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Critical Success Factors in Construction Projects: An Interpretive Structure Modeling Approach

Mirza Mabood Ali Beg

Abstract

The objective of this research is to define the critical factors that lead to project success and provide a forecasting tool to enable parties to rapidly assess the possibility of a successful project from their viewpoint. If project participants can predict probability of success better, they can take steps to: (1) Avoid unsuccessful projects; (2) Identify good projects worth pursuing; and (3) Identify problems on current projects and take corrective action. The general objectives were met through accomplishment of several specific tasks. The following research tasks were completed: (1) Define the project success criteria and (2) Develop an initial model for CPSFs by using ISM model. The study has a practical significance for the Construction Industry Top Management for determining the success factors. ISM has the capability to develop an initial model through managerial techniques such as brainstorming, nominal group techniques, etc.

Key Words: *Critical Success Factors, Interpretive Structured Modeling (ISM), Construction.*

INTRODUCTION

The construction industry is dynamic in nature due to the increasing uncertainties in technology, budgets, and development processes. Nowadays, building projects are becoming much more complex and difficult. Therefore, the completion of construction projects has become more complex and challenging. The mantra for a successful construction project has been ambiguously defined in the minds of the construction professionals. Study on the determinants of project success/critical success factors is believed to improve the effectiveness of the projects. Various attempts were made by different researchers to determine CSFs in construction. A number of variables influencing project success have been proposed. Some variables are common to more than one list, but there is no general

Mirza Mabood Ali Beg
Doctoral Research Scholar
Vinod Gupta School of Management
Indian Institute of Technology
Kharagpur, West Bengal
maboodbe@gmail.com

agreement on the variables. The Interpretive Structured Modeling process (ISM) method was then adopted in order to determine the relative importance of these CSF. It is used to identify how the CSF were weighed and prioritized by the construction professionals who were all working in different areas of the construction industry. The purpose of this paper is to present research that explores and determines the effective use of the ISM methodology and its ability to capture both subjective and objective criteria Thereby, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives and provide a useful mechanism for checking the consistency of the evaluation measures and alternatives. This would help in reducing bias in decision making and identifying potential gaps between the views of different stakeholders. ISM methodology suggests the use of the expert opinions based on various management techniques such as brain storming, nominal technique, etc., in developing the contextual relationship among the variables. Thus, in this research for identifying the contextual relationship among the critical success factors in construction projects, two experts, one each from the construction industry and the academia, were consulted for the same. These experts from the industry and academia were well conversant with critical success factors in construction industry having an experience of over 10 years.

