International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 6 (2015) pp. 13823-13840

http://www.ripublication.com

Interpreting Delay Factors for Improving Productivity in Indian Construction Industry

Mugdha Kshirsagar[1], Sayali Sandbhor[2], Rohan Botre[3]
[1,2]Assistant Professor, Department of Civil Engineering, Symbiosis Institute of Technology, SIU, India.
[3] Graduate Scholar, Department of Civil Engineering, Purdue University, USA.

Abstract

Construction delays have been affecting the schedules and budgets of projects leading to time and cost overruns. Delays are a result of various factors that affect the progress of the project thus hampering the productivity. Total Interpretive Structural Modeling (TISM) based approach has been implemented to identify underlined relation between factors causing delays on construction site to improve productivity. It helps device a policy to avoid occurrence of delays by finding the driving and dependence relations. Total 18 factors have been identified based on extensive literature review. Questionnaire survey conducted for Indian population of contractors and consultants helps reduce number of factors to 10 most important factors further used for the study. The result of TISM shows that contractor's inadequate experience, mistakes during construction stages, lack of communication between parties have high driving power and low dependency. Problems with subcontractor, shortage in material, contractor's poor site management have high dependence power and low driving power. Factors with high driving power should be given due importance to avoid delays. It is an effort of its kind in application of TISM in construction delays.

Keywords: Construction industry, construction delays, Interpretive Structural Modeling (ISM), TISM, productivity.

1.0 Introduction

Time and cost are the two common concerns of construction management. Many factors relate to delay and cost overruns and vary along with types of project, locations, sizes, and scopes. (Le-Hoai L. et al, 2008). India's rapid economic growth over the last decade has resulted in boom in infrastructural development. Over 40% of Indian construction projects are facing time overrun ranging from 1 to 252 months; the reasons for which are being studied by researchers to suggest possible remedial measures (Iyer K.C. and Jha K.N., 2006). Activity delays can negatively affect several dimensions of construction project performance. Delays can lengthen schedules, increase project costs and jeopardize quality as well as safety (Gonzalez P. et al, 2013). Thus, the delay in completion of a construction project can be a major problem for contractor companies leading to costly disputes and adverse relationships amongst project participants. Projects can be delayed for a large number of reasons. The reasons are related to the various types of uncertainty associated with activities during the construction process (Alwi S. and Hampson K., 2003). Although schedule delays seem to be embedded in all projects, identifying the main causes and preventing these problems from occurring are better than resolving subsequent delay-related disputes (Yang J.B. and Wei P.R., 2010). Delays are common in various construction projects and cause considerable losses to project parties. The common results of delays include late completion of project, increased cost, disruption of work, loss of productivity, third party claims, disputes and abandonment or termination of contracts (Aziz R.F., 2013).

For construction industry, productivity can be improved by reducing time and cost overruns. Time overrun is the result of various factors, which are required to be studied to understand their priority so as to take corrective action and minimize the delays. To cater to this, it is the responsibility of the construction manager to identify factors leading to delays of construction projects. Nature of Total Interpretive Structural Modeling (TISM) as a methodology has been discussed for dealing with delay factors of construction projects. Aspects of managing complexity relating particularly to the use of TISM are explored. Use of this technique gives a systematic relation between the factors causing delays on construction site. The relation thus obtained by applying TISM would enable the contractor to minimize delays and achieve higher profits.

1.1 Literature Review

Literature survey reveals eighteen most important factors causing delays (Table I). Assaf S.A. et.al (1995) examined the causes of delays in large building construction projects and identified 56 causes of delay grouping them into 9 major categories. Chan D.W.M. and Kumaraswamy M.M. (1997) conducted a survey to evaluate the relative importance of 83 potential delay factors falling into 8 major categories in Hong Kong construction projects. Alwi S. and Hampson K. (2003) carried out survey for identifying the important causes of delays in building construction projects in Indonesia. A questionnaire survey was carried out targeting 89 respondents to assess the level of importance of 31 potential delay factors grouped into six major groups. Assaf S.A. and Al-Hejji S. (2006) studied the causes of delays in large construction projects in Saudi Arabia identifying 73 causes of delays. Alaghbari W. et al (2007) studied significant factors causing delay of building construction project in Malaysia. Sambasivan M. and Soon Y.W. (2007) identified 10 most important causes of delay from list of 28 different causes and six different effects of delay and further established empirical relationship between each cause and effect. Yang J.B. and Wei P.R. (2010) identified and ranked delay causes in the planning and design phases. This study identified the delay causes and analyzed the importance and frequency of delays using the relative importance index. Hamzah N. et al (2011) categorized the various types of delays and have proposed a comprehensive delay framework. Gunduz M. et al (2013) listed 83 factors categorizing them into nine major groups. The study identified 15 most important factors visualized by the Ishikawa (fishbone).The relative importance of the identified delay factors was quantified and the ranking of the factors and groups were demonstrated according to their importance level on delay. Eight major categories of material, labour, equipment, finance, contractor, client, consultant, external factors were subcategorized into 57 factors causing non excusable delays by Ibironke O.T. et al (2013). Aziz R. F. (2013) has shortlisted 99 factors to be made part of the questionnaire survey and categorized them into 9 major categories. The study of success factors is to improve the effectiveness of the project and its overall performance. Sandbhor S. et.al (2014) identifies nineteen significant factors leading to success of construction project taking into account few factors causing delays.

