

ISM and MICMAC Model for Construction Delay

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Abstract - For delay in construction projects, there are several reasons responsible. These reasons are inter-related to each other. This paper is based on the study of the inter-relations of various reason for such delay in construction through analytical methods used to properly reason and relate the primary causes with secondary causes. In order to minimize the delay, these relations must be understood by the project manager in order to focus on them, avoid the delay and increase productivity. This paper deals with the qualitative study regarding the above-mentioned aspect using the ISM and MICMAC Analysis.

The data is collected from the construction field experts to conduct ISM and MICMAC Analysis using Java coding. The ISM model finds the inter-relations between several factors as stated above and models a hierarchal structure showing factors influencing each other and causing delay in the project. MICMAC model finds the strength of the influence of a factor on the other. From these analytical models, the relation among the influencing factors and depending factors is determined. Its practical implications in understanding the flow of events causing delay in construction is then understood.

Key Words: Delay Analysis, Construction, Interpretive Structural Modelling, Matrix Impact Cross Multiplication Analysis of Classifications, Project Management

1. INTRODUCTION

Any construction project has an uncertainty and chance that it may be delayed. It is due to involvement of multiple factors and stakeholders adding to the dynamics and complexity in management of such projects. It is important to minimize any possibility and impact of the occurrences delay causing events. To do so, it is important to understand the causes of delay, the inter-relation of these causes among each-other. It is because of the potential of problems which are basic to other subsequent challenges. They must be recognized and based on this knowledge, the project manager can avoid or stop the potential of delay before it affects the work by identifying the possible path of delay.

Construction projects as a whole are generally non-repetitive. Delay in construction is very common, it occurs at different stages of a project. Every project is unique on its own and so, every project has its unique challenges but the underlying bases and the nature of all the construction projects is same. For instance, there are many stakeholders involved and they all have their unique role and challenges throughout the project. As these stakeholders are in relation to each other, their challenges also may emerge from some problems that are common to all construction projects.

The causes of delay are chained and inter-related among themselves and it is complicated to ascertain it. Study of this assertion is the research gap that is covered through analytical model based on the logic and understanding of the factors or causes of delay considered under this study. There are many Analytical Methods to do this out of with RII Method is very common although this study is not conducted using the ISM and MICMAC Analytical Models that are used to do this study. ISM Model implies a general path for understanding the delay that can be represented in a hierarchal chart and MICMAC Model can imply the influence to understand the intensity of the same. These methods are inter-disciplinary and is used in variety of research areas providing more comprehensive results.

2. ISM AND MICMAC ANALYSIS

2.1 INTERPRETIVE STRUCTURAL MODELLING

ISM Analysis was first introduced by John Warfield in 1974. The factors or parameters which are interrelated to each other are studied such that the logical and mathematical approach derives and explains the relation among them. These factors affect the system and thus, analysing these variables allows us to analyse and understand the whole system. These variables are considered for the study and are structured into a comprehensive model. Warfield quotes "To expedite the process of creating the digraph, which can be converted to a structural model and then inspected, revised to capture the user's best perceptions of the situation."

The structure of this analysis is extracted from the set of variables based on the mode of relationships. This basic data is very primitive as all the results of the analysis are based on this. The system follows GIGO analogy according to which the

wrong input will give the wrong result. Again, the perception of the situation is all subjective and so the it is important to ensure that the input is correct. This analytical modelling results in specific relationships and the overall structures will portrait the digraph model or the hierarchal model for easier and better understanding. Sage quotes "ISM provides a means by which people can impose order and direction on the complex relationships among elements of a system" It is often used in the complex studies where multiple factors play equally important role. In such situations, getting a structured relationship is very crucial.

2.2 CROSS-IMPACT MATRIX MULTIPLICATION APPLIED TO CLASSIFICATION (MICMAC)

The Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) tool was developed by Duperrin and Godet [1973] It is a tool used for categorizing variables based on hidden and indirect relationships and it is used to understand the extent to which they influence each other. It is based on the principle states that in a binary matrix which identifies the existence of influence length through a path has variable X directly influencing variable Y and Y directly influencing variable Z, then X indirectly influences variable Z. But, when that binary matrix (say A) is squared using Boolean Algebra, the second order relationship between variables X and Z are revealed. Like-wise, the multiple order of the relationships are revealed with the multiple order of power raised for the binary matrix in consideration. Each time, the process is repeated, a new and more indirect set of relationship is revealed. The influence referenced at the same cell if occurs multiple times, then the strength of that relationship represented through such cell is counted as the measure of the influence. After a stage of increasing order, the variation in the sets is not seen. At such stage, it is concluded that all the indirect relations are revealed.

2.3 APPLICATION OF ISM AND MICMAC ANALYSIS

ISM approach helps us understand the direct relationship between the variables and develop a hierarchal structure and MICMAC Analysis helps us understand indirect relationships among all the variables. It gives a model, comprehensive and simple to understand the complexity of factors interrelating to each other. It is used to answer simplest and most complicated question with assertion of logic which is based on the input. Together, the ISM and MICMAC Analysis helps us understand the system properly.

