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Managing Construction Uncertainty In The Nigerian Construction Industry Through The Application Of Fuzzy Logic Model

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Abstract— Delays in construction projects can be due to a number of factors, which need to be classified and identified. For the success of a construction project, estimation of the plausibility of delay resulting from different factors must be carried out or fully investigated. This research is the extension of delay analysis techniques by using fuzzy logic method. The paper presents a practical application of fuzzy logic theory in predicting construction project delay using Fuzzy toolbox of MATLAB Program Software, the delay factors are identified based on literature review from other studies and opinion from some selected construction professionals were ranked using Relative Important Index (RII) scale. Fuzzy logic provides a unique way to arrive at a definite conclusion based upon vague, imprecise or missing input information. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact. The results derived from this model indicate a systematic and effective way for analyzing construction project delays.

Keywords— Construction project, delays, fuzzy logic, Matlab program software

I. INTRODUCTION

The Nigerian construction industry is recognized as an important sector of the economy, being a principal economic driver, it has occupied a significant state in the economy of the country. Because of its various activities, it was regarded as a significant contributor to the economy with a 25% GDP growth in 2011 but despite this economic significance, the industry face a major challenge to its future growth, project uncertainties such as project delays, decrease in productivity, weather events etc these obstacles stem from the inherent risk of uncertainties in the industry. Nigeria as a nation is regarded as a developing country by statistics, this developing nature has significantly affect every other sectors, including the construction industry where majority of the construction activities relies on human to make decisions related to planning, execution, control and the knowledge to determine uncertainties, this knowledge are however, undocumented which is the major flaws of human. [1] state that "when market fluctuation cannot be predicted with certainty, managers have to make decisions under condition of uncertainty. Under these conditions, decisions to make or not are often based on managers "human intuitions, common sense and experience, rather than the availability of clear, concise and accurate data [2]. For the Nigerian construction industry to be able to accomplish is basic construction objectives; it must be able to manage the varieties of uncertainties such as random fluctuations, weather conditions, geological properties and project delays. According to [3] the level of uncertainty and changing nature of construction industry, practical construction management problem are complex and ill- structured. Therefore, the success of any construction projects depends on the level of management which makes it imperatives to look into other alternative method of predicting uncertainties such as fuzzy logic method. The fuzzy logic method has the ability to simulate human inference emulating human brain as well as the use of analytical tools such as fuzzy MATLOB model or state of the art. Imitating the process of human inference will be effective in solving the problem of uncertainty in the industry. The use of fuzzy logic (FL) and fuzzy hybrid techniques make it possible for handling complex or poorly structured problem of uncertainty in the industry. [4] they are used by managers in direct support of managerial decision making. Therefore, the methods presented in this paper describe a fuzzy logic model such as fuzzy toolbox of MATLAB program software to analyze the uncertainties in the industry. Hence, since there are varieties of project uncertainties, this paper will focus mainly on the application of fuzzy logic to analyze project delays in the Nigerian construction industry. The method is adopted to analyze a small survey from professionals in the construction industry and indentify important delay factors. A summarized interview was conducted to ascertain the kinds of delays taking place in the project as observed by project team members. The causes of project delays were grouped and categorized in different factors. The interview results were used in the assessment model and probability of schedule delay as evaluated. Based on the results obtained from the model, the relative important areas were discussed. The results obtained were vague, précised and accurately acceptable.

II. REVIEW OF LITERATURE

A. *Fuzzy logic as an Artificial intelligence tool. What is Artificial intelligence?*

Artificial intelligence was explained according to the following authors:

- Artificial intelligence is the exciting new effort to make computer think machine with minds, in the full and literal science [5]

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- Artificial intelligence is the branch of science that is concerned with the automation of intelligent behavior [6].
- Is a field of study that seeks to explain and emulate intelligent behavior in terms of computation processes [7].
- Is the study of the computation that make it possible to perceive, reason and act [8]
- Is the study of how to make computer do things at which, at the moment, people are better [9]
- Is the art of creating machines that perform functions that requires intelligence when performed by people [10]

