-	-
112	Location of the project	12 (VL)	-	-	-
113	Missing or poor organization charts to link project parties	34 (L)	-	-	-
114	poor site utilities	22 (L)	-	-	-
115	Public holidays	16 (VL)	-	-	-
116	Lack of meetings & information	33 (L)	-	-	-
117	Social and cultural conditions	12 (VL)	-	-	-
118	Conflict between project party (personal issue)	27 (L)	-	-	-

Table 6. List of the most critical Causes of Delay identified using Delphi technique

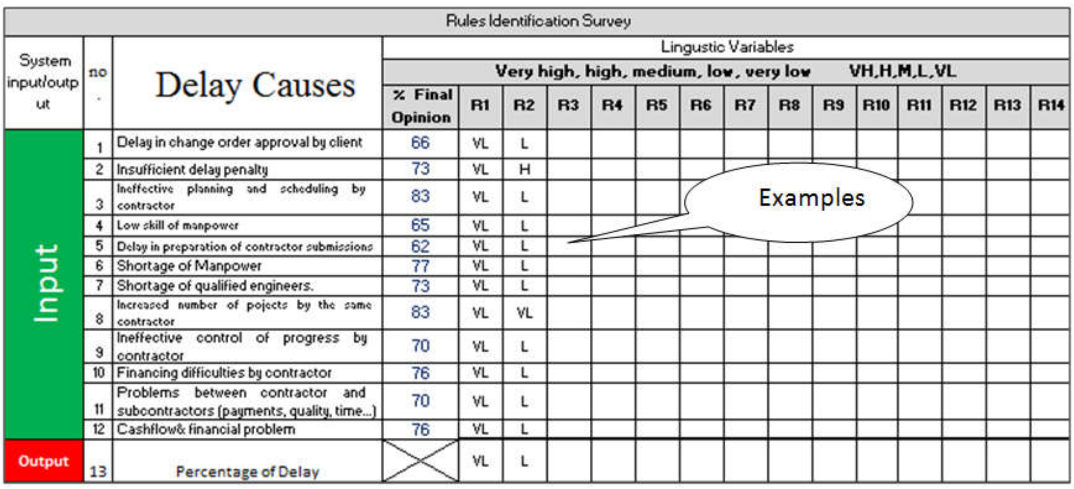
No.	Delay Causes	Final Results % of Opinion
1	Delay in change order approval by client	66
2	Insufficient delay penalty	73
3	Ineffective planning and scheduling by contractor	83
4	Low skill of manpower	65
5	Delay in preparation of contractor submissions	62
6	Shortage of Manpower	77
7	Shortage of qualified engineers.	73
8	Increased number of projects by the same contractor	83
9	Ineffective control of progress by contractor	70
10	Financing difficulties by contractor	76
11	Problems between contractor and subcontractors (payments, quality, time…)	70
12	Cash flow& financial problem	76



Y: Degree of Membership function

X: Variable (input) or (output)

Figure 1. Membership function for all linguistic variables



Rules Identification Survey

System input/output	no.	Delay Causes	% Final Opinion	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
			Lingustic Variables: Very high, high, medium, low, very low VH,H,M,L,VL														
Input	1	Delay in change order approval by client	66	VL	L												
	2	Insufficient delay penalty	73	VL	H												
	3	Ineffective planning and scheduling by contractor	83	VL	L												
	4	Low skill of manpower	65	VL	L												
	5	Delay in preparation of contractor submissions	62	VL	L												
	6	Shortage of Manpower	77	VL	L												
	7	Shortage of qualified engineers.	73	VL	L												
	8	Increased number of pojects by the same contractor	83	VL	VL												
	9	Ineffective control of progress by contractor	70	VL	L												
	10	Financing difficulties by contractor	76	VL	L												
	11	Problems between contractor and subcontractors (payments, quality, time...)	70	VL	L												
	12	Cashflow& financial problem	76	VL	L												
Output	13	Percentage of Delay		VL	L												