There are numerous applications of these approaches. In this study, the factors causing delay are numerous. It is important to understand the nature of the relationship among these factors causing delay in order to prevent the same. To do so, ISM and MICMAC Analysis must be conducted on these factors.

2. GENERAL PROCEDURE

The procedure of ISM Analysis and MICMAC Analysis initially have a few common steps. They are explained in the following steps

Step 1: Defining a set of variables that affect the system

The variables or factors which are inter-related can be taken as the set of variables for the analysis. In the following study, the causes of delay are taken as the set of variables as the input. Based on the insights given by the experts in the field of work during interviews, 27 factors or causes of delay that are generally classified into 6 groups are taken into consideration for this analysis. This is the limiting step of the analysis

Step 2: Establishing a contextual relationship among variables

As the result of this analysis is based on the information provided in this step, the accuracy of the information taken here is imperative. In this step, a pair-wise comparison is made among all the variables taken into consideration. The contextual relationship implies such that a variable may either cause and lead or assist or both unless it does not affect another variable. It is represented by (say) A, B, C, D in the Variable Relationship Table (VRT) as explained in step III. Understanding this relationship is important and the succeeding steps are depending on this understanding.

For this analysis, the understanding of the input describing the inter-relations of factors causing delay in construction projects is based on the inputs and insights given by the experts in the field of study and stakeholders of various projects is considered. They have provided with the pair-wise comparison of each cause of delay and how it affects the other. This is prepared based on a questionnaire asking the inter-relationship of each variable with every other variable. Where, variable is the factor causing delay.

Step 3: Establishing a contextual relationship among variables

The pair-wise relationships which were identified are now expressed in a tabular way creating a matrix. The relations are expressed in terms of 4 suffixes indicating the type or nature of the relationship of the variables under consideration. The table has row and columns both representing the factors taken into consideration. And the cell value indicating the relationship expressed for a row variable i with respect to the column variable j

1. V implies that variable i relates directly to variable j
2. A implies that variable j relates directly to variable i
3. X implies both A and B
4. O implies neither A nor B

In this analysis, this table is expressed as Variable Relationship Table (VRT) and the cell values V, A, X, O are expressed by the variables A, B, C, D. If the input of value of cell $ij=A$ in upper triangle of matrix then, its equivalent value of cell $ji=B$ but if the cell value is either C or D then, values are same i.e. $cell\ ij=cell\ ji$

Table -1: Variable Relationship Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	C	A	A	C	C	C	C	B	C	C	A	A	A	C	A	A	A	C	C	A	A	C	B	C	A	A	C
2	C	C	C	A	A	A	A	C	A	A	A	A	B	A	B	C	D	A	A	C	B	A	C	A	B	B	A
3	A	C	C	B	B	B	A	A	B	B	C	C	B	B	B	A	D	B	B	A	B	B	A	B	D	B	D
4	A	C	A	C	B	D	D	A	D	D	D	D	D	D	A	D	D	D	A	D	D	A	D	D	D	D	D
5	C	A	A	A	C	A	A	D	A	A	D	D	C	A	C	C	B	A	A	C	D	A	D	A	D	D	A
6	A	C	A	D	A	C	A	A	D	D	C	C	D	D	D	A	C	D	D	A	D	D	A	D	C	C	D
7	A	C	A	D	B	B	C	A	D	D	B	D	D	D	D	A	D	D	D	A	D	D	A	D	D	D	D
8	A	C	A	B	D	B	B	C	B	B	D	D	D	B	B	A	D	B	B	A	B	D	A	B	D	D	D
9	A	C	A	D	B	D	D	A	C	D	D	D	D	D	A	D	D	D	A	D	D	A	D	D	D	D	D
10	A	C	A	D	B	D	D	A	D	C	D	D	D	D	A	D	D	D	A	D	D	A	D	D	D	D	D
11	B	A	B	D	D	B	C	D	D	D	C	B	B	D	D	D	D	D	D	D	D	B	D	D	B	B	D
12	B	A	C	D	D	B	D	D	D	D	A	C	B	D	D	D	D	D	D	D	D	B	D	D	B	B	D
13	B	A	C	D	B	D	D	D	D	D	A	A	C	D	D	D	B	D	D	D	D	D	D	D	D	D	D
14	A	C	A	D	B	D	D	A	D	D	D	D	D	C	D	A	D	D	D	A	D	D	A	D	D	D	D
15	A	C	A	D	B	D	D	A	D	D	D	D	D	D	C	A	B	D	D	A	D	D	A	D	D	D	D
16	A	C	A	B	B	B	B	A	B	B	D	D	D	B	B	C	B	B	B	A	B	D	A	B	D	D	D
17	A	D	D	D	C	B	D	D	D	D	D	D	D	A	D	A	A	C	D	D	A	D	D	D	B	D	D
18	A	C	A	D	B	D	D	A	D	D	D	D	D	D	A	D	C	D	A	D	D	A	D	D	D	D	D
19	A	C	A	D	B	D	D	A	D	D	D	D	D	D	D	C	A	D	D	A	D	D	A	D	D	D	D
20	A	C	A	B	B	B	B	A	B	B	D	D	D	B	B	A	B	B	B	C	B	D	A	B	D	D	D
21	A	C	A	D	D	D	D	A	D	D	D	D	D	D	A	D	D	D	A	C	D	A	D	D	D	B	D
22	B	A	C	D	B	D	D	D	D	A	A	D	D	D	D	D	D	D	D	D	D	C	D	D	D	D	D
23	A	C	A	B	D	B	A	B	B	D	D	D	B	B	A	D	B	B	A	B	D	C	B	D	D	D	D
24	A	C	A	D	B	D	D	A	D	D	D	D	D	D	A	D	D	D	A	D	D	A	C	D	D	D	D
25	B	A	D	D	D	C	D	D	D	D	A	A	D	D	D	D	A	D	D	D	D	D	D	D	C	A	D
26	B	A	C	D	D	B	D	D	D	D	A	A	D	D	D	D	D	D	D	D	D	D	D	D	B	C	D
27	B	A	D	D	B	D	D	D	D	D	D	D	D	D	D	D	D	D	D	C	D	D	D	D	D	D	C