Table 1: Important factors causing delays

Sr. No	Factors	References
1.	Lack of experience of consultant in construction projects	Gunduz,M.(2013), Alwi,S. and Hampson, K.(2003), Assaf S.A. et.al (1995), Yang, J.B.et al (2010), Sambasivan, M. and Soon Y.W. (2007), Yehiel,R.(2013), Aziz R. F. (2013).
2.	Inadequate contractor experience	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003), Lo, T.Y.(2006), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010), Assaf S.A. et.al (1995), Le-Hoai, L. et al(2008), Sambasivan, M. and Soon Y.W.(2007), Alaghbari W. et. al (2007), Aziz R. F. (2013).
3.	Ineffective project planning and scheduling/ Contractor's improper planning	Yang, J.B.et al (2010), Gunduz,M.(2013), Alwi,S. and Hampson,K.(2003), Assaf S.A. et.al (1995), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010), Le-Hoai, L. et al (2008), Sambasivan M. and Soon Y.W.(2007), Yehiel,R.(2013), Assaf, S. A. and Al-Hejji, S. (2006), Alaghbari W. et. al (2007), Ibironke, O. T. et al (2013).
4.	Contractor's Poor site management and supervision	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003), Lo, T.Y.(2006) Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010), Le-Hoai, L. et al(2008), Sambasivan, M. and Soon Y.W.(2007), Yehiel,R.(2013), Assaf, S. A. and Al-Hejji, S. (2006), Alaghbari W. et. al (2007), Aziz R. F. (2013).
5.	Unreliable subcontractors/ Problems with sub-contractor	Gunduz M.(2013), Alwi S. and Hampson, K.(2003), Sambasivan, M. and Soon Y.W. (2007), Alaghbari W. et. al (2007), Ibironke,O. T. et al(2013), Aziz R. F. (2013).
6.	Delay in	Gunduz M .(2013), Alwi,S. and Hampson, K.(2003)

	performing inspection and testing	Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010).
7.	Unqualified/inexperienced workers	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003), Aziz R. F. (2013).
8.	Change orders/ Poor scope definition	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003) Yang, J.B.et al (2010),Lo, T.Y. (2006), Assaf S.A. et.al (1995), Yehiel,R. (2013), Ibironke,O. T. et al(2013), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010) , Aziz R. F. (2013).
9.	Delay in site delivery/ shortage of materials	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010), Assaf S.A. et.al (1995), Ibironke,O. T. et al(2013)., Alaghbari W. et. al (2007), Sambasivan, M. and Soon Y.W.(2007), Aziz R. F. (2013).
10.	Delay in approving design documents	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003) Fugar F.D.K.(2010), Yehiel,R. (2013).
11.	Delay in progress payments/ Lack of running capital/ Cash flow/ Inadequate client's finance / payment for completed work	Gunduz M.(2013), Lo, T.Y.(2006), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010), Assaf S.A. et.al (1995), Le-Hoai, L. et al(2008), Sambasivan, M. and Soon Y.W. (2007), Yehiel,R.(2013), Assaf, S. A., Al-Hejji, S. (2006), Alaghbari W. et. al (2007), Ibironke,O. T. et al(2013), Aziz R. F. (2013).
12.	Slowness in decision making	Gunduz M.(2013), Alwi,S. and Hampson, K.(2003), Assaf S.A. et.al (1995), Assaf, S. A., Al-Hejji, S. (2006), Ibironke,O. T. et al(2013), Aziz R. F. (2013).
13.	Lack/ Poor communication and coordination with other parties	Gunduz M.(2013), Yehiel,R.(2013), Ibironke, O. T. et al(2013), Alaghbari W. et. al (2007), Aziz R. F. (2013).
14.	Unexpected surface and subsurface conditions	Gunduz M.(2013), Fugar, F.D.K. and Agyakwah-Baah, A.B. (2010), Assaf S.A. et.al (1995), , Yehiel,R.(2013).
15.	Project complexity	Yang J.B.et al (2010), Gunduz M.(2013), Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010) , Aziz R. F. (2013).
16.	Labour Supply	Assaf S.A. et.al (1995), Fugar, F.D.K. and Agyakwah-Baah, A.B. (2010), Alwi,S. and Hampson,K.(2003), Le-Hoai, L. et al(2008), Sambasivan, M. and Soon Y.W.(2007), Alaghbari W. et. al (2007), Ibironke,O. T. et al(2013).
17.	Equipment	Assaf S.A. et.al (1995), Fugar, F.D.K. and Agyakwah-

	availability and failure	Baah, A.B. (2010), Alwi,S. and Hampson,K.(2003), Sambasivan, M. and Soon Y.W.(2007), Alaghbari W. et. al (2007), Ibironke,O. T. et al(2013).
18.	Mistakes during construction stages	Assaf S.A. et.al (1995), Le-Hoai, L. et al (2008), Sambasivan, M. and Soon Y.W. (2007), Assaf, S. A. and Al-Hejji, S. (2006), Alaghbari W. et. al (2007).

1.2 Research Objective and Methodology

The main objective of the research is

- To identify factors causing delays on construction sites.
- To establish contextual relation among the factors through discussions with the experts.
- To develop structural model using TISM.

To carry out matrice d'impacts croises multiplication appliqué a un classement (MICMAC) analysis to classify the factors based on dependence and driving power.

A questionnaire has been developed to assess the perceptions of contractors and consultants regarding the relative importance of the causes and effects of delays for Indian scenario. The questionnaire consists of the identified factors that contribute to delays. The questionnaire approach has been adopted because the study intends to capture the perceptions of various stakeholders in consulting and contracting organizations. A total of 10 construction firms and 10 consulting firms in India have been selected. The selected firms have records of experiencing non-excusable delays at some point in the past. Professionals in these firms have been identified as respondents to the questionnaire. Convenience sampling method has been adapted to identifying the respondents.

