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STANDARDISATION OF RISK ASSESSMENT PROCESS BY MODIFYING THE RISK MATRIX

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ABSTRACT

Risk Matrix is mostly used tool in the Risk Evaluation phase of the Risk assessment process. Risk assessment is a process of identifying and quantifying of risks that may happen in future due to uncertainties in the construction activities. Risk assessment is concerned with determining those events which are especially dangerous and determining the likelihood & severity of unacceptable risk. Although the conventional Risk Matrix provides a standard tool for treating the relationship between the severity of consequences and the likelihood (probability) in assessing process risks, it has its own limitations.

In this paper a study is made on some of the disadvantages of risk matrix and a solution is proposed to handle the disadvantages. A risk matrix merged with Fuzzy Logic model is developed to enhance the risk assessment process which is dealing with uncertainties that arise in each phase of the risk assessment process.

Keywords: Fuzzy Logic, Risk Assessment Process, Risk Matrix, Risk Rating.

I. INTRODUCTION

From ISO 31000:2009 Risk Management —Principles and Guidelineson Implementation on the 13th of November 2009 for theimplementation of risk management "Project risk can be defined as an effect of uncertainties on project objectives''.

In general, risk is used to answer:

- What can go wrong?
- What are the damageeffects?
- How likely is it that this will happen?
- What are the uncertainties?

Project risk management (PRM) aims to identify and assess risks in order to enable the risks to be understood clearly and managed effectively.

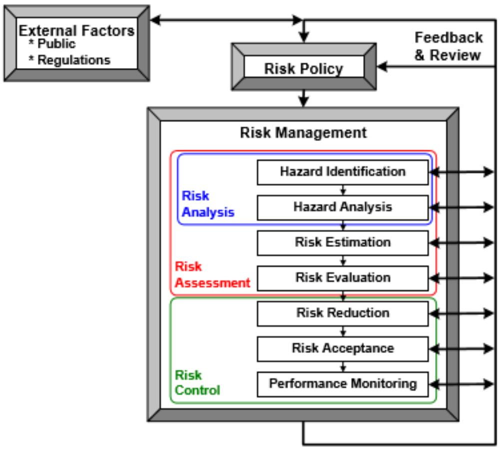

Fig. 1. Project risk management flow chart.

The aim of the risk assessment is to identify the significant risks to health and safety to any person arising out of, or in connection with any work activity. It should identify how the risks arise, and how they impact on those affected. The information is needed so that decisions can be made about how to manage the risks in an informed, rational and structured manner and so that the action taken is proportionate.There are variety of tools used in risk identification and control. These tools include the risk list, risk matrix, risk map and Risk Breakdown Structure (RBS).

The risk matrix has been in use for many years and in many forms. Ale (2007) credited Napoleon with the first use of a risk matrix based on the likelihood of consequences. Risk matrix is the most commonly used tool in risk assessment process all over the world because it is simple, easily understandable, and proven tool. Risk matrix provides a standard tool for treating the relationship between the severity of consequences and the likelihood (probability) in assessing process.

But the risk matrix has some disadvantages. Bahill &Smith (2009) "The data used in the risk matrix have different degrees of uncertainty. Some of the values are known with precision, others are wild guess. However, in addition to uncertainty, all data have opportunity for errors''.

This paper deals with some of the limitations of risk matrix in handling uncertain data. A possible solution is proposed by modifying the risk matrix using a Fuzzy logic model to deal with the uncertainties. The paper is organized as follows; the next session explains the risk assessment process briefly. The following session discusses the risk matrix, its advantages & limitations. Then the concept of fuzzy logic and its application in risk assessment process is explained before we provide a solution for the problem discussed in the paper.

II. RISK ASSESSMENT.

The definition of risk assessment goes like this "the overall process of risk identification, risk analysis and risk evaluation". That is, risk assessment includes the risk analysis stage.

Risk assessments are required to be suitable and sufficient. This means they should:

- Identify the significant risks arising out of the work activity.
- Consider all those who may be affected.
- Be appropriate to the nature of the work.

- Be such that they remain valid for a reasonable period of time.