A: $i \rightarrow j$	i relates to j
B: $i \leftarrow j$	j relates to i
C: $i \leftrightarrow j$	i relates to j && j relates to i
D: $i \nleftrightarrow j$	i doesn't relate to j && j doesn't relate to i

Step 4: Developing a Reachability Matrix from the SSIM and checking the matrix for transitivity.

In order to check for the transitivity of the relations in the VRT developed in step 3, we must first develop the initial reachability matrix. Many individual results were different and it was based on different understanding. All the places where such different was observed, the understanding was reviewed and the doubts were clarified such that the nature of system flow has no conflict. The input of such conflicts was resolved with the flag system where the implications were taken as both influencing and depending nature if not un-related. This resolved the flags. The consolidated final VRT is given in the Table 1.

1. This table is modified such that the cells indicating the forward relation from row to column as in the unit's place of Standard 2x2 binary matrix with values (00, 01, 10, 11) respectively. It implies that cells with value 'A' and 'C' are replaced with '1' and with value 'B' and 'D' with '0'. The Initial Reachability Matrix (IRM) obtained is given in Table No. 2
2. Using the logic of transitivity explained in Section 3 with Java Code, the Final Reachability Matrix (FRM) is obtained from the Boolean algebra with IRM as input. The Final Reachability Matrix is given in Table No. 3

Table -2: Initial Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	0	1	1	1	0	0	1
3	1	1	1	0	0	0	1	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0
4	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
5	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	1	1	1	0	1	0	1	0	1	0
6	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	1	0	0	1	0	0	1	0	0	1	0	1
7	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
8	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
9	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
10	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
11	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	1	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	0	0
15	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	0
16	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
17	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	1	0	0	1	0	0	0
18	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	1	0	0	0
19	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0
20	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
21	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	1	0	0
22	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
23	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
24	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0
25	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
26	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
27	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1

A → 1
B → 0
C → 1
D → 0

Table -3: Final Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
1	1	1	0	0	1	1	1	1	0	1	1	0	0	0	1	0	0	0	1	1	0	1	1	0	1	0	1	1
2	1	1	1	1	0	1	1	1	1	1	0	0	0	1	0	1	0	1	1	1	1	1*	1	1	1	1	0	0
3	1	1	1	1*	1*	0	1	0	1*	1*	1	1	1*	1*	0	1	0	1*	1*	1	1*	1*	1	1*	0	1*	1*	
4	1	1	1	1	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	0	1	0	1*	1*	1	1*	1*	1	1*	0	1*	1*	
5	1	0	0	0	1	1	0	0	1	1	0	0	1	0	1	1	0	1	1	1	1	1*	1	0	0	0	0	
6	0	1	0	0	1	1	1	1	0	1*	1	1	1*	0	1*	1	1	1*	1*	1	0	0	1	1*	1	1	1*	
7	1	1	1	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1*	0	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	
8	0	1	1	1*	1*	0	1*	1*	1*	1*	1*	0	0	0	0	1	0	1*	1*	1	1*	1*	1	1*	0	0	1*	
9	1	1	0	1*	1*	1*	1*	1	1	1*	1*	0	1*	0	0	0	0	1*	1*	0	1*	1*	1	1*	0	0	1*	
10	0	1	1	1*	1*	0	1*	1*	1	0	0	0	1*	0	0	0	1*	1*	1*	1	1*	1*	0	0	1*	0	1*	
11	0	0	0	0	1*	0	1	0	0	1*	1	1*	1*	0	1*	0	0	1*	1*	1*	1*	1*	0	0	0	0	1*	
12	0	0	1	1*	1*	1*	1*	0	0	1*	1	1	1*	0	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	
13	0	0	1	1*	1*	0	0	0	1*	0	0	1	1	1*	0	1*	1*	0	0	0	0	0	0	0	0	0	1*	
14	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	0	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	
15	0	1	1	1*	1*	1*	0	0	1*	0	1*	1*	1*	0	0	1	0	1*	1*	1*	1*	0	0	0	1*	0	0	
16	0	1	1	1*	1*	1*	1*	1	1*	0	0	1*	1*	1*	1*	1	1*	1*	1*	1	1*	1*	0	1*	1*	1*	1*	
17	0	0	0	0	1	1*	0	1*	1*	1*	0	1*	1	0	1	0	1	1*	1*	1	1*	1*	0	0	1*	0	0	
18	1	1	1	1*	1*	1*	1*	1*	1*	1*	0	1*	1*	1*	1*	1	1*	1*	1	1*	1*	1	1*	1*	0	1*	1*	
19	1	1	1	1*	0	1*	1*	1	1*	0	0	1*	0	1*	0	1	1*	1*	1	1	1*	1*	1	1*	0	1*	1*	
20	1	1	1	1*	1*	1*	1*	1	1*	1*	1*	1*	0	0	1*	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	0	
21	1	1	1	1*	1*	1*	1*	1	1*	1*	0	1*	0	1*	0	1	1*	1*	1*	1	1*	1*	1	1*	1*	0	1*	
22	0	0	0	1*	1*	1*	1*	1*	1*	1*	0	1	0	1*	0	1*	0	1*	1*	1*	1*	1*	1	1*	1*	0	0	
23	1	1	1	1*	0	1*	1*	1	1*	1*	0	1*	0	1*	1*	1	1*	1*	1*	1	1*	1*	1	1*	1*	1*	1*	
24	1	1	1	0	1*	1*	1*	1	0	1*	0	1*	1*	0	1*	1	1*	1*	1*	1	1*	1*	1	1	1	0	1*	
25	0	0	0	0	0	1	0	1*	0	1*	1	1	1*	0	1*	0	1	0	1*	1*	1*	1*	0	0	1*	1	1*	
26	1*	0	1	1*	1*	1*	0	0	1*	1*	0	1	1*	0	0	0	0	1*	1*	1*	1*	1*	0	0	1*	1*	1	
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	