The questionnaire is divided into two parts. The first part requests background information about the respondents. The second part of the questionnaire focuses on causes of delays. The respondents have been asked to indicate their responses to 18 delay factors. Sixty copies of the questionnaire were administered to a random sample of 30 contractors and 30 consultants to assess their perceptions of the relative importance of the causes and effects of non-excusable delays. With the modified set of factors causing delays, a group of construction professionals is asked to give their opinion about relation among these factors. This exercise helps to develop contextual relationship between factors. Group of professional involve owners, contractors as well as consultants from India.

2.0 ISM and TISM Technique

Interpretive Structural Modeling (ISM) is a methodology which enables to establish complex relationships between multiple elements in a complex situation (Warfield J.N. 1974). ISM is an interactive learning process and a tool which permits identification of structure within a system. The system may be technical, social, medical or any system which contains identifiable elements which are related to one another in some fashion (Farris D.R. and Sage A.P., 1975). In this method, the group's judgment decides whether and how items are related. On the basis of the relationship, an overall structure is extracted from the complex set of items. The specific relationships and overall structure are portrayed in a digraph model (Sage A.P. 1977). Research related to ISM dates back to 1970s. A study by Watson R.H. (1978) explains the rationale for the use of ISM in activities such as technology assessment and the basic concepts underlying the technique. ISM has been implemented to analyze factors contributing to vendor selection (Mandal A. and Deshmukh S.G. 1994), improving group decision making to limit conflict and increase shared knowledge (Bolanos R. et al, 2005) , success factors affecting implementation of advanced manufacturing technologies (Singh R.K. et al, 2007), knowledge management barriers (Singh M.D. and Kant R., 2008), supply chain management (Quereshi M.N. et al, 2008; Singh R.K. 2011; Shahbadkar P. et al, 2012), growth enablers of construction companies (Bhattacharya S. and Momaya K, 2009), six sigma (Soti A. et al. 2010), quality management (Sahney S. et al, 2010), barriers of total quality management (Talib F. et al, 2011), production planning (Haleem A. et al, 2012), total quality management for airline performance (Singh A.K. et al, 2012)and exploring the involvement aspect of customers towards greening of the supply chain (Kumar S. et al, 2013).

TISM has originated from ISM technique which facilitates development of graphical representations of complex systems. The process of interpretive structural modeling has been revisited and upgraded to TISM by incorporating the interpretation of each relation. It not only gives direct relation but also gives transitive relation. This is not only useful in making the structural model fully interpretive, but also contributes in creating a knowledge base of the interpretive logic of all the relations. TISM is an innovative version of Warfield’s ISM technique, and is used to model and structure the factors for greater understanding of the interplay of these factors (Sushil, 2005a, 2005b, 2012). TISM is used by Nasim S. (2011) to model and structure the forces of change and continuity in e-government. Prasad, U.C. and Suri,R.K. (2011) have applied TISM to model continuity and change forces in private higher technical education. In the study by Wasuja S. et al (2012), TISM is used to create a hierarchy amongst the various factors of cognitive bias in selling specialty drugs and interpret the relationships amongst them. TISM has been used to model strategic performance factors for effective strategy execution (Srivastava A.K. and sushil, 2013). It has also been applied to improve labour productivity in construction projects (Sandbhor S. and Botre R., 2014). In Sandbhor S.et al (2015), TISM is implemented as a methodology for identifying and summarizing relationships among factors which lead to success of construction project.

3.0 Application of TISM to Delay Causing Factors

Since the factors under consideration cause delays on construction sites, it is ideal to reduce their occurrence and effect during the project. All these factors cannot be given same amount of attention by the management since it is practically not feasible. Thus efforts in reducing their effect or occurrence at the root level have to be undertaken. This can be achieved by finding their relationship with one another and with overall productivity. This can be achieved by systematic interpretive logic represented by TISM.

TISM starts with identification of factors, which are relevant to the problem or issue. It then extends with a group problem solving technique to develop contextual relationship. Having decided on the element set and the contextual relation, the steps followed are as given below:

a) Developing a structural self-interaction matrix (SSIM) based on contextual relationship factors
b) Conversion of SSIM into a reachability matrix (RM)
c) Checking its transitivity and obtaining matrix model.
d) Partitioning of the elements and extraction of the structural model.

3.1 Structural Self Interaction Matrix (SSIM)

The factors are identified as V1 to V10 in the given sequence for simplifying further study. A matrix (Table 2) helps to establish relation between row factor i and column factor j. The existence of a relation between any two factors and the associated direction of relation is asked to a group of experts. Four symbols V, A, O and X are used for the type of relation existing between the two factors under consideration. The symbols are:

V- When i leads to j but j does not lead to i;
A- When j leads to i but i does not lead to j;
X- When I leads to j and j leads to i;
O- When the relation between the elements does not appear valid.

The structural self-interaction matrix (SSIM) for the element under consideration is then prepared by filling in the responses of the group for each pair-wise interaction between the elements (Sushil, 2012) as shown in Table 2 below.

Table 2: Structural self interaction matrix

Code	Factor	V10	V9	V8	V7	V6	V5	V4	V3	V2	V1
V1	Contractor's improper planning	X	V	V	V	V	A	O	A	V	-
V2	Contractor's poor site management	X	A	A	V	X	A	A	A	-	
V3	Inadequate contractor's experience	V	V	V	V	V	V	O	-		
V4	Inadequate client's finance/ payment for completed work	A	V	O	O	V	A	-			
V5	Lack of communication between parties	V	O	V	V	V	-				
V6	Problems with sub-contractor	O	O	X	A	-					
V7	Shortage in material	O	O	O	-						
V8	Labour Supply	O	O	-							
V9	Equipment availability and failure	O	-								
V10	Mistakes during construction stages	-									

3.2 Reachability Matrix (RM)

RM is prepared from SSIM by transforming the information in each entry of the SSIM into 1's and 0's in the reachability matrix. This transformation is based on the relation given in table 3. RM thus prepared is given in Table 4 below. Entry for a factor with itself is represented by 1 (Sandbhor S. and Botre R., 2014).