B. Fuzzy Logic Explained

According to Robinson (n.d) fuzzy logic was comprehensively explained as a techniques used to capture expert knowledge and engineering judgment and combine the subjective element with project data enabling us to develop approaches to improve construction decision making, performance and productivity. He further explains in details that fuzzy logic allows us to capture and model uncertainty related to subjectivity and imprecision that we previously could model. This means that with fuzzy logic we can model both qualitative factors and capitalize on expert knowledge to develop better systems and solution for construction. Likewise, fuzzy logic techniques is very useful in the area of improving the accuracy of construction models due to the fact that it takes into account the part of a projects that cannot be measured in certain terms, subjective or may not have exact or complete value. Fuzzy techniques also refer to all fuzzy concepts, which include fuzzy set, fuzzy logic, and hybrid fuzzy techniques (those who combine fuzzy set (fuzzy logic with other techniques) such as fuzzy neural network, neurofuzzy, fuzzy reasoning, fuzzy expert system, fuzzy analysis, and fuzzy clustering [11]. We live in the world of ambiguity and uncertainty in such a fuzzy world, using tools that are close to natural language and have the ability to conclude like human mind, and even deal with more data and complex relation that are important [2].

Reasons for using Fuzzy logic model to analyze project delays in construction are as explained according to [12]:

- The modeling of vague input is successfully done with the use of membership functions
- The inherent ability of fuzzy logic systems to explain its reasoning ensures that the modeling process is understood and could also be intuitively verified
- The parallel nature in which rules are activated in a fuzzy system ensures that all factors are considered in a harmonized manner
- The results of fuzzy systems can naturally be scaled to be comparable with each other, with the use of the scaling membership functions.
- Fuzzy logic`s use of linguistic sets and rules ensures that the terminology of the user interface and modeling structure can be tailored toward the specific environments.

III. THEORETICAL DESCRIPTION OF UNCERTAINTY

The term uncertainty is used in most of scientific literature concerning risk management. Theoretically uncertainty can be defined as a lack of certainty involving variability or ambiguity. Uncertainty is also a lack of complete certainty. Uncertainty is also a situation where the actual outcome of a particular event or activity is likely to deviate from the estimate or forecast value. A certainty outcome of any event is completely unknown and cannot be measured or guessed. Uncertainty is an inevitable aspect of most projects but even the most proficient managers have difficulty handling it. Though some projects have little uncertainty, only the complexity of tasks and relationship matters, the general practice is to classify uncertainty by their source or by potential impact but be categories in relationship to its management. Project uncertainty is a cause that makes project to finish with overrun on their schedules and budgets, and with products of compromised specifications, in spite of costly planning and attentive risk management. However, the greater the uncertainty in a project, the more difficult it is to rely solely on the discretion of the manager, uncertainty can therefore be understood according to the four categories.

A. Foreseen uncertainty

Foreseen uncertainties are identifiable and understood influences that the team cannot be sure will occur, it is distinct in nature and requires several alternative plan. A developer of a new drug can anticipate possible side effect because they have appeared previously in related drugs. It can outline contingency plans to change the prescribe dosage. The side effect is the foreseen uncertainty, that is whether the side effect occur or not. According to [13] these uncertainties can be indentified but possess uncertain influence on the project

B. Unforeseen uncertainty

This type of uncertainties cannot be identified immediately or during project initiation or planning. There is no plan B, the team is unaware of the event that might occur and therefore not bothered about creating contingencies. It can arise from the unanticipated interaction of many events each of which might be foreseeable

C. Variation:

variation such as activities duration, costs and exact performance level delivered by resources is a common source of project uncertainty. Where the sequence, objectives , plan and nature of project are well known, the project schedules and budgets often exhibits variation, also certain project tolerance should be implemented into the project plan, as myriads of small factors and events cannot be anticipated, but overall impact will cause schedules and budget to vary from their projected numbers.

Variation can be generated by many factors such as workers sickness, delay supply, bad weather, or anything else that matters. A typical example is where a contractor experience of previous projects allows him to develop near optimal project plan, but the exact project duration and cost varies, more or less, around their projected value.

D. Chaos:

Refers to the fundamental uncertainty about the basic structure of the project plan itself. Projects that occur in periods of technological discontinuity are characteristic of this situation. A chaos is also a "total uncertainty" in all areas of the project. Such a project may have to loose constraints on time or budget, as well as it can end with outcomes being fully different from original desired.

