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Research paper

Creating A Fuzzy Logic Model for Early Assessment o Payment Problems in Construction Projects In Iraq

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Abstract

The aim of this research is to create a fuzzy logic model that can aid in assessing payment problems encountered in construction projects in Iraq. The model was created based on the findings of a previous study of the authors in which (67) causes of payment problems in construction projects in Iraq were identified. The causes were ranked by (72) professionals from (38) Iraqi firms based on the frequency and severity of causes. All causes were employed in the model after categorizing them in four groups: owner-related, contractor-related, consultant-related and external causes. The model was constructed using MATLAB Program Software Version 2. Finally the model was tested against (10) real life projects and found to be appropriate to aid owners and contractors in the Iraqi Construction Industry to early assess payment problems in order to take preventive actions.

Keywords: *Construction projects, Fuzzy logic, Payment problems.*

1. Introduction

Payment problems are a common phenomenon in the construction industry. When payments are delayed, contractors find it difficult to continue while bearing daily construction expenses [1]. It is evident that payment problems lead to contractual conflicts and disputes [2]. Payment problems severely impact progress and accomplishment of construction projects within expected cost, time and quality [3]. Delayed payment is number one cause of schedule delays in construction projects with highest average percentage of occurrence [4].

On the other hand; Forecasting data related to construction works are almost stochastic and probabilistic. One of the techniques used to deal with such inexact or uncertain data is Fuzzy Logic [5]. The combination of construction management principles and fuzzy logic is commonly used in modeling construction management problems. Fuzzy Logic is used to model systems that cannot be determined precisely for it can encompass imprecision and subjectivity into model formulation and solution. It is capable to model cases with vague, imprecise and lack of information, for it facilitates handling uncertainty through a trade-off process between factors [6].

1.1. Research aim and objectives

The aim of this research is to afford a model that can aid in early assessment of payment problems in construction projects in Iraq in order to pave the way for early preventive actions. Three objectives have been set to achieve this aim:

1. Employing all possible causes of payment problems in construction projects in Iraq to create fuzzy membership functions.
2. Utilizing the frequency and impact of each cause of payment problem into the fuzzy model rules.
3. Testing the fuzzy model in real life projects.

1.2. Research justification

Delayed, short or non-payments have a direct effect on contractors' liquidity which in turn drives them to seek for additional funding by means of financial overdraft, credits or other means of finance. Otherwise they might lose their ability to continue. Thus it is essential to provide appropriate tools for payment problems assessment such as the model created in this research especially for there is no locally designed model.

1.3. Research methodology

The research was conducted according to the deduction approach. It is an exploratory research based on a quantitative analysis of payment problems causes obtained in a previous study of the authors including all necessary statistical analysis [7]. Suitable linguistic variables and fuzzy membership functions were properly determined. Fuzzy (IF...THEN) rules were constructed using the Relative Importance Index (RII) as rule's weights. Aggregation and defuzzification methods were employed to construct the model. The constructed fuzzy assessment model was tested in a real life case. The model was constructed by aid of "Fuzzy Logic Toolbox" of the MATLAB Program Software Version 2.

2. Literature review

The application of fuzzy logic in construction projects management was affirmed by:

Cheng and Roy, in (2010) developed a fuzzy model to control project performance based on cash-flow prediction. Fuzzy logic was used to address vagueness and approximate reasoning of data. Weighted support vector machine (SVM) was used for fuzzy input-output mapping based on time series data. A genetic algorithm was used as an optimization tool for search parameters. The model was able to overcome difficulties inherent to cash-flow problems, such as the complex relationship between input and output variables and the uncertainty inherent in the construction phase [8].

Liang et al., in (2011) developed a fuzzy model to solve project management decisions accompanied with fuzzy objectives. The model was utilized to minimize the total cost based on direct and indirect costs, penalties and durations against available budget. The model provides a systematic framework to enable a decision maker to modify imprecise data and parameters until a satisfactory solution is obtained [9].

Rashidi et al., in (2011) developed a fuzzy system to identify the leading criteria in selecting project managers using (IF-THEN) rules and genetic algorithm to improve accuracy. The membership function parameters were approximated by means of clustering and projection. Results showed high capability of the system in selecting project managers [10].