3. LOGIC OF TRANSITIVITY OF RELATIONS

The transitivity(s) are computed based on the following principle of transitivity which states that if a variable A is related to variable B and variable B is related to variable C, then it implies that variable A also relates with variable C.

$$(ArB) \cap (BrC) \rightarrow (ArC)$$

(3.1)

The transitivity is obtained in the Reachability Matrices by computing the following logic where we multiply the sum of above Matrix input and the identity matrix with itself. All the operations and iterations are based on Boolean Algebra. This

is continued until the successive powers produce the identical matrices indicating that the longest path has been reached. The power in the final iteration (say r) is defined as $r \leq s$, where s , is the number of points in the set. Mathematically, it is stated as follows

$$(A+I) \neq (A+I)^2 \neq \dots \neq (A+I)^{R-1} = (A+I)^R = M \quad (3.2)$$

4. PROCEEDING PROCEDURE OF ISM ANALYSIS

After the general common steps mentioned above are followed, the Final Reachability Matrix is obtained, the ISM Analysis is conducted separately

Step 1: Partitioning the Reachability Matrix into different levels

The reachability matrix is the processed to form different levels of the structural model. It involves many sub-steps. Based on the matrix rows, a Reachability Set (Set R) is made for each variable or factor such that it includes all the column numbers indicating the factor expressed in the influenced counterpart of the system. Conversely, based on the matrix columns, an Antecedent Set (Set A) is also obtained for each variable or factor such that it includes all the row numbers indicating the factor expressed in the influencing counterpart of the system. Such influencing and influenced factors are read for the cell values equal to 1. Again, the interception of set R and set A is obtained by

$$(Set R) \cap (Set A) = Set R \cap A = Set C \text{ (say)} \quad (3.3)$$

The Set C is compared with Set A for all the variables and those variables where the compared sets are identical are eliminated. With this elimination, the variables get eliminated. This elimination is carried forward in all the other sets of variables. This updates all the Reachability Sets and Antecedent Sets of the remaining variables. The process is repeated in the next iteration until all the variables are eliminated.

The group of iterations is formed where all elements eliminated in the respective iteration are stacked together. Each iteration indicates a level of hierarchal structure in the final model and the variables in that iteration are separated accordingly.

Step 2: Forming a canonical form of the matrix

A canonical form of the above elimination and grouping of variables into different levels is made by re-arranging the variable of the reachability matrix according to its level. The resulting matrix is identical to the lower triangular matrix or its transpose.

Step 3: Computing the dependencies and flow relation

The sum of the rows and columns is taken and the comparison of the value of this sum is taken for each the variable in row and in column separately. A matrix indicating the values of difference in row and column equivalent is taken and a flow relation is prepared. The linear values are taken and the jump indication of the levels is considered to read the flow of dependency.

Step 4: Preparing the Hierarchal Chart

All the variables are placed into the ascending order of the level in with they belong. The inter-relationships are obtained from the corresponding entries of the canonical form and the dependency flow relation obtained by grouping the variable of same level. It is formed by the group of sub-groups of levels indicating the sets or matrices which indicate the reachability among the levels for the variable. These submatrices become the identity matrix if no cycles are remaining. Thus, for every subsequent step a digraph is prepared based on which, the hierarchal model is prepared with the top-down approach and replacing the variable nodes of the variable level.