Figure 2. Sample of input and output scenarios in rules identification survey

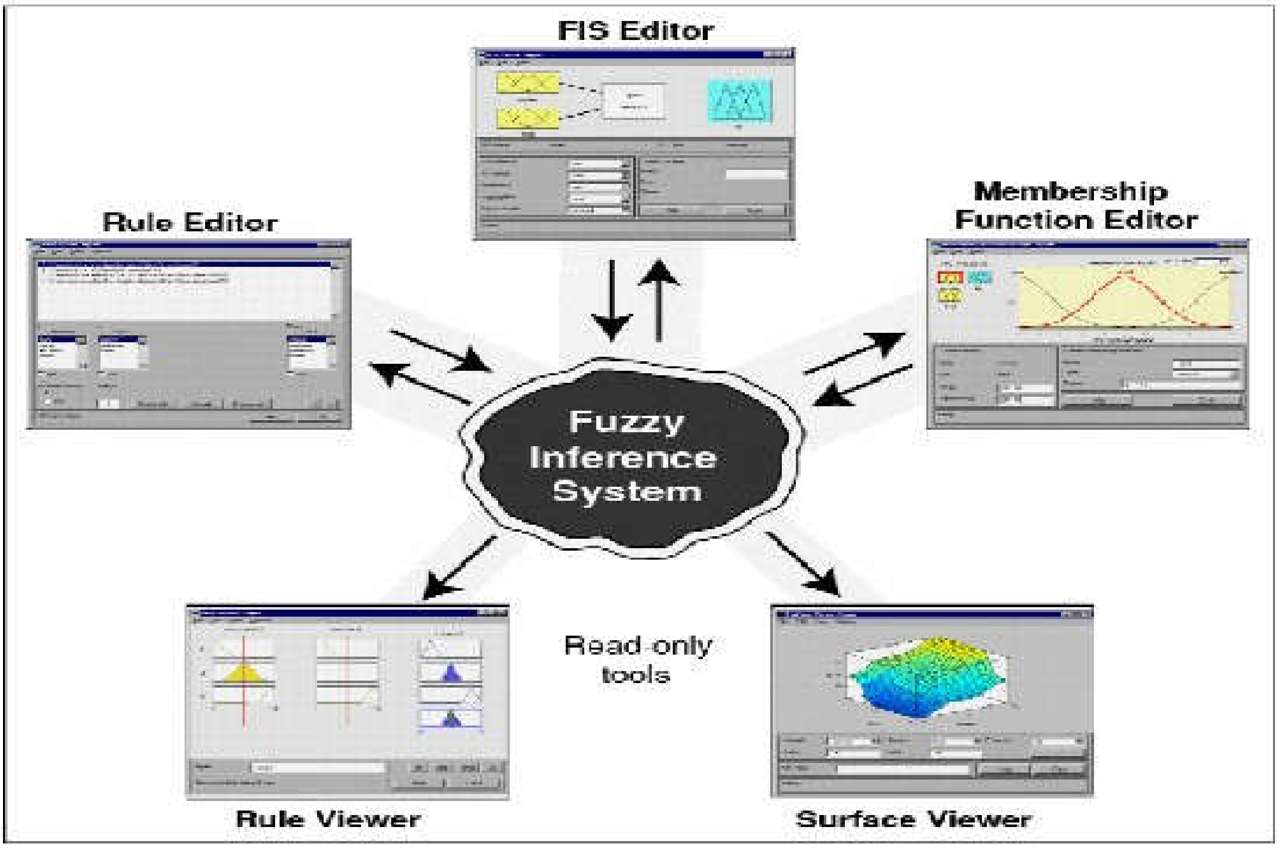


Figure 3. Graphical user interface tools to construct the fuzzy assessment model in the fuzzy logic toolbox