Table 3: Rule for transforming SSIM to RM

(i-j) Entry	(i to j) Relation	(j to i) Relation
V	1	0
A	0	1
X	1	1
O	0	0

Table 4: Reachability matrix

Factor Code	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	1	1	0	0	0	1	1	1	1	1
V2	0	1	0	0	0	1	1	0	0	1
V3	1	1	1	0	1	1	1	1	1	1
V4	0	1	0	1	0	1	0	0	1	0
V5	1	1	0	1	1	1	1	1	0	1
V6	0	1	0	0	0	1	0	1	0	0
V7	0	0	0	0	0	1	1	0	0	0
V8	0	1	0	0	0	1	0	1	0	0
V9	0	1	0	0	0	0	0	0	1	0
V10	1	1	0	1	0	0	0	0	0	1

3.3 Partitioning the Reachability Matrix into Different Level

The level partition is carried out to know the placement of factors level-wise. Reachability set for a factor represents factors that carry value 1 in row of that factor. Similarly, antecedent set for a factor represents factors that carry value 1 in column of that factor. Intersection of the reachability set and the antecedent set will be the same as the reachability set if the element is at the top level. The top level elements satisfying the above condition should be removed from the element set and the exercise is to be repeated iteratively till all the levels are determined (Sushil, 2012). Table 5 shows the iterations and corresponding levels of factors.

Table 5: Level partition of factors

Iteration	Factor	Reachability Set (RS)	Antecedent Set (AS)	AS ∩ RS	Level
1	V1	1,2,6,7,8,9,10	1,3,5,10	1,10	
	V2	2,6,7,10	1,2,3,4,5,6,8,9,10	2,6	
	V3	1,2,3,5,6,7,8,9,10	3	3	
	V4	2,4,6,9	4,5,10	4	
	V5	1,2,4,5,6,7,8,10	3,5	5	
	V6	2,6,8	1,2,3,4,5,6,7,8	2,6,8	I
	V7	6,7	1,2,3,5,7	7	
	V8	2,6,8	1,3,4,5,8	8	
	V9	2,9	1,3,4,9	9	
	V10	1,2,4,10	1,2,3,5,10	1,2,10	
2	V1	1,2,7,8,9,10	1,3,5,10	1,10	
	V2	2,7,10	1,2,3,4,5,8,9,10	2	
	V3	1,2,3,5,7,8,9,10	3	3	
	V4	2,4,9	4,5,10	4	
	V5	1,2,4,5,7,8,10	3,5	5	
	V7	7	1,2,3,5,7	7	II
	V8	2,8	1,3,4,5,8	8	
	V9	2,9	1,3,4,9	9	
	V10	1,2,4,10	1,2,3,5,10	1,2,10	
3	V1	1,2,8,9,10	1,3,5,10	1,10	
	V2	2,10	1,2,3,4,5,8,9,10	2,10	III
	V3	1,2,3,5,8,9,10	3	3	
	V4	2,4,9	4,5,10	4	
	V5	1,2,4,5,8,10	3,5	5	
	V8	2,8	1,3,4,5,8	8	
	V9	2,9	1,3,4,9	9	
	V10	1,2,4,10	1,2,3,5,10	1,2,10	
4	V1	1,8,9,10	1,3,5,10	1,10	
	V3	1,3,5,8,9,10	3	3	
	V4	4,9	4,5,10	4	
	V5	1,4,5,8,10	3,5	5	
	V8	8	1,3,4,5,8	8	IV
	V9	9	1,3,4,9	9	IV
	V10	1,4,10	1,3,5,10	1,10	
5	V1	1,10	1,3,5,10	1,10	V
	V3	1,3,5,10	3	3	
	V4	4	4,5,10	4	V
	V5	1,4,5,10	3,5	5	
	V10	1,4,10	1,3,5,10	1,10	
6	V3	3,5,10	3	3	
	V5	5,10	3,5	5	
	V10	10	1,3,5,10	10	VI
7	V3	3,5	3	3	
	V5	5	3,5	5	VII
8	V3	3	3	3	VIII

Table 6 below gives levels of all the factors. Total seven levels are observed.

Table 6: Factor and respective level

Sr.No.	Factor	Code	Level in TISM
1	Problems with sub-contractor	V6	I
2	Shortage in material	V7	II
3	Contractor's poor site management	V2	III
4	Labour Supply	V8	IV
5	Equipment availability and failure	V9	IV
6	Contractor's improper planning	V1	V
7	Inadequate client's finance / payment for completed work	V4	V
8	Mistakes during construction stages	V10	VI
9	Lack of communication between parties	V5	VII
10	Inadequate contractor's experience	V3	VIII

3.4 Diagraph with Significant Transitive Links

The elements are arranged graphically in levels and the directed and significant links are shown as per the relationships observed in the reachability matrix. Fig. 1 below gives the diagrammatic representation of total interpretive model obtained from the study. Level VI, VII &VIII factors are considered to be the base factors. Level IV & V are middle factors and I, II, III as the top factors with importance in descending order. With level VIII factor being the most significant factor, all the higher level factors are observed to depend on the same. It is an independent factor as compared with others. Contractor's inadequate experience is observed to be the major factor that leads to the other factors causing delays. Hence it should be the prime most responsibility of the client or owner to hire contractor with sufficient experience to carry out similar projects. It is found to lead to lack of communication directly and seven other factors indirectly. Likewise, relationships can be established based on the diagraph below in Fig 1.