The hierarchal structure is given in Figure 1 shown in the section 5

5. PROCEEDING PROCEDURE OF MICMAC ANALYSIS

After the initial common steps where the Final Reachability Matrix is obtained, the MICMAC Analysis is conducted separately. The Matrix of Direct Influence is taken as input in the MICMAC Software developed by Lipsor in France which auto generates the MICMAC Results based on the input data.

The input data consists of the information of intensity of interaction in the levels represented by 0, 1, 2, 3. These are ordered sequence of intensities which are derived from the FRM obtained according to logic given in the step 1, described below.

Step 1: Developing the Matrix of Direct Influence (MDI)

The basic relationship among the variables is represented by 3. The transverse relationship is represented by 1. If the relationship exists for the variables in the matrix indicating the reciprocal of the same, expressed such that the value of the cell $ij == cell ji$ then such cell value will be replaced by 2. The Matrix of Direct Influence is given in Table No. 4

Table -4: Matrix of Direct Influence

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
1	0	0	0	3	3	3	3	0	3	3	0	0	0	3	0	0	0	3	3	0	3	3	0	3	0	3	3		
2	3	0	3	3	0	3	3	3	3	3	0	0	0	3	0	3	0	3	3	3	2	3	3	3	0	0	2	3	
3	3	3	0	2	2	0	3	0	2	2	3	3	2	2	0	3	0	2	2	3	2	2	3	2	0	2	2	2	
4	3	3	3	0	2	0	1	3	1	1	2	1	1	1	0	3	0	1	1	3	1	1	3	2	0	1	2	2	
5	3	0	0	0	0	3	0	0	3	3	0	0	3	0	3	3	0	3	3	3	3	1	3	0	0	0	0	3	
6	0	3	0	0	3	0	3	3	0	2	3	3	2	0	1	3	3	1	1	3	0	0	3	1	3	3	3	2	
7	3	3	3	1	2	2	0	3	1	1	2	1	2	1	0	3	2	1	1	3	1	1	3	1	2	2	2	2	
8	0	3	3	2	0	2	2	0	2	2	2	0	0	0	0	3	0	2	2	3	2	1	3	2	0	0	2	2	
9	3	3	0	1	2	2	1	3	0	1	2	0	1	0	0	0	0	1	1	0	1	1	3	2	0	0	0	2	
10	0	3	3	1	2	0	1	3	1	0	0	0	0	1	0	0	1	1	2	2	3	1	0	0	1	0	1	2	
11	0	0	0	0	2	0	3	0	0	2	0	2	2	0	1	0	0	2	2	1	0	0	0	0	0	2	0	2	2
12	0	0	3	1	2	2	1	0	0	2	3	0	2	0	1	1	1	1	1	1	1	2	1	1	0	2	2	2	
13	0	0	3	1	2	0	0	0	1	0	0	3	0	1	0	1	2	0	0	0	0	0	0	1	0	0	0	2	
14	3	3	3	1	2	2	1	3	2	1	2	2	1	0	2	3	2	1	1	3	1	1	3	2	2	2	2	2	
15	0	3	3	2	2	1	0	0	2	0	1	1	0	0	0	0	2	1	2	0	0	0	0	0	1	0	0	2	
16	0	3	3	2	2	2	2	3	2	0	0	1	1	2	2	0	2	2	2	3	2	1	0	2	2	2	2	2	
17	0	0	0	0	3	2	0	2	2	1	0	1	3	0	3	0	0	1	1	3	1	0	0	1	0	0	0	2	
18	3	3	3	1	2	1	1	3	1	1	0	1	2	1	1	3	1	0	1	3	1	1	3	1	0	1	2	2	
19	3	3	3	1	0	1	1	3	1	0	0	1	0	1	0	3	1	1	0	3	1	1	3	1	0	1	0	1	2
20	3	3	3	2	2	2	2	3	2	2	1	1	0	0	2	3	2	2	2	0	2	1	3	2	1	0	2	2	
21	3	3	3	1	1	2	1	3	1	1	0	1	0	1	0	3	1	1	1	3	0	1	3	1	0	1	2	2	
22	0	0	3	1	2	2	1	1	1	2	0	3	0	1	0	1	0	1	1	1	1	1	0	1	1	0	0	2	
23	3	3	3	2	0	2	2	3	2	2	0	1	0	2	2	3	2	2	2	3	2	1	0	2	2	2	2	2	
24	3	3	3	0	2	1	1	3	0	1	0	1	1	0	1	3	1	1	1	3	1	1	3	0	0	1	2	2	
25	0	0	0	0	0	3	0	2	0	2	3	3	2	0	2	0	3	0	2	1	2	0	0	2	0	3	2	2	
26	2	0	3	1	2	2	0	0	2	1	0	3	2	0	0	0	0	1	1	2	1	0	0	1	2	0	1	1	
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	1

Step 2: Using MDI as input in the MICMAC Software

The MDI developed is used as input in the MICMAC Software developed by Lipsor in France. The software computes the matrix and gives the result of MICMAC Analysis in the form of Graphs and Maps of Direct and Indirect Influence along with the Displacement Map. The maps are similar to the Scatter Diagram but it is spread over 4 region or co-ordinates representing the nature of the variable which lies in it. These are known as Zones of Influence. In MICMAC Analysis we get Autonomous Zone, Independent Zone, Dependent Zone and Linking Zone. Details of the same are explained later with the analysis. The MDI is taken as input after the validation of the software to get the results consisting of the following