Kishore et al., in (2011) developed a method based on fuzzy logic to estimate the cash-flow of a package of projects considering different composition. Expert opinions regarding project selection, risk assessment and cash-flow control were collected to create a fuzzy model that predicts projects' risks. The model was assessed by the same group of contractors for overall logic, appropriateness of cash-flow calculations and practicality through application on a hypothetical test case [11].

Gunduz et al., in (2011) developed a fuzzy model using relative importance index (RII), in which (83) delay causes were identified and categorized into (9) major groups. The model was developed as a support tool for contractors to quantify the probability of delay in construction projects before the bidding stage [12].

3. Building the fuzzy model

The following steps were carried out to build the model.

3.1. Data preparation

The model was created based on the findings of the aforementioned previous study of the authors in which (67) causes of payment problems in construction projects in Iraq were identified and ranked according to their frequency and severity [7]. All causes were categorized in four groups: owner-related, contractor-related, consultant-related and external causes.

3.2. Using MATLAB fuzzy logic toolbox

MATLAB Fuzzy Logic Toolbox™ software provides the following five graphical user interface tools for building, editing, and observing fuzzy inference systems, as shown in Figure 1 [13]:

1. Fuzzy Inference System (FIS) Editor: to define input and output parameters.
2. Membership Function Editor: to define the shapes of the membership functions.
3. Rule Editor: for editing the list of rules that defines the behaviour of the system.
4. Rule Viewer: for the purpose of identifying tool activated to display or edit.
5. Surface Viewer: to display the dependency of an output on the inputs.

3.3. Feeding the weights of causes

Tables 1 to 4 list all possible causes of payment problems related to the four groups, acronyms assigned for each of them, and more information to be refer to later. Their weights based on their (RII) were used as input data for the model.

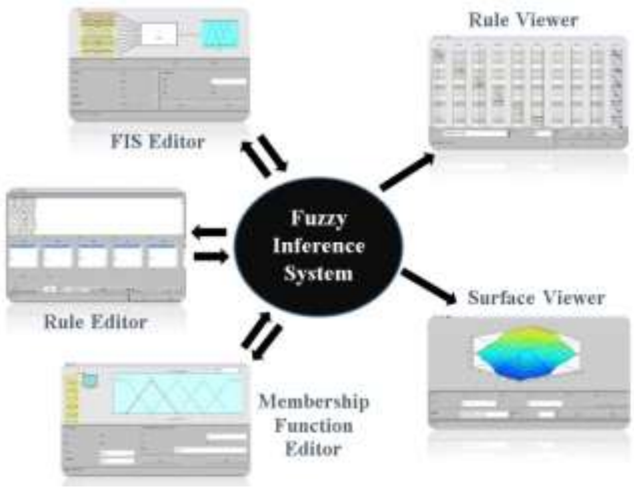

Fig. 1: Fuzzy Inference System (FIS) tools

Table 2: Owner-related payment problems causes

Acronyms	Causes	Weights	Likelyhoods
O1	Stop payment for no reason	0.4639	20%
O2	Owner Bankruptcy	0.4361	20%
O3	Lean on external finance	0.4167	15%
O4	Inaccurate pre-estimation of cost	0.65	20%
O5	Poor financial planning	0.6694	25%
O6	Deficient liquidity	0.675	50%
O7	Payment priority given to other issues	0.5722	10%
O8	Delayed interim payments	0.5639	33%
O9	Delayed final payment	0.6306	40%
O10	Delayed releasing of retentions and bonds	0.5889	40%
O11	Under-measurement of completed works	0.5	10%
O12	Disregarding payments timings	0.5889	30%
O13	Ignorance of claims and disputes	0.6639	60%
O14	Bureaucracy and complexity in payment	0.6972	50%
O15	Carelessness of his staff	0.5722	65%
O16	Form of contract according to delivery method	0.4972	23%
O17	Type of contract according to payment method	0.5333	17%
O18	Contract Conditions	0.5611	27%
O19	Instructions of Governmental Contracts	0.6056	63%
O20	Instructions of the Federal Budget	0.6556	73%
O21	Delayed tests of built-in materials and equipment	0.6917	77%
O22	Delayed certificates of origin for imported items	0.6056	73%
O23	Internal conflicts with the Promoter or User	0.5861	27%