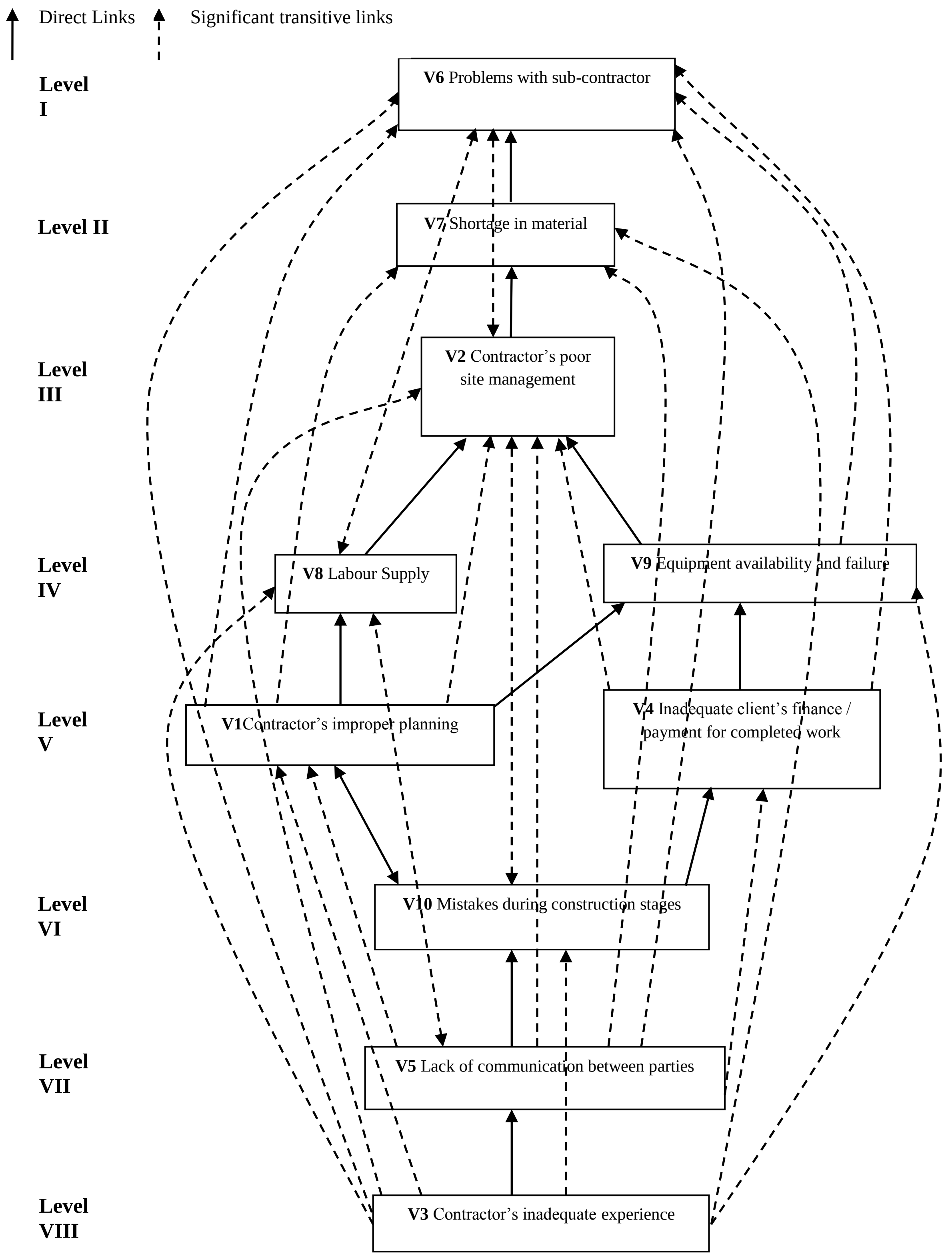

Figure 1: Diagraph indicating relationship of factors causing delays

4.0 Observations and Discussion

Table 7 below shows interaction matrix showing relation between the factors, direct link represented by ^{d} and significant transitive link represented by ^{s}.

Table 7: Interaction matrix

Factor code	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	-	1^s	0	0	0	1^s	1^s	1^d	1^d	1^d
V2	0	-	0	0	0	1^s	1^d	0	0	1^s
V3	1^s	1^s	-	0	1^d	1^s	1^s	1^s	1^s	1^s
V4	0	1^s	0	-	0	1^s	0	0	1^d	0
V5	1^s	1^s	0	1^s	-	1^s	1^s	1^s	0	1^d
V6	0	1^s	0	0	0	-	0	1^s	0	0
V7	0	0	0	0	0	1^d	-	0	0	0
V8	0	1^d	0	0	0	1^s	0	-	0	0
V9	0	1^d	0	0	0	0	0	0	-	0
V10	1^d	1^s	0	1^d	0	0	0	0	0	-

^{d}- Direct link ^{s}- Significant link

It is observed that the root cause of the delay is inadequately experienced contractor. Minimum standard pertaining to contractor's experience should be decided for different types of construction works. Furthermore, the reason for delay in next level of hierarchy is lack of communication between the parties. For this, a standard procedure should be set and the flow of all the processes should be identified and validated at various stages.