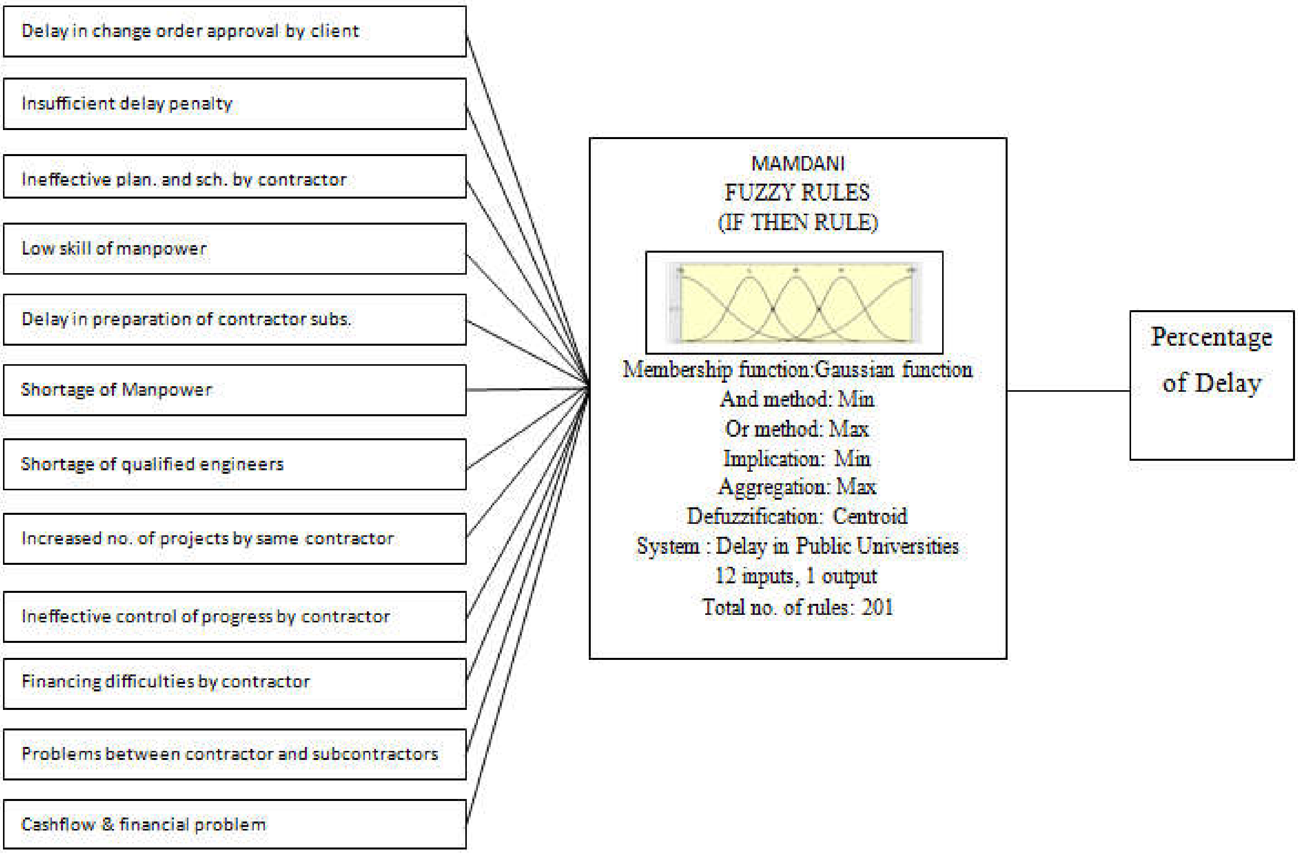


Figure 4. Fuzzy logic prototype system

Construction Projects Delays in Saudi Arabia

PART 1: General Information:

Project Title……………………………………………………………………(optional)

1- Do you have any delay in your project? ▫ Yes ▫ No

Percentage of delay…………% Project start date ……………………………

Project Duration……………………

2- Do you have time extension? ▫ Yes ▫ No

Amount of time extension ……………………………………………

Expected completion date……………………………………………

PART 2: Causes of Delay:

Rate the contribution of each of the following factors in the project delay:

No.	Causes of Delay	VH	H	M	L	VL
1	Delay in change order approval by client	☐	☐	☐	☐	☐
2	Insufficient delay penalty	☐	☐	☐	☐	☐
3	Ineffective planning and scheduling by contractor	☐	☐	☐	☐	☐
4	Low skill of manpower	☐	☐	☐	☐	☐
5	Delay in preparation of contractor submissions	☐	☐	☐	☐	☐
6	Shortage of Manpower	☐	☐	☐	☐	☐
7	Shortage of qualified engineers.	☐	☐	☐	☐	☐
8	Increased number of projects by the same contractor	☐	☐	☐	☐	☐
9	Ineffective control of progress by contractor	☐	☐	☐	☐	☐
10	Financing difficulties by contractor	☐	☐	☐	☐	☐
11	Problems between contractor and subcontractors (payments, quality, time…)	☐	☐	☐	☐	☐
12	Cash flow& financial problem	☐	☐	☐	☐	☐