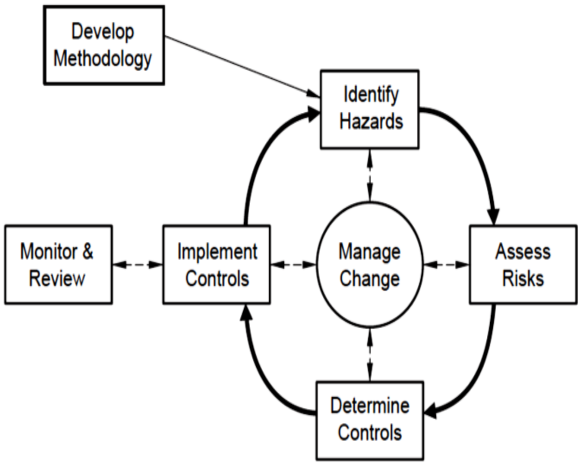

Fig. 2. Risk assessment process.

Risk assessment can be a qualitative, semi-quantitative or quantitative process. Any assessmentshould begin with a simple qualitative assessment, including consideration of whether any relevant good practice is applicable. In some cases it will be appropriate to supplement the qualitative assessment by a more rigorous semi-quantitative or quantitative assessment, depending upon the level of risk identified. There are variety of tools used in risk identification and control. These tools include the risk list, risk matrix, risk map and Risk breakdown structure (RBS). RBS combined with risk matrix is a common and very practical tool, widely used during the various stages of project life in risk management. It can be used in the risk identification stage and it can provide a support in the later stages (risk assessment and risk response), since it offers an overview on the risks which affect the project.

2.1 Inputs for risk assessment

Inputs to the risk assessment processes can include, but are not limited to, information or data on the following:

a. Details of location(s) where work is carried out.
b. The proximity and scope for hazardous interaction between activities in the workplace.
c. The human capabilities, behaviour, competence, training and experience of those who normally and/or occasionally carry out hazardous tasks.
d. Manufacturers' or suppliers' instructions for operation and maintenance of equipment and facilities.
e. The availability and use of control measures [e.g. for ventilation, guarding, personal protective equipment (PPE), etc.].
f. Environmental conditions affecting the workplace.
g. The potential for failure of plant and machinery components and safety devices.
h. Details of access to, and adequacy/condition of emergency procedures, emergency escape plans, emergency equipment.
i. Emergency escape routes (including signage), emergency communication facilities, and external emergency support, etc.,

j. Monitoring data related to incidents associated — with specific work activities,

k. The findings of any existing assessments relating to hazardous work activity.

l. Details of previous unsafe acts either by the individuals performing the activity or by others (e.g. adjacent personnel, visitors, contractors, etc.).

m. The duration and frequency at which tasks are carried out.

The overall purpose of the hazard identification & risk assessment process is to recognize and understand the hazards that might arise in the course of the organization's activities and ensure that the risks to people arising from these hazards are assessed, prioritized and controlled to a level that is acceptable.

III. RISK MATRIX

A common method used for risk ranking utilises risk matrices; these are typically 3×3,4x4 or 5x5 matrices, having event consequences along one axis and event frequency along the other.Cox (2008) defined risk matrix as "a table that has several categories of "probability," "likelihood," or "frequency" for its rows (or columns) and several categories of ''severity'', ''consequences'', or ''impact'' for its columns (or rows) respectively.

Three types of risk matrices are commonly used for risk ranking. A purely qualitative risk matrix will have its blocks defined in descriptive or qualitative terms. A purely quantitative risk matrix has its blocks defined in measurable or quantitative terms. Relative or absolute numerical scales are used on quantitative matrices, whereas scales on qualitative matrices are relative but not numerical. The third type of risk matrix is a hybrid: a semi-quantitative matrix with one scale (usually frequency) expressed quantitatively, while the other scale is expressed qualitatively. We concentrate our study on the qualitative risk matrix in this paper.

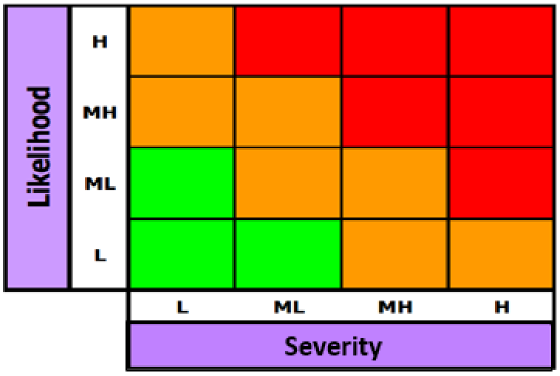

Fig. 3. A standard model of Risk matrix

3.1 Qualitative Risk Matrix

The qualitative risk matrix is basically hazard analysis with some relative judgments made in order to categorise the hazards. When the 3×3, 4x4 or 5x5 matrix is used, both the frequency(likelihood) and consequence(severity) of each accident scenario are then estimated on simple relative scales, such as low, medium and high. The risk for each scenarios is the product of the frequency(likelihood) rating andconsequence(severity) rating. This indicates that the qualitative risk in this case falls into various distinct regions low, medium, & high. Clearly Low x Low region has the lowest risk, while the High x High region has the highest risk.