Mistakes during construction work can be avoided with vocational training or workshops for labours and subcontractors to enhance their skill set and equip them with latest technology. Middle hierarchical level comprises of inadequate client's finance/payment for completed work, contractor's improper planning, labour supply and equipment availability and failure. Inadequate client's finance/payment for completed work forms the crucial factor which can be reduced or eliminated if accurate estimates are specified to the owner well in advance during tendering process. It is observed that contractor's improper planning directly influences the labour and equipment availability which further leads to poor site management. This in turn affects the material availability due to change in usage rate, possibility of wastage and theft. Timely audits and operational verifications will reduce the delay factors in top hierarchy.

4.1 MICMAC analysis

Matrice d'impacts croises multiplication appliqué a un classement (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC (Mudgal R.K. et al. 2009). In the MICMAC analysis, the dependence power and driver power of the factors are analyzed. Factors will be classified into four clusters. The four clusters are autonomous, dependent, linkage, and driver/independent. In the final reachability matrix, the driving power and dependence power of each of the factors are plotted. Autonomous factors (first cluster) have weak driving power and weak dependence power. These factors can be disconnected from the system. The second cluster named dependent factors has weak driving power and strong dependence power. The third cluster named linkage factors has strong driving power and strong dependence power. The fourth cluster named independent factors has strong driving power and weak dependence power (Kumar S. et al, 2013).

Figure 2 gives the driving power and dependence power of selected factors as obtained from the model. Quadrant I represents autonomous factors, quadrant II represents dependent factors, quadrant III represents linkage factors and quadrant IV represents independent (driver) factors.

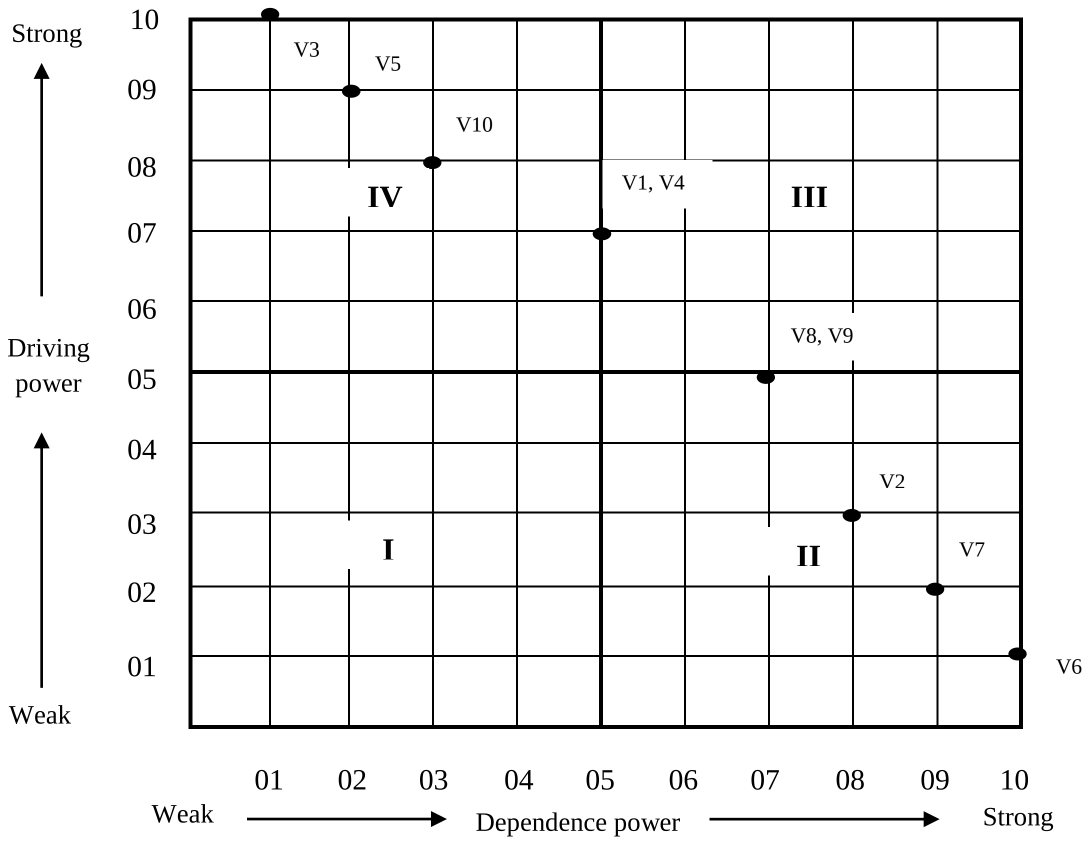

Figure 2: Driving power and dependence diagram

It is observed that V3 (inadequate contractor's experience), V5 (lack of communication between parties) and V10 (mistakes during construction stages) have strong driving power and weak dependence power. Factors V1 (contractor's improper planning) and V4 (inadequate client's finance / payment for completed work) lie on the borderline between quadrant II and IV, with high driving power and medium dependence power. V8 (labour Supply) and V9 (equipment availability and failure) fall on the borderline of quadrant II and III with medium driving power and high dependence power. V2 (contractor's poor site management), V7 Shortage in material and V6 (problems with sub-contractor) have strong dependence and weak driving power. V6 (problems with sub-contractor) has the highest dependence power.