Table 4: Contractor-related payment problems causes

Acronyms	Causes	Weights	Likelyhoods
C1	Bankruptcy of the contractor or his funding entity	0.5944	40%
C2	Financial commitment is higher than his capacity	0.6861	40%
C3	Liquidity distress due to other projects late payment	0.7028	65%
C4	Difficult to obtain a Financial Bond	0.4972	13%
C5	Misjudgment of the owner's payment capacity	0.5889	13%
C6	Wrong estimating of the contract cost	0.5889	50%
C7	Bad loading of bid prices	0.5722	53%
C8	Poor financial planning	0.6333	50%
C9	Costs exceed estimations	0.6333	53%
C10	Unexpected prices rise	0.5806	43%
C11	Additional costs due to change-orders	0.6528	15%
C12	Delay in preparing claims and change-orders	0.6278	63%
C13	Lag of final measurement site requirements	0.5806	30%
C14	Ignoring financing costs caused by payments delay	0.5722	40%
C15	Misunderstanding of owner's requirements	0.5583	40%
C16	Inefficiency of his staff	0.5556	47%
C17	Discounts due to ill-quality works	0.5722	43%
C18	Liquidated Damages (Delay Penalties)	0.6361	37%
C19	Increased indirect costs due to project delay	0.6278	75%
C20	Increased capital cost due to project delay	0.5278	50%

C21	Failure in claims submission	0.5444	75%
C22	Insurance companies fail to compensate	0.5167	35%
C23	Internal conflicts with suppliers or subcontractors	0.6083	45%

Table 3: Consultant-related payment problems causes

Acro-nyms	Causes	Weights	Likely-hoods
D1	Design imperfection	0.5806	60%
D2	Design contradictions	0.5889	37%
D3	Misunderstanding of owner's requirements	0.5083	33%
D4	Internal conflicts between different disciplines	0.4833	20%
D5	Appointing other supervising consultant	0.5583	20%
D6	Multiple supervision entities	0.4972	23%
D7	Inefficiency of consultant supervision team	0.4833	17%
D8	Lack of site-visits examine works & solve problems	0.5694	33%
D9	Delay in providing illustrative drawings	0.5750	43%
D10	Late approval of workshop drawings or submittals	0.5472	27%
D11	Late approval of change-orders or claims	0.6361	45%
D12	Weak coordination with other parties	0.5750	50%

Table 1: External payment problems causes

Acro-nyms	Causes	Weights	Likely-hoods
E1	Increased inflation	0.5194	40%
E2	Increased interest rate on loans	0.4667	67%
E3	Change in currency exchange rate	0.5722	45%
E4	Change in other economic conditions of the country	0.6417	55%
E5	Supply and demand change in markets conditions	0.6389	73%
E6	Political and security conditions of the country	0.725	75%
E7	Unexpected severe changes in weather	0.5056	35%
E8	Natural disasters	0.2833	10%
E9	Unavailability of public utilities	0.575	65%

3.4. Linguistic variables and membership functions

Trapezoidal and triangular forms of membership functions were adopted to build the model for they were commonly used in relevant literature such as [14] and [15]. The adopted linguistic variables are defined as: Never, Scarcely, Occasionally, Frequently, and Always, using a 5-grade scale (0-100). Therefore five membership functions were defined for these linguistic variables. The expressions in linguistic terms were transformed into a combination of trapezoidal and triangular forms of fuzzy numbers as shown in Figure 2.