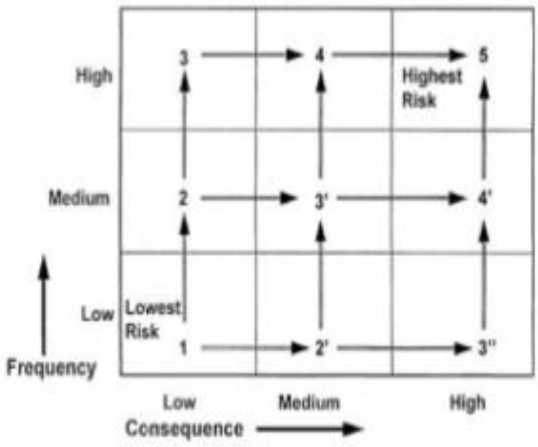

Fig. 4. The risk categorisation model of a risk matrix.

The intermediate regions are more difficult to interpret because some regions are directly comparable and others are not (Altenbach, 1995).

3.2 Advantages of risk matrix

The main advantages of risk matrices are that they (Cox 2008):

- Enable the combination of likelihood and severity to be represented graphically.
- Are an easily understood representation of different levels of risks?
- Enable decision-makers to focus on the highest priority risks with some consistency.
- Enable quick ranking.
- Can be compiled relatively quickly
- Promote discussion in risk workshops.
- Easy to apply can be used by non-experts.

3.3 Limitations of risk matrix

Bahill &Smith (2009) "The data used in the risk matrix have different degrees of uncertainty. Some of the values are known with precision, others are wild guess. However, in addition to uncertainty, all data have opportunity for errors''. Cox (2008) demonstrated why a matrix should not use too many colours or labels to represent levels of risk. Three colours (e.g., red, yellow and green) or levels seemed a minimum and five a maximum.Evans (2012) argued that individual people have different risk tolerances. This can further distort how matrix can be used. People with low risk tolerance will over rate risks, while the people with high risk tolerance will under rate risks. Some of the disadvantages of risk matrix are;

- Often use uncertain, opaque or obscure design data.
- May tempt users to under- or over-state the severity and their likelihood resulting in incorrect analysis of the level of risk.
- Results can be inconsistent between users.
- Cannot compare alternatives in same risk class.

IV. INAPPROPRIATE USE OF RISK MATRIX

We discussed here how a risk matrix can be inappropriately used in analysing the risks for the activities whose likelihood or severity ratings are at the boundaries. For this study we considered fifteen activities of concreting work. These fifteen activities were considered because their likelihood and severity ratings are at boundaries of their respective categories. Only medium and high categories are considered because their impact will be high on the project.

The risks are considered based on their effect on the people, assets, and environment.

The likelihood and severity of the fifteen activities are as follows.

Likelihood={2.3,1.5,2.5,2.8,2.3,2.6,2.4,2,2.2,2.7,2.2,1.8,2,1.6,1.9}.

Severity={2,2,2,2,2,2,2.5,2,2.6,2.2,2,2.5,2.3,1.6,2.3}

RISK	LIKELIHOOI	SEVEIRTY	RISK IMPA	RISK RATING
1.Loading & unloading of aggregates	2.3	2	4.6	M
2.Shifting of aggregates from outside site to inside site	1.5	2	3	M
3.Positioning of forklift & telehandlers while unloading the admixtutes	2.5	2	5	M
4.Lowering of telehandler forklift & shifting admixture barrles to stock yard	2.8	2	5.6	H
5.Loading & unloading of cement bags using telehandlers	2.3	2	4.6	M
6.Loading & unloading of materials using tower crane material basket	2.6	2	5.2	H
7.Movement of mobile crane to designated area for erection of batching plant	2.4	2.5	6	M
9.Loading & unloading of batching plant accessories by crane	2.2	2.6	5.72	H
10.Providing power supply to batching plant	2.7	2.2	5.94	H
11.Placement of concrete by concrete pump, tyre mounted placers, static placer booms	2.2	2	4.4	M
12.Filling, lifting & placing of concrete by concrete bucket using	1.8	2.5	4.5	M
13.Clearance & isolation of working area	2	2.3	4.6	M
14.Pouring the concrete into the hooper of concrete pump	1.6	1.6	2.56	M
15.Using the concrete	1.9	2.3	4.37	M

Fig. 5. Risk considered for this study and their ratings.