5.0 Conclusion

Construction delays account for lost revenue, lost profit as well as lost reputation of the contractor. They also result in cost overruns and many such consequences. It is thus a matter of high importance for the contractor as well as the owner to give due consideration to this problem to avoid its ill effects. Application of TISM to better understand the factors causing delays on construction site provides a tool to analyze and plan corrective actions to achieve scheduled dates of completion improving overall performance of the construction site. It can be concluded that the contractors should give more importance to factors with high driving power to avoid the effect of dependent factors which have less significance. From the model, it is seen that inadequately experienced contractor would become a root cause of problems leading to delays. Owner can take corrective actions as per the model depending upon issues faced on construction site. Since only 10 factors are considered; the model may not be applicable to scenarios where factors other than these are more significant. Further research can be carried out to analyze various other factors not considered in the present study. Also, statistical validation of the model can be done with the help of structural equation modeling. TISM approach implemented for the study can be applied to areas where analysis of numbers of factors contributing to a problem is necessary.

References

[1]. Alaghbari,W., Kadir,M.R.A., Salim, A. and Ernawati (2007), "*The significant factors causing delay of building construction projects in Malaysia*", Engineering, Construction and Architectural Management Vol. 14 Issue: 2, pp.192 – 206.

[2]. Alwi, S and Hampson, K (2003), "*Identifying the important causes of delays in building construction projects"*, In proceedings the 9th East Asia-Pacific Conference on Structural Engineering and Construction, Bali, Indonesia.

[3]. Assaf, S.A., Al-Hejji, S. (2006), "*Causes of delay in large construction projects"*, International Journal of Project Management, 24, pp. 349-357.

[4]. Assaf, S.A., AI-Khalil M., and AI-Hazmi M. (1996), "*Causes of delay in large building construction projects"*, Journal of Management in Engineering, Vol. II, No.2, March/April, 1995. ASCE, Paper No. 27055.

[5]. Aziz, R.F. (2013), "*Ranking of delay factors in construction projects after Egyptian revolution"*, Alexandria Engineering Journal (2013) 52, pp. 387–406.

[6]. Bhattacharya, S. and Momaya, K. (2009), "*Interpretive structural modeling of growth enablers in construction companies"*, Singapore Management Review, 2009, Volume: 31 Issue: 1, pp.73-97.

[7]. Bolanos, R., Fontela, E., Nenclares, A., Pastor, P., (2005), "*Using interpretive structural modeling in strategic decision-making groups*", Management Decision, Vol. 43 No. 6, 2005, pp. 877-895.

[8]. Chan, D.W.M., and Kumaraswamy, M.M. (1997). "*A comparative study of causes of time delays in Hong Kong construction projects*", International Journal of Project Management, Vol.15 (1), 55–63.

[9]. Farris, D.R., Sage, A.P. (1975), "*On the use of interpretive structural modeling for worth assessment"*, Journal of Computers & Electrical Engineering, Volume 2, Issues 2–3, June 1975, Pages 149–174.

[10]. Fugar, F.D.K. and Agyakwah- Baah, A.B. (2010) "*Delays in building construction projects in Ghana*", Australasian Journal of Construction Economics and Building, 10 (1/2), pp. 103-116.

[11]. Gonzalez, P., Gonzalez, V., Molenaar, K. and Orozco, F. (2013), "*Analysis of Causes of Delay and Time Performance in Construction Projects"*, Journal of Construction Engineering and Management 2014.140., ASCE, pp. 1-9.

[12]. Gunduz, M. Yasemin Nielsen, Y. and Mustafa Ozdemir, M. (2013) *"Quantification of Delay Factors Using the Relative Importance Index Method for Construction Projects in Turkey"*, Journal of Management in Engineering, Vol. 29, No. 2, ASCE, pp. 133-139.

[13]. Haleem, A., Sushil, Qadri, M.A. and Kumar, S. (2012), "*Analysis of critical success factors of world class manufacturing practices: an application of interpretive structural modeling and interpretative ranking process"*, Production Planning and Control: The Management of Operations, Vol. 23 Nos. 10-11, pp. 722-34.

[14]. Hamzah, N., Khoiry, M.A., Arshad, I., Tawil, N. M. and Che Ani A. I. (2011), "*Cause of Construction Delay – Theoretical Framework",* The 2nd International Building Control Conference 2011, Procedia Engineering ,20, pp. 490 – 495, Elsevier.

[15]. Ibironke, O.T., Oladinrin ,T.O ,Adeniyi O. and Eboreime ,I.V. (2013), "*Analysis of Non-Excusable Delay Factors Influencing Contractors' Performance in Lagos State, Nigeria*", Journal of Construction in Developing Countries, 18(1), pp. 53–72, 2013.

[16]. Iyer, K.C. and Jha, K.N. (2006), *"Critical Factors Affecting Schedule Performance: Evidence from Indian Construction Projects",* Journal of Construction Engineering and Management, Vol. 132, No. 8, ASCE, pp. 871–881

[17]. Kumar S., Luthra S, Haleem A. (2013), "*Customer involvement in greening the supply chain: an interpretive structural modeling methodology",* Journal of Industrial Engineering International, Vol.9, No. 6.

[18]. Le-Hoai, L., Lee, Y.D. and Lee, J.Y.(2008); "*Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries*"; KSCE Journal of Civil Engineering ,12(6), pp. 367-377

[19]. Lo, T.Y., Fung, I.W.H. and Tung K.C.F. (2006), "*Construction Delays in Hong Kong Civil Engineering Projects"*, Journal of Construction Engineering and Management, Vol. 132, No. 6, ASCE, pp. 636–649.

[20]. Mandal, A. and Deshmukh, S.G. (1994), "*Vendor selection using interpretive structural modeling (ISM)"*, International Journal of Operations and Production Management, Vol. 14 No. 6, pp. 52-9.

[21]. Mudgal, R.K., Shankar, R., Talib, P., Raj, T. (2009), "*Greening the supply chain practices: an Indian perspective of enablers' relationship"*, International Journal of Advanced Operation Management (2–3), pp. 151–176.