1. Direct Influence Map

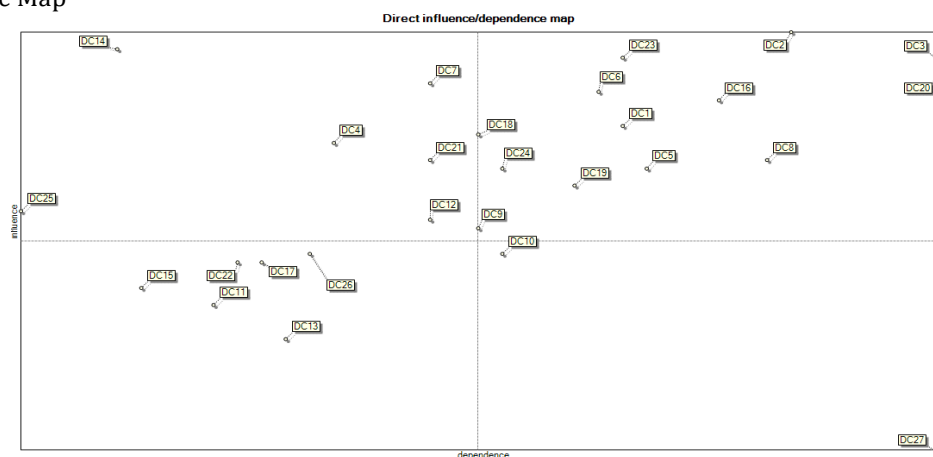


Fig -1: MICMAC Direct Influence Map

2. Direct Influence Graph

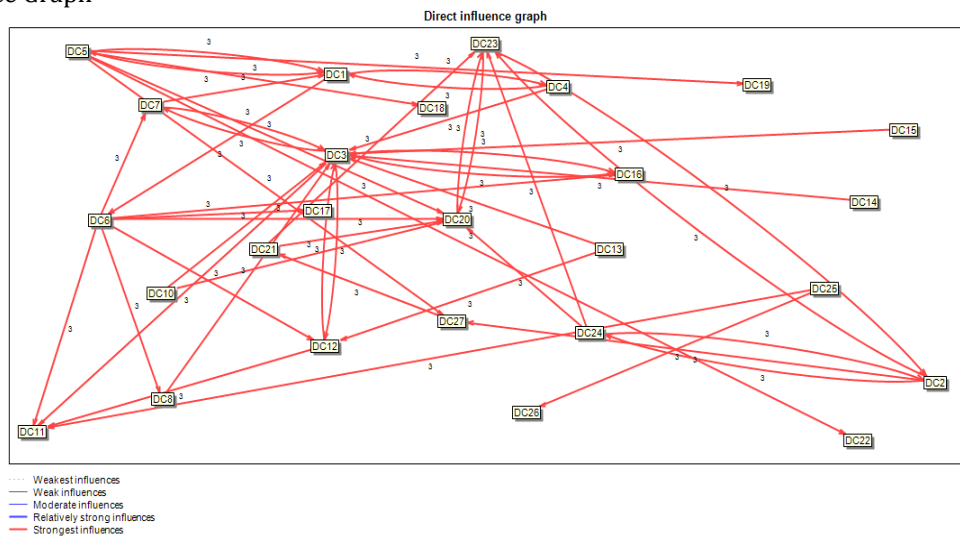


Fig -2: MICMAC Direct Influence Graph

3. Indirect Influence Map

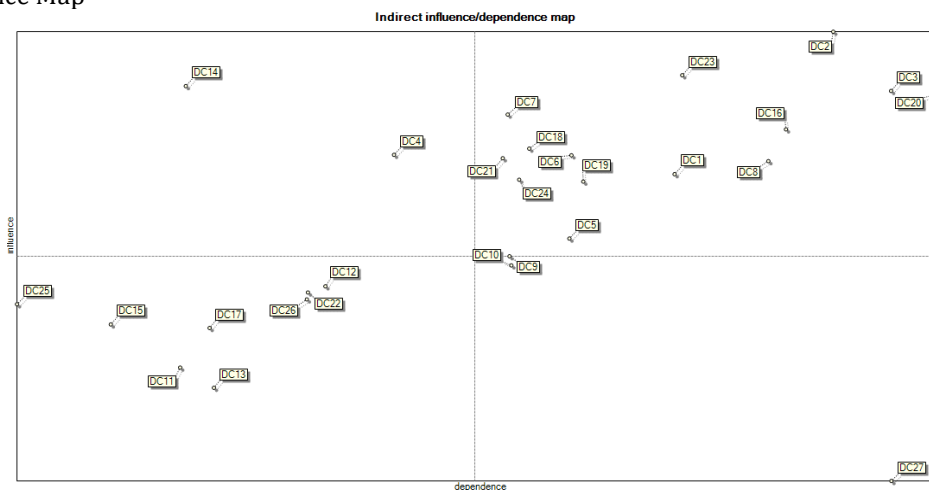


Fig -3: MICMAC Indirect Influence Map

4. Indirect Influence Graph

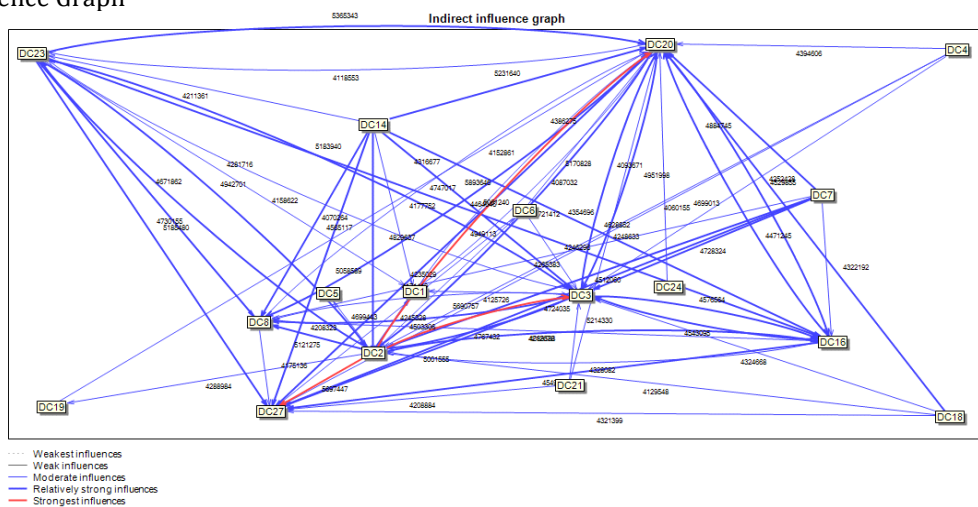


Fig -4: MICMAC Indirect Influence Graph

5. Direct – Indirect Displacement Map

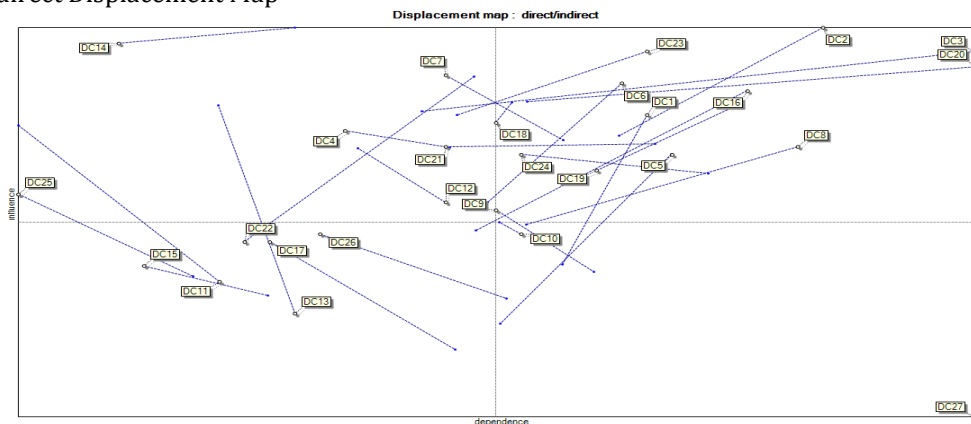


Fig -5: Direct - Indirect Displacement Map

5. RESULTS

5.1 ISM Results

In the final step of ISM, the variables were eliminated in iterations representing the hierarchal structure of the allocation of the variables. The variables eliminated in the first iteration are primary and they are dependent on other variables. This nature of dependency is followed by all the variables in the sub-sequent iterations. After that, the dependencies are analysed through the inter-relations of the variables with other variables. This follows the directional flow of the dependencies according to the sequence of the iterated variables. This gives the hierarchal structure of dependencies of the variables representing the factors which are under the study.