In general the risk impact is calculated as the product of likelihood and severity.

Risk impact = likelihood × severity.

The risk rating is the risk level that is derived from the risk matrix when the above mentioned likelihood and severity rating are used.

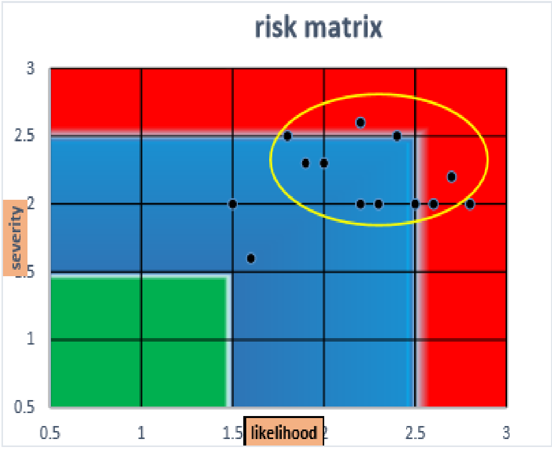

Fig. 6. Risk matrix with different risks categories.

From the Fig.6 it is clearly visible that many risks are the boundary of categories medium and high. This implies that the impact value of all these risks on the project is more or less same. But the risks are categorised into medium and high irrespective of their impact on the project.

Table. 1. Risk impact and risk rating calculated from risk matrix

Risk number	Risk impact	Risk rating
3	5	M
4	5.6	H
6	5.2	H
7	6	M
8	5.72	H
9	5.94	H

And also from Fig.5 the risk impact of risks 6, 7, 8 are 5.2, 6, 5.72 and the risk ratings are H, M, and H. Even though the risk impacts of 6, 8 are lower than the risk impact of 7, both 6, 8 are rated as H(high) and 7 is rated as M(medium).

This creates lot of uncertainties in the overall risk assessment process. So to avoid this problem the risk matrix should be modified. The categorisation should be continuous rather than having crisp boundary. The risk rating should be done based on the impact value.

V. FUZZY LOGIC MODEL

Fuzzy logic is an extension of Boolean logic by Lotfi Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory. By introducing the notion of degree in the verification of a condition, thus enabling a condition to be in a state other than true or false, fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties.

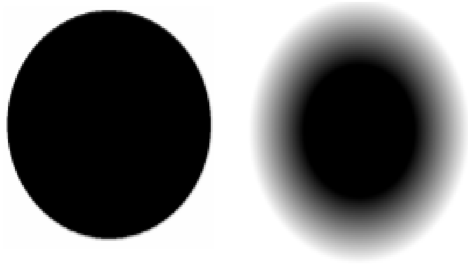

Fig. 7. Graphical representation of fuzzy logic model.

Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership. It deals with degrees of membership and degrees of truth. It reflects how people think and attempts to model our sense of words, our decision making and our common sense. The basic structure of a fuzzy inference system consists of three conceptual components: a rule base, which contains a selection of fuzzy rules; a database which defines the membership function used in the fuzzy rules; and a reasoning mechanism which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion.

One advantage of fuzzy logic in order to formalize human reasoning is that the rules are set in natural language by using the linguistic variables e.g.: high, medium, and low. This concept of membership is very important because fuzzy logic is based on the concept of fuzzy membership.

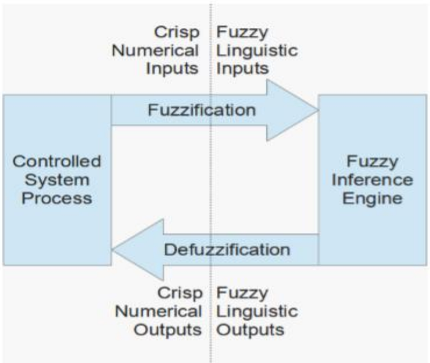

Fig. 8. An overview of fuzzy logic model.

This simply means that 'X' can belong to a set to 0.8, in contrast to classical set theory where as we have just seen membership is either 0 (not owned) or 1 (part).

The shape of the membership function is chosen arbitrarily by following the advice of the expert or by statistical studies: triangular, trapezoidal, Gaussian, hyperbolic, tangent, exponential, or any other form can be used. The only condition is, the chosen function should in a range of [0, 1].