[22]. Nasim, S. (2011)," *Total interpretive structural modeling of continuity and change forces in e-government"*, Journal of Enterprise Transformation, Vol. 1 No. 2, pp. 147-68.

[23]. Prasad, U.C. and Suri, R.K. (2011), "*Modeling of continuity and change forces in private higher technical education using total interpretive structural modeling (TISM)",* Global Journal of Flexible Systems Management, Vol. 12, No. 3 & 4, pp. 31-40.

[24]. Qureshi, M.N., Kumar, D. and Kumar, P. (2008), "*An integrated model to identify and classify the key criteria and their role in the assessment of 3PL services providers"*, Asia Pacific Journal of Marketing and Logistics, Vol. 20 No. 2, pp. 227-49.

[25]. Sahney, S., Banwet. D.K. and Karunes, S. (2010), "*Quality framework in education through the application of interpretive structural modeling: an administrative staff perspective in the Indian context"*, The TQM Journal, Vol. 22 No. 1, pp. 56-71.

[26]. Sage, A.P. (1977), "*Interpretive Structural Modeling: Methodology for Large Scale Systems"*, McGraw-Hill, New York, pp. 91-164.

[27]. Sambasivan, M., Soon, Y.W. (2007) , "*Causes and effects of delays in Malaysian construction industry"*, International Journal of Project Management 25, pp. 517–526

[28]. Sandbhor S. and Botre R.(2014)" *Applying total interpretive structural modeling to study factors affecting construction labour productivity*", Australasian Journal of Construction Economics and building, 14(1), pp.20-31.

[29]. Sandbhor S., Choudhari S., Arora A., Katoch P., "*Identification of factors leading to construction project success using principal component analysis*", International Journal of Applied Engineering Research, Research India Publications, Vol. 9, Number 17, 2014, pp. 4169-4180.

[30]. Sandbhor S., Mugdha Kshirsagar, Choudhari S., Arora A., Katoch P. (2015), *"Analyzing factors leading to Construction Project Success Using Total Interpretive Structural Modeling",* International Journal of Applied Engineering Research, ISSN 0973-4562 Volume 10, Number 2 (2015) pp.

2855-2868.

[31]. Shahabadkar, P., Hebbal, S.S., Prashant, S. (2012), "*Deployment of Interpretive Structural Modeling Methodology in Supply Chain Management –An Overview"*, International Journal of Industrial Engineering & Production Research, September 2012, Volume 23, Number 3, pp. 195-205.

[32]. Singh A.K., Sushil (2012), "*Modeling enablers of TQM to improve airline performance"*, International Journal of Productivity and Performance Management Vol. 62 No. 3, pp. 250-275.

[33]. Singh, M.D., Kant, R. (2008), "*Knowledge management barriers: An interpretive structural modeling approach"*, International Journal of Management Science and Engineering Management Vol. 3 (2008) No. 2, pp. 141-150.

[34]. Singh, R.K., Garg, S.K., Deshmukh, S.G., Kumar, M. (2007), "*Modeling of critical success factors for implementation of AMTs"*, Journal of Modeling in Management, Vol. 2 No. 3, 2007, pp. 232-250.

[35]. Singh, R.K. (2011), "*Developing the framework for coordination in supply chain of SMEs"*, Business Process Management Journal, Vol. 17 No. 4, pp. 619-38.

[36]. Soti, A., Shankar, R. and Kaushal, O.P. (2010), "*Modeling the enablers of Six Sigma using interpreting structural modeling*", Journal of Modeling in Management, Vol. 5 No. 2, pp. 124-141.

[37]. Srivastava A.K., Sushil (2013), "*Modeling strategic performance factors for effective strategy execution"*, International Journal of Productivity and Performance Management, Vol. 62 No. 6, 2013, pp. 554-582.

[38]. Sushil (2005a), "*Interpretive matrix: a tool to aid interpretation of management in social research"*, Global Journal of Flexible System Management, Vol. 6 No. 2, pp. 27-30.

[39]. Sushil, (2005b), "*A flexible strategy framework for managing continuity and change"*, International Journal of Global Business and Competitiveness, Vol. 1 No. 1, pp. 22-32.

[40]. Sushil (2012), "*Interpreting the interpretive structural model: organization research methods"*, Global Journal of Flexible Systems Management, 13(2), pp. 87-106.

[41]. Talib, F., Rahman, Z., Qureshi, M.N. (2011), "*Analysis of interaction among the barriers to total quality management implementation using interpretive structural modeling approach"*, Benchmarking: An International Journal, Vol. 18 No. 4, pp. 563-587.

[42]. Wasuja, S., Mahim, S., Sushil (2012), "*Cognitive bias in salespersons in specialty drug selling of pharmaceutical industry"*, International Journal of Pharmaceutical and Healthcare Marketing Vol. 6 No. 4, pp. 310-335.

[43]. Warfield, J.N. (1974), "*Towards interpretation of complex structural model*", IEEE, Vol-smc-4, issue-5.

[44]. Watson, R.H. (1978), "*Interpretive structural modeling—A useful tool for technology assessment",* Technological, Volume 11, Issue 2, pp. 165-185.

[45]. Yang, J.B. and Wei, P.R. (2010*), "Causes of Delay in the Planning and Design Phases for Construction Projects"*, Journal of Architectural Engineering, Vol. 16, No. 2, ASCE, pp. 80–83.

[46]. Yehiel, R., (2013), *"Root-Cause Analysis of Construction-Cost Overruns*", Journal of Construction Engineering and Management, ASCE, pp. 1-10.