Signature__________________ Date__________________

Figure 5. Model Validation form

Table 7. Sample of Fuzzy Rules (IF THEN RULE)

Rule number	If Input1	&2	&3	&4	&5	&6	&7	&8	&9	&10	&11	&12	Then, Output
1	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
43	L	H	L	L	L	L	L	VL	L	L	L	L	L
119	H	H	H	M	M	M	M	M	M	H	M	H	M
148	M	L	L	L	L	L	M	L	L	L	L	L	L
195	VH	H	VH	VH	H	VH	VH	VH	VH	VH	H	VH	VH

Table 8. Model Validation Results

No.	Project code	Actual Amount of Delay (%) = Revised finish date - Original finish date (1)	Estimated Fuzzy System Amount of Delay (%) =Calculated by fuzzy in *MATLAB* (2)	Difference (%) = | col. (1)- col. (2) |
1	1-TU	65	50	15
2	2-TU	68.1	71.1	3
3	3-TU	74.4	72.4	2
4	4-TU	49.7	55.2	5.5
5	5-TU	51.8	52.2	0.4
6	6-TU	39	52.2	13.2
7	7-TU	100	81.4	18.6
8	1-KAU	68.2	56	12.2
9	2-KAU	62.3	56	6.3
10	3-KAU	54.9	56	1.1
11	4-KAU	44.8	56	11.2
12	5-KAU	83.3	64.5	18.8
13	6-KAU	21.6	30	8.4
14	7-KAU	25.2	23.1	2.1

Research Methodology

The literature review revealed 118 causes of delay applicable to Saudi construction industry. Delphi technique is used to identify the most critical causes of delays in public university projects with the help of domain experts.23 domain experts were contacted and 10 out of them agreed to participate in the study (3 of them were From KAU and 7 from TU). This number of experts is sufficient according to Hallowell and Gambatese (2010), Table 3 presents the experts details.

The identified main causes of delays in public universities were used to develop fuzzy system using *MATLAB* to estimate the percentage of delay in this type of projects.

Identifying Causes of Delay using Delphi Technique

Delphi surveys were prepared and distributed to the experts in several rounds. In the first round, survey containing a list of 118 proposed causes of delay. It is sent to the experts asking for their opinions about the most critical causes of delays.

Filling out the survey is done by using classifications and ranges mentioned in Table 4.The results indicated no causes assigned as Very High, 13 causes assigned as High, 31 causes assigned as Medium and the rest of the causes assigned as Low and Very low. In the second round, the survey is sent to experts containing 44 identified most critical causes of delay from first round after removing Low and Very low causes. This survey asked again about identifying most critical causes of delay. The results showed 15 causes as High and 29 causes as Medium. After applying third round of survey with the same procedure of the second round but only containing the15 identified causes "rated as High" in second survey.

The results showed 2 causes as Very high, 10 causes as High and 3 causes as Medium. The twelve identified causes as Very High and High are considered to be the most critical causes of delay. Table 5 summaries all of Delphi rounds and Table6 lists the most critical causes of delay identified using Delphi technique.

Fuzzy Logic System to Estimate Amount of Expected Delay

After reaching expert's consensuses about the most critical causes of delays, shown in Table 6. A fuzzy system is developed based on Mamdani stylein fuzzy inference system (FIS) using *MATLAB*. The proposed system estimates the expected amount of delay as percentage of project original duration. The following steps are used to construct the proposed fuzzy system:

1- Input and output parameters were defined.
2- Determination of membership functions shapes for each variable.
3- Establishing the behavior of the system by defining aggregation, defuzzification and list of rules.
4- Getting plots of output value by rule viewer.

Finally, a quantifiable fuzzy system is used to estimate the expected amount of delay to help all of the project parties to overcome expected delays that may happen during construction. Figure 3 shows graphical user interface (GUI) to construct a fuzzy logic system.

Application of the model

Main Input of fuzzy system

The twelve critical causes of delay shown in Table 6 are used as the main inputs in the developedfuzzy logic system.

LinguisticVariables and Fuzzy Membership Functions

This research will use linguistic variable for inputs and output as follow: Very high (VH), High (H), Medium (M), Low (L) and Very low (VL).The range of inputs and output will be from 0 to 100. Membership functions of the inputs and output will be in a Gaussian function forms as shown in Figure 1.