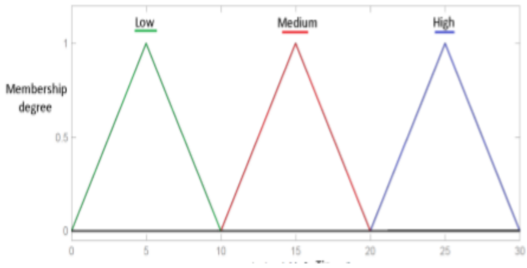

Fig. 9. A triangular membership function.

The primary reasons for using fuzzy logic risk analysis model are:

- The modelling 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 u nderstood and could also be intuitively verified.
- The parallel nature in which rules are activated in a fuzzy system ensures that all factors are considered i n 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.

VI. MODIFIED RISK MATRIX

To handle the above discussed problem the risk matrix should be modified, so that uncertainties in the input data i.e. likelihood & severity are taken care and the output results i.e. risk rating was appropriately performed. To this modification in the risk matrix we used fuzzy logic model. The whole risk assessment process was done in MATLAB using fuzzy logic toolbox. The input functions are likelihood & severity and the output is risk impact. The triangular membership function is chosen for all. The rules are defined and the risk impact is calculated.

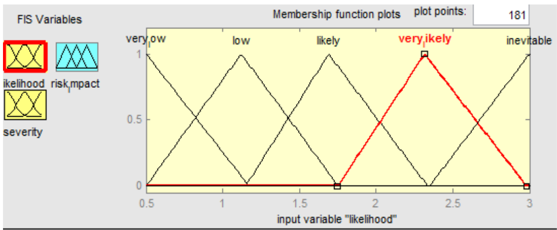

Fig. 10. Graphical user interface of fuzzy logic toolbox for defining input and output functions.

The modified risk matrix will be:

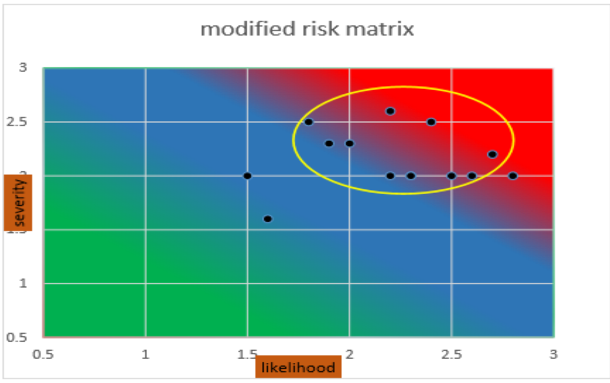

Fig. 11. Modified risk matrix with different risk categories.

From the Fig. 11 the modified risk matrix have no crisp boundaries. The risk categorisation is continuous. There will be no confusion in differentiating the risks. Now the risks are rated only based on the impact on the project objectives.

Table. 2. A comparison original risk impact and modifies risk impact values.

Risk number	Risk impact	Modified Risk impact
3	5	5.4
4	5.2	6.2
6	5.6	5.7
7	6	5.3
8	5.72	5.6
9	5.94	6

Fig. 12. Shows how the risk impact varies in a 3D view. This impact value varies gradually at the boundaries of risk categories, but it varies rapidly in the other regions.

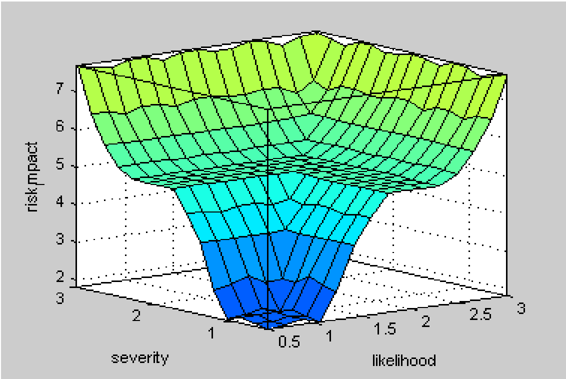

Fig. 12. A 3D representation of how the modified risk impact varies with likelihood and severity.

VII. CONCLUSION

Risk rating is an important part in risk analysis. It defines how the risk will affect the project objectives. The input data may also uncertainties and guesses. A false rating of a risk may have serious impact on the project. Hence the risk impact must be calculated by using mathematical models. The fuzzy logic is such a mathematical tool which can handle the uncertain data and provides solution reasonable manner which is similar to human thinking. By using the fuzzy logic the risk matrix is modified by eliminating the crisp boundaries and introducing flexible boundaries. This flexibility allows the user to use the risk matrix in a more comfortable way without any confusions.

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