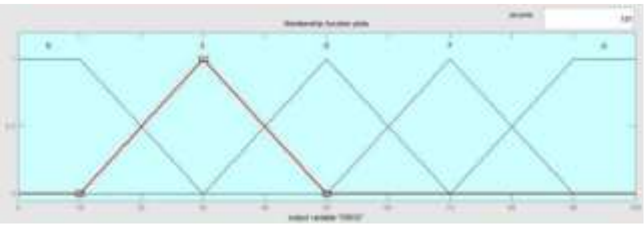

Fig. 2: Membership functions for linguistic variables

3.5. If ... then rules

The interrelationships between inputs (weights of payment problems causes) and outputs (likelihood of payment problems causes) were initially established in natural language formats. Such formats allowed expressing all payment problems causes regardless the absence of definite exact values. They enable the model to add new rules (payment problems interrelationships/memberships) in addition to manipulating or eliminating irrelevant rules. In order to perform these fuzzy inference rules, (IF...THEN) forms were used to describe the desired interrelationships. The aforementioned likelihood and payment problems acronyms were used to construct a whole of (335) rules.

3.6. Implementing steps

The payment problems fuzzy model was constructed by following the instructions of the MATLAB Fuzzy Logic Toolbox. First, the Editor of the Fuzzy Inference System (FIS) was used to define input and output parameters. Second, the Membership Function Editor was used to define the adopted shapes of the membership functions. Third, the Rule Editor was used to edit the adopted rules that define the behaviour of the system. Fourth, the Rule Viewer was used to activate the tool of displaying and editing. Fifth and final, the Surface Viewer was used to display the dependency of an output on the inputs. Samples of these Editors are shown in Figures 3 to 7.