IV. CONSTRUCTION PROJECT DELAYS

Since project uncertainty brought about delays most especially in a more complex project as well as where schedules is being used to plan the work activities, delay still happen most times. Delays most times are very expensive because of the construction loans involved and the charged interest. These project delays can plague any industry, team or individual project, understanding what causes delay is very important in preventing it from occurring. According to [14] states" the effect of delay as a phenomenon can be a destructive factor for all construction plans if it is not tackled properly.

TABLE I. CLASSIFICATION OF DELAY FACTORS IN CONSTRUCTION PROJECTS

Alnuaimi & Muhammed 2013	Singh & Trivedi 2012
Design related factors	**Labour related factors**
Possible change in initial design	Labour strike
Complexity of the project	Conflicts among labors
Construction related factors	Inexperienced labour
Variation and claims	Labour shortage
Change of scope of project	Absent of labor
Financial/economic related factors	**Project related factors**
Financial ability of the owner	Delays penalties
Not enough funds	Project complexities
Management /Administration related factors	Dispute among project parties
Availability of suitable management team	Improper project management assistance
Unspecialized subcontractors	**Consultant related factors**
Lack of project management	Inexperienced consultants
Lack of experience consultant	Inspecting and testing delays
Lack of experience contractor	Conflict between consultant and design engineers
Regulations & Code related factors	Poor communication and coordination with other parties
New legal instruction or rules	Delay in approval of design documents
	Contractor related factors
	Poor site management and supervision
	Poor planning and scheduling
	Shuffling of subcontractors
	Poor communication and coordination with other parties
	Rework due to errors
	Inexperienced contractors
	External related factors
	Inclement weather conditions
	Variation in price
	Global financial crisis
	Change in government regulation and law
	Unexpected surface and subsurface conditions
	Delays in providing services from utility
	Owner related factors
	Slow decision making
	Delay in approving design documents
	Late site delivery
	Change in order by owner
	Improper study of design
	Progress payments delay
	Poor communication and coordination with other parties
	Inexperienced owner
	Material related factors
	Material manufacturing delay
	Damage of materials
	Material shortage
	Delay in delivery
	Rising price of materials
	Design related factors
	Inadequate experience of the design team
	Complexity in project design
	Errors made by designers
	Delays in making design document
	Unclear details in drawing
	Insufficient data collection
	Equipment related factors
	Damaged equipment
	Equipment shortage
	Breakdown of equipment
	Low efficiency
	Problem in allocation

V. METHODOLOGY

The project delay factors are identified through literature review and with the help of construction professionals. These project delay factors are then ranked and analyze for their relative importance. After ranking the project delay factors, a model is then developed in the fuzzy inference system. The assessment model for the factors identified is developed using fuzzy logic MATLAB programs based on the procedure previously

A. Ranking of causes of project delay factors

The following procedure is adopted to calculate the rank and assess the importance index of project delay factors:

- The causes of project delay factors in the construction industry are identified.
- A questionnaire survey is conducted through open ended interview for judging the level of importance of the

above identified factors. The respondents were asked to highlight the relative importance of these factors.

- The five-point scale ranged from 1 (not important) to 5 (very very important) is adopted to calculate the relative importance indices (RII) for each factor. The relative importance index (RII) is calculated by using the relation as given below:

$$RII = \sum \frac{\sum w}{A * N}$$

Where W is the weighting given to each factor by the respondent (ranging from1 to 5), A is the highest weight and N is the total number of respondent. Hence, the respondent was asked to fill in the given questionnaire and give values to the causes of delays in the questionnaire using a guideline ranging from 0 to 100. These values were converted into percentage and used as fuzzy weights; these fuzzy weights will now be used in the Fuzzy Logic Toolbox of Matlab to serve as a fuzzy rule weights assigned to each causes of delays variables. Table 2 shows the relative importance value for the causes of project delays