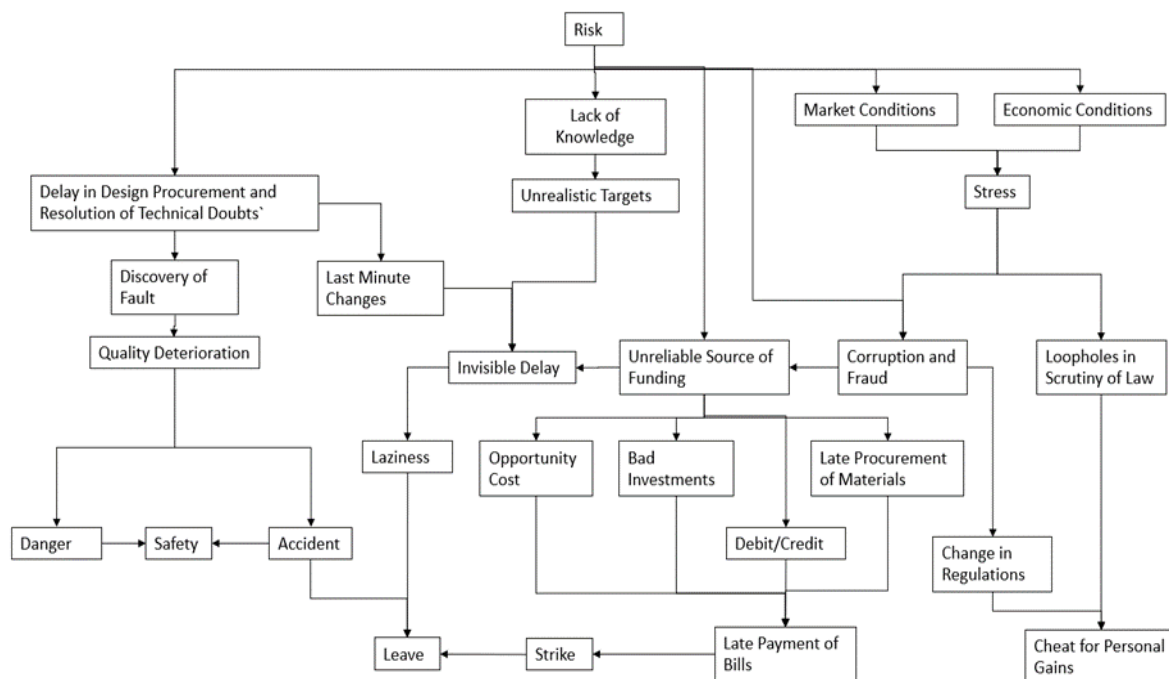


Fig -6: ISM Hierarchal Structure

This structure is validated and approved by the experts who provided the information used as the input in the analysis during the survey. They approved of the above prepared structure as it made the logical sense.

5.2 MICMAC Results

MICMAC Results mentioned above indicate the distribution of the variables in the influence maps and the intensity of the relations from the influence graph. The direct influence map provides the information on the dependencies of the factors. The map has variables spread in 4 regions represented by Z1, Z2, Z3, Z4 respective to the II, III, I, IV quadrants in a geometrical plane (Jorge Arnaldo Troche-Escobar, 2018). These are known as Variable Zones

1. Zone 1 is for the Independent Variables: The variables which are not dependent on other variables but have more leverage are in this region.

- a. Strike
- b. Danger
- c. Late Payment of Bill
- d. Unreliable Source of Funds
- e. Last Minute Change or Corrections in Design

The above-mentioned variables are the independent reasons which cause the delay in the construction project. Management must understand that these reasons are primitive. These causes of delay can seriously impact the work and must be addressed properly so to avoid any of these occurring to avoid the delay in the construction project

2. Zone 2 is for the Autonomous Variables: The variables which are dependent and have more leverage are in this region

- a. Safety
- b. Discovery of Fault or issue during the execution
- c. Delay due to Laziness
- d. Corruption and Fraud
- e. Accident
- f. Lack of Knowledge

These causes of delay are dependent and have more influence in the project. Management must understand that these are the challenges which can be avoided in order to ensure the smoothness in the work flow. As long as proper care is taken, these issues should not be the problem

3. Zone 3 is for the Linkage Variables: The variables which are not dependent and have less leverage are in the group

- a. Bad Investments
- b. Change in Regulations
- c. Debt-Credit
- d. Leave of Absence
- e. Late Procurement of Materials
- f. Cheat for personal gains
- g. Quality Deterioration
- h. Opportunity Cost
- i. Unrealistic Targets
- j. Market Conditions
- k. Stress
- l. Economic Conditions
- m. Invisible Delay due to execution strategies

These are the Linkage Variables which cause the delay in the project. These are unpredictable factors which are linked with the other variables such that any of these occurring may cause an effect to the variables which are linked with these variables. In a way, these causes lead other causes follow as a consequence. Management must understand that these issues may cause or may be caused by these.

4. Zone 4 is for the Dependent Variables: The variables which are dependent and have less leverage are in this group

- a. Delay in procurement of Design and resolution of the technical doubts
- b. Risk

These variables are dependent and have less leverage. They have high dependencies and so many variables relate with them. Management must understand that these things are caused due to other variables. The Influence Graph gives the intensity of the relations among the variables interacting with each other directly and indirectly.

The strong indirect relations show how much the factors are interactive among each other. The above-mentioned graphs indicate the strong indirect influence among Risk (DC 27) related Delay Causes related to Change in Regulations (DC 20) and Finance and Accounting such as Opportunity Cost (DC 1), Debt-Credit (DC 2), Bad Investments (DC 3). It signifies that the Financial strength and Compliance with the regulations play a very critical part in the stability of the project.

6. CONCLUSIONS

1. This study confirms the applicability of the ISM and MICMAC Analysis on construction projects to analyze the factors causing delay.
2. In a project, at a stage where delay occurs, we can back trace and predict the succeeding and preceding factors to stop the larger impact and minimize the delay.
3. These relationship and interdependencies were considered for the ISM and MICMAC Analysis are generally applicable to all types of construction project
4. The above research also concludes that the delay is subjected to a few important factors. If these are not handled properly, then several other factors intensify the delay, ultimately this delay affects the overall project cost.
5. Such study allows to get a different perspective for the same problem and give a better understanding of the subject in study. The above analysis gives a generalized statement regarding the delay analysis.
6. The major risk is due to Market and Economic Conditions along with the Financial and Accounting Conditions which may jeopardize the safety of the project and its completion. It helps to better understand the challenges to deal with then provide an insight regarding the subject studied

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