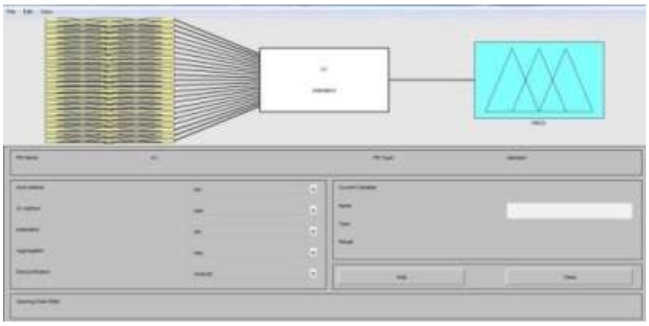

Fig. 3: FIS for linguistic variables inputs of owner-related causes

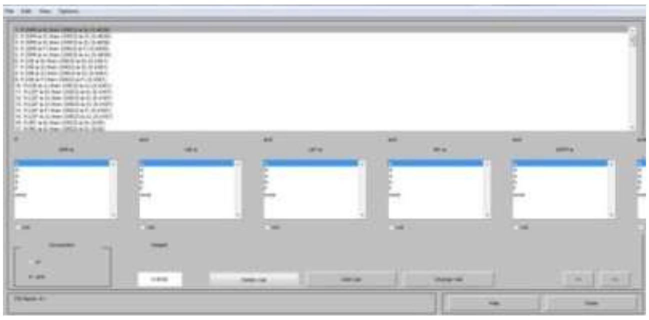

Fig. 4: Rules for linguistic variables inputs of owner-related causes

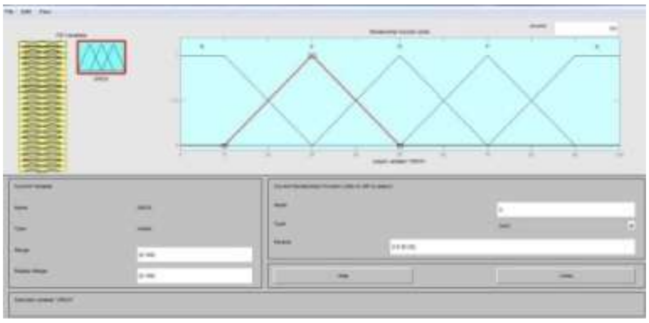

Fig. 5: Memberships for linguistic variables inputs of owner-related causes

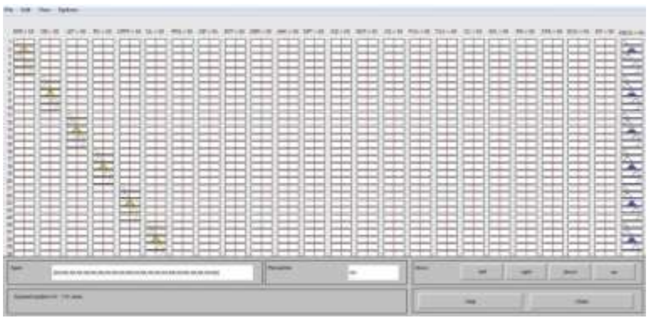

Fig. 6: Rule Viewer for owner-related causes

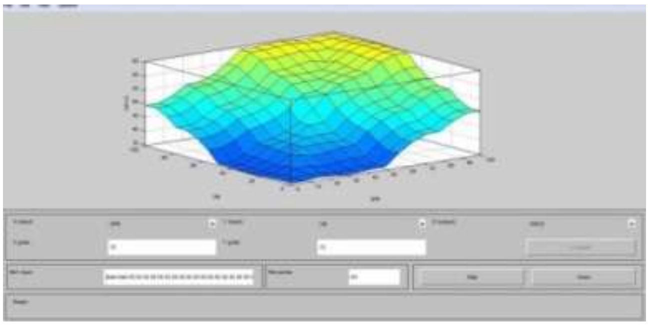

Figure 7: Surface Viewer for owner-related causes

4. Testing the model

The model was tested in real life case which included (10) projects being executed by one construction contracting company for buildings and infrastructure projects. The company holds the 1st rank in civil works and the 2nd rank in mechanical, electrical and chemical works. The company was invited to identify the likelihood of payment problems causes according to the specific circumstances of the company and the owners of the (10) projects via a questionnaire form supported by direct interviews. The questionnaire form was designed using the 5-point Likert's scale in order to be compliant with the ranking score initially used to obtain the inputs of the model which consists of five ranks of likelihood starting from (Never) which means (0%) to (Always) which means (100%). The Executive Director of the company and two leading staff senior engineers contributed jointly to answer the questionnaire. The results are also shown in Tables 1 to 4.

5. Model application outputs

As a result of applying the fuzzy model, it has been found that the group of external causes is the most likely group with the following most likely causes:

1. Political and security problems in the country with a likelihood of (75%).
2. Supply/demand change in the markets of resources with a likelihood of (73%).
3. High rates of interest on loans with a likelihood of (67%).
4. Shortage of public utilities with a likelihood of (65%).

The group of owner-related causes comes next with the following most likely causes:

1. Delayed tests results especially for built items with a likelihood of (77%).
2. Consequences of the Federal Budget instructions with a likelihood of (73%).
3. Delayed certificates of origin for imported items with a likelihood of (73%).
4. Carelessness of owners' staff with a likelihood of (65%).

Then comes contractor-related causes with the following most likely causes:

1. Increased indirect costs due to project time overrun with a likelihood of (75%).
2. Failure to submit claims properly in time with a likelihood of (75%).
3. Liquidity distress due to late payments in other projects with (65%).

Finally the group of consultant-related causes comes last with the most likely cause of design imperfection with a likelihood of (60%).

6. Conclusions

This research proposed a fuzzy model to assess payment problems in any construction project according to its specific conditions. The model was built using (67) causes of payment problems which were classified into four groups; owner-related, contractor-related, consultant-related and external causes. The likelihoods of those causes were incorporated in the proposed fuzzy model based on their (RII) of the field survey. Then the model was tested by a real life case study so as to be used as a supportive tool for practitioners in the Iraqi Construction Industry for the sake of assessing the most likely payment problems causes.

Based on the findings of this research, it can be concluded that the most influential causes of payment problems in the case study were:

1. Delayed tests results especially for built items.
2. Political and security problems in the country.
3. Increased indirect costs due to project time overrun.
4. Failure to submit claims properly in time.
5. Supply/demand change in the markets of resources.
6. Consequences of the Federal Budget instructions.
7. Delayed certificates of origin for imported items.

In addition, it can be concluded that fuzzy logic proved to be suitable to build a model that can be used by owners and contractors in the Iraqi Construction Industry to assess the most likely payment problems they might face according to the project specific conditions.

Recommendations

Stakeholders in the Iraqi Construction Industry are invited to use the proposed fuzzy model for early identification of payment problems in construction projects. Both owners and contractors should identify risks that may lead to payment problems and have a good will to work jointly to overcome them with special care to be paid to the most influential causes confirmed in this research.

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