TABLE II. RELATIVE IMPORTANCE INDEX FOR THE CAUSES OF PROJECT DELAYS

Labour related factors	**RII values**
Labour strike	0.60
Conflicts among labors	0.55
Inexperienced labour	0.75
Labour shortage	0.45
Absent of labor	0.60
Project related factors	
Delays penalties	0.37
Project complexities	0.80
Dispute among project parties	0.84
Improper project management assistance	0.45
Consultant related factors	
Inexperienced consultants	0.60
Inspecting and testing delays	0.50
Conflict between consultant and design engineers	0.55
Poor communication and coordination with other parties	0.82
Delay in approval of design documents	0.71
Contractor related factors	
Poor site management and supervision	0.77
Poor planning and scheduling	0.64
Shuffling of subcontractors	0.55
Poor communication and coordination with other parties	0.30
Rework due to errors	0.80
Inexperienced contractors	0.74
External related factors	
Inclement weather conditions	0.79
Variation in price	0.57
Global financial crisis	0.71
Change in government regulation and law	0.56
Unexpected surface and subsurface conditions	0.42
Delays in providing services from utility	0.36
Owner related factors	
Slow decision making	0.84
Delay in approving design documents	0.77
Late site delivery	0.81
Change in order by owner	0.79
Improper study of design	0.77
Progress payments delay	0.85
Poor communication and coordination with other parties	0.44
Inexperienced owner	0.65
Material related factors	
Material manufacturing delay	0.38
Damage of materials	0.89
Material shortage	0.67
Delay in delivery	0.75
Rising price of materials	0.58
Design related factors	
Inadequate experience of the design team	0.91
Complexity in project design	0.50
Errors made by designers	0.42
Delays in making design document	0.70
Unclear details in drawing	0.57
Insufficient data collection	0.52
Change in initial design	0.47
Construction related factors	
Variation and claims	0.46
Change of scope of project	0.55
Equipment related factors	
Damaged equipment	0.65
Equipment shortage	0.71
Breakdown of equipment	0.89
Low efficiency	0.55
Problem in allocation	0.62
Financial/economic related factors	
Financial ability of the owner	0.72
Not enough funds	0.35
Management /Administration related factors	
Availability of suitable management team	0.56
Unspecialized subcontractors	0.50
Lack of project management	0.46
Lack of experience consultant	0.45
Lack of experience contractor	0.54
Regulations & Code related factors	
New legal instruction or rules	0.71

B. Steps Taken for the Model Development

To develop the model, following steps are performed on fuzzy logic tool box of MATLAB.

- An input system was constructed each showing the output and input members respectively. The identified project delay factors and “the variable causes” are entered as input members and output member respectively
- Membership functions associated with all of the input and output variables are defined in membership function editor.
- To perform fuzzy inference, rules which connect input variables to output variables are defined.
- Rule1: If the probability output of a variable is low the contributing factors is either high or very low likewise low
- Rule2: If the probability of a delay factors variable is low the corresponding delay factors is low
- Rule3: If the probability output is medium the contributing factors is medium

- Rule4: If the probability output is high the contributing factors is high
- Rule5: If the probability output is very high the contributing factors is very high
- The relative importance indices (RII‟s) of percentage range (0-100) project delay factors are assigned as weight to the fuzzy rules to develop the assessment model to estimate the probability of project delays.

VI. CASE STUDY

Most of the causes of scheduled delay were derived from literature of past researcher in this areas while some additional variables were determine through the interview of some selected construction professionals such as contractors, architect and builders on selected ongoing project. The major purpose of giving out the questionnaire to the professionals is to gather additional factors as discuss earlier and assign values to the identified factors based on table 3 above. From the parameters above in summary, "1" denote "probability very low" and 100 represent "probability very high" (represented by 5). The following value were obtain based on the range from the respondents as presented in Table 3 below

TABLE III. PROBABILITY RATING OF EACH IDENTIFIED DELAY FACTORS

Labour related factors	**Probability x**
Labour strike	55
Conflicts among labors	60
Inexperienced labour	65
Labour shortage	30
Absent of labor	60
Project related factors	
Delays penalties	65
Project complexities	45
Dispute among project parties	70
Improper project management assistance	55
Consultant related factors	
Inexperienced consultants	30
Inspecting and testing delays	40
Conflict between consultant and design engineers	50
Poor communication and coordination with other parties	65
Delay in approval of design documents	70
Contractor related factors	
Poor site management and supervision	70
Poor planning and scheduling	75
Shuffling of subcontractors	50
Poor communication and coordination with other parties	65
Rework due to errors	75
Inexperienced contractors	40
External related factors	
Inclement weather conditions	65
Variation in price	70
Global financial crisis	30
Change in government regulation and law	40
Unexpected surface and subsurface conditions	45
Delays in providing services from utility	60
Owner related factors	
Slow decision making	80
Delay in approving design documents	85
Late site delivery	75
Change in order by owner	82
Improper study of design	65
Progress payments delay	60
Poor communication and coordination with other parties	30
Inexperienced owner	45
Material related factors	
Material manufacturing delay	82
Damage of materials	40
Material shortage	85
Delay in delivery	90
Rising price of materials	75
Design related factors	
Inadequate experience of the design team	60
Complexity in project design	55
Errors made by designers	70
Delays in making design document	50
Unclear details in drawing	25
Insufficient data collection	30
Change in initial design	65
Construction related factors	
Variation and claims	85
Change of scope of project	90
Equipment related factors	
Damaged equipment	40
Equipment shortage	25
Breakdown of equipment	30
Low efficiency	50
Problem in allocation	65
Financial/economic related factors	
Financial ability of the owner	75
Not enough funds	65
Management /Administration related factors	
Availability of suitable management team	30
Unspecialized subcontractors	28
Lack of project management	40
Lack of experience consultant	42
Lack of experience contractor	25
Regulations & Code related factors	
New legal instruction or rules	30