EstablishingFuzzy Rules, Aggregation and Defuzzification

In this research, Mamdani Style is used due to its widespread acceptance and suitability to human brains as mentioned by Kaur and Kaur (2012).If-Then Rules are used to connect inputs with output in form of linguistic variables. Aggregation is an operation that combine fuzzy sets into single fuzzy set. Aggregation is set to *Max* method which is common in useaccording to Gunduz, Nielsen, and Ozdemir (2013). Defuzzification is used to reach fuzzy output from fuzzy sets. The most common method for Defuzzification is *center of gravity*according to Naaz, Alam and Biswas (2012)which is used in this research. If then rules were constructed by sending the survey, shown in Figure 2, to the experts asking them for giving a possible scenarios based on their experience. Each column of the Table in Figure 2 must be filledvertically by a linguistic variable VL, L, M, H, VH according to ranging scale mentioned previously in Table 4.

The total number of generated rules by experts were 201. Table 7 shows sample of fuzzy rules, these rules will be entered into FIS in the following form:

if INPUT 1 is H & INPUT 2 is VH & ..…&INPUT 12 is H *Then* OUTPUT is VH …………………(Eq.1)

Constructing Fuzzy System to Estimate Amount of Expected Delay

The Proposed fuzzy system is constructed by using GUI, shown in Figure 3, of fuzzy logic toolbox in MATLAB. First, inputs and output are defined. Second, membership function numbers, ranges and forms are entered for each variables of inputs and output. Third, the list of rules as well as the aggregation and defuzzification methods establishing the behavior of the system were defined and entered. Based on that, the system will start to work and can give a percentage result of delay. Figure 4 shows the proposed fuzzy system to estimate percentage of delay.

Fuzzy System Validation

The developed system is validated using fourteen actual delayed project cases from KAU & TU. To collect the validation data, the form shown in Figure 5 was prepared. The validation form is divided into two parts. The first part is asking about actual amount of delays and the second part asking about rating of each delay cause on scale from VH to VL. The form is filled by conducting direct interviews with the projects representatives. Fourteen construction projects were visited in both universities. The results of the second part of the form are used as inputs in the developed fuzzy system and the output from the system is compared with actual amount of delay identified by the same project respondent in the first part of the form, as shown in Table 8. The results were satisfactory because the difference between both values were reasonable. It was found that causes of delay ratings differ in both universities. Although, the model gives good results in estimating the amount of delay for both of them. It was found that High and Very High causes of delay in KAU were as follow: Financing difficulties by contractor, Problems between contractor and subcontractors (payments, quality, time…) and Cashflow & financial problem. On the other hand, in TU the following causes considered to be High and Very High by majority of respondents as follow: Insufficient delay penalty, Ineffective planning and scheduling by contractor, Delay in preparation of contractor submissions, Shortage of Manpower, Shortage of qualified engineers, Increased number of projects by the same contractor, Ineffective control of progress by contractor, Financing difficulties by contractor and Cashflow & financial problem.

Conclusion and Recommendation

This research work focused on studying delays in the construction of public universities projects. KAU & TU are used in the study because they constitute 15.3% of the total budget allocated in 2015 to public universities which equals to 54.17 billion SR as mentioned by Ministry of Education (2015). This research proposed a fuzzy system to estimate the expected percentage of delay in the construction of public universities projects. This will help owner and contractors to pay more attention regarding causes of delay to avoid project losses based on most critical causes of delay. After finishing literature review and using Delphi Technique, 12 critical causes of delay were identified out of 118 causes found. The most critical causes of delay are used as fuzzy inputs and the required output is calculated as percentage of delay. Domain experts are used to develop the fuzzy rules by assigning relations between critical causes using IF THEN RULE. Mamdani style have been used in developed fuzzy model. Aggregation was *Max* and Defuzzification method used were *Center of Gravity* which are common in use. Fuzzy system is constructed by using *MATLAB* software. Model validation was done using data collected from fourteen actual delayed projects in KAU and TU to check the proposed system accuracy, the comparison was satisfactory. The maximum difference between actual delay Vs. fuzzy system delay was 18.8 % while minimum difference was 0.4 % with overall standard deviation= 6.45 %.

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