The results obtained from the table above will represent the basis for the calculation in the Matlab Program Software. The Following schedule delay probability outputs results were obtained using Fuzzy Logic Toolbox of Matlab Program Software as shown below

TABLE IV. RESULTS OF MATLAB PROGRAM SOFTWARE

Scheduled delay group factors	**Probability output**
Labour related factors	44.1
Project related factors	48.5
Consultant related factors	39.2
Contractor related factors	39.6
External related factors	42.3
Owners related factors	51.5
Material related factors	59.5
Design related factors	50.9
Equipment related factors	42.9
Financial/economic related factors	44.8
Management/administration related factors	42.6
Regulations & code related factors	27.6

VII. DISCUSSION OF RESULTS

The result from table 4.0 was used to calculate the probability output as shown in table 5 above. From the parameters under the scheduled delay factors, the probability output for labor related factors was calculated as 44.1 which if compared with the range in table 3.0 falls under "Low medium probability delay level" comprising of conflict among labor(60, very high probability) and labor shortage(30, very low probability). Other parameters are: project related factors with a probability output of 48.5(medium probability) consisting of contributing factors of delay penalties (65, very high probability) and project complexity (45, very low probability). Consultant related factors consist of 39.2 very low probability output level, delay in approval of design document (70, very high probability) and inexperience consultant (30, very low probability). Contractor related factors consist of 39.6 probability output which falls under low medium probability delay level with contributing factors of rework due to errors(75, very high probability) and inexperience contractor(40, low medium probability). External related factors has a probability output of 42.3 showing low medium probability delay level while the most contributing factors are inclement weather condition(65, very high probability) and global financial crisis(30, very low probability). Owner related factors has a very high probability delay level of 65 consisting of the contributing factors of delay in approving design document (85, very high probability) and poor coordination with other parties (30, very low probability). Material related factors has a probability delay level of 59.5 which signify a high probability delay level comprising of the contributing factors of delay in delivery (90, very high probability) and damage of materials (40, very low probability). Design related factors consist of 50.9 probability output delay level with the most contributing factors of errors made by designers (70, very high probability) and unclear details in drawing (25, very low probability). Equipment related factors has a probability output delay level of 42.9 showing low medium delay level, the most contributing factors are problem in allocation(65, very high probability) and equipment shortage(25, very low probability). Financial/ economic related factors has a probability output of 44.8 showing low medium probability delay level, the most contributing factors for this delay are financial ability of the owner(75, very high probability) and not enough fund(65, also very high probability). Management/administrative related factors was calculated as 42.6 showing low medium probability delay level, the most contributing factors for this delays are lack of experience consultant(42, low medium probability) and lack of experience contractors(25, low medium probability). Regulation and code related factors has only a probability output of 27.6 showing a low medium probability level with a contributing factor of 30(New legal instruction or rules)

VIII. CONCLUSION

In this research we tried to propose a fuzzy delay analysis for construction projects. Although the computations involved in the model of the fuzzy risk analysis are tedious if performed manually A systematic procedure is presented for developing the project delay factors assessment model in fuzzy environment using Fuzzy toolbox of MATLAB Program Software. The procedure consists of identification of project delay factors and analyzing their rank according to relative importance index. Using these relative importance indexes as model has in fuzzy inference system (FIS). Construction professionals can now predict the major causes of delay in construction project before they start the implementation. The proposed fuzzy delay assessment provides an effective, systematic ways to analyze and assess construction project delays

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