LITERATURE REVIEW

In 1982, CSFs were are defined for the first time by Rockart as the few areas of activity in which favourable results are absolutely necessary for a manager to achieve the goals stated for the project (Li *et al.,* 2005, Chan *et al.,* 2004, Sanvido *et al.,* 1992). Evidence indicates that construction managers work with both a work with both a qualitative and a quantitative concept of success. There is always one critical success factor that leads the project; the subjective concept of success incorporates aspects of the end user and personal satisfaction, and the specific characteristics of the project (Latorre, 2009). The fact that there are few CSF might be arguable; furthermore, it could also be said that success factors are viewed by the literature as targets to meet, rather than areas of activity. Critical success factors are the key aspects of the project and lead to the accomplishment of project objectives. Identifying the critical factors to a project's success enables adequate resource allocation (Chua *et al.,* 1999). The two factors most frequently identified by the literature as critical success factors are time and cost (Naaranoja and Uden 2007). Rubin and Seeling (1967) use the tangible performance data of cost, schedule and quality/performance as a measure of success (Belassi and Tukel 1996). These performance objectives were coined as 'the iron triangle', and have been the criteria traditionally used to assess the success of a construction project (Chua *et al.,* 1999). Evidence shows that the specific weightings of each CSF may vary according to the Projects and the client's needs or expectations. Furthermore, the importance one CSF has over others will determine which skills are more desirable in a construction manager, in order to achieve a better project outcome (Latorre 2009). De Wit (1988) suggests, however, that overall project success should be measured against broader objectives from the viewpoint of all concerned stakeholders, contending that a project can be a success for one party but a disaster for another. Several authors believe that a completely incorrect conclusion regarding project success could be arrived at if the traditional project success criteria only are considered, while on the other hand, subjective measures are only meaningful when considered from the point of view of a particular observer (Hughes *et al.,* 2004). Consequently, it may be suggested that in order to measure the performance of a project, one must identify a particular observer, and use both objective and subjective criteria. Chua *et al.,* (1999) provide a multi criteria decision making approach in order to determine critical success factors to project success. This is achieved by consulting "experts" and using the Analytical Hierarchy Process (AHP) as proposed by Saaty in 1980. This approach contributes to answering the question of what is a critical factor by demonstrating that there has to be consistency in nomenclature and scope in order to effectively determine this set of factors. This need for consistency and clarity is a key aspect and has only been taken into consideration in the literature by Chua *et al.* It is important to note therefore that "Project success factors" may be defined as 'those key areas of activity in which favourable results are absolutely necessary for a manager to reach his/her goals' (Rockart 1982). "Project success criteria", on the other hand, are defined as 'the measures by which the success or failure of a project will be judged' (Cooke-Davies 2002: 185). Furthermore, Latorre (2009) identifies variations in the weightings of the traditional CSF according to client and to context. It is evident from the review of current literature that project success is subjective in nature and as a consequence, in order to determine the performance of a project, one must first identify a particular observer from whose perspective to assess. This raises a second issue in that one must determine whether the observer perceives success from a project management perspective, or from a product perspective. Ideally, as Baccarini (1999) proposed, project success should be determined using both project management and product success criteria. However, Turner (1999) points out that success is affected by time. As a consequence, the determination of product success tends to be long-term in nature and often orientated toward the total life span of a completed project, while project management success is measured during and at the end of the project (Munns and Bjeirmi 1996). A third issue to emerge is that many authors agree in that success has both 'hard' and 'soft' dimensions, and therefore, from whichever perspective project success is measured, both objective and subjective criteria must be taken into account to gain a complete assessment (Baccarini 1999, Baker *et al.*, 1988, de Wit 1988). Other authors, however, have specifically identified leadership and management as success factors. Cooke-Davies (2002) identified what he called the twelve 'real' success factors, derived from both 'hard' and 'soft' data from large national and multinational organizations, and again none of these factors were directly concerned with 'human factors'. However Cooke-Davies contends that it is becoming accepted wisdom that it is people who deliver projects, and so there are human dimensions to nearly every success factor identified. Using AHP allows the incorporation of both objective and subjective aspects into the CSFs in order to understand how their relative importance varies according to the several criteria.

Factors Affecting Project Success

A number of variables influencing the success of project implementation were identified following a thorough review of these articles. A careful study of previous literature suggests that CSFs can be grouped under the following categories.

1. Project-Related Factors
2. Project Management Factors
3. Procurement-related Factors
4. Client-related Factors
5. Design team-related Factors
6. Contractor-related Factors
7. Project Manager-related Factors
8. Business and Work Environment-related Factors
9. Other H.R Related

ANALYSIS

Structural Self-Interaction Matrix

For analyzing the critical success factors, a contextual relationship of **b** leads to **Q** type is chosen. This means that one variable leads to another variable. Based on this, contextual relationship between the variables is developed. Keeping in mind the contextual relationship for each variable, the existence of a relation between any two barriers (i and j) and the associated direction of the relation is questioned. Four symbols are used to

Table 1: SSIM

	i								
	Enablers	9	8	7	6	5	4	3	2
j	1.Project Related Factors	A	A	V	V	V	X	V	V
	2. Project Management Factors	X	A	V	X	X	A	V	
	3. Procurement Related	O	X	A	A	A	A		
	4. Client Related	O	O	V	V	X			
	5. Design Team Related	X	O	X	A				
	6. Contractor Related	A	X	X					
	7. Project Manager Related	X	A						
	8.Business & Work Environment	O							
	9.Other H.R Related								

denote the direction of relationship between the barriers (i and j):

V: Factors i will help alleviate Factors j;

A: Factors j will be alleviated by Factors i;

X: Factors i and j will help achieve each other; and

O: Factors i and j are unrelated.

The following would explain the use of the symbols V, A, X, and O in SSIM (Table 1).

Based on similar contextual relationships, the SSIM is developed for all the 9 critical factors for the construction projects (Table 1).

Reachability Matrix

The SSIM is transformed into a binary matrix, called the initial reach ability matrix by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1's and 0's are the following:

1. If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reach-ability matrix becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reach-ability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reach-ability matrix becomes 1 and the (j, i) entry also becomes 1.
4. If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reach-ability matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, initial reach-ability matrix for the success factors is shown in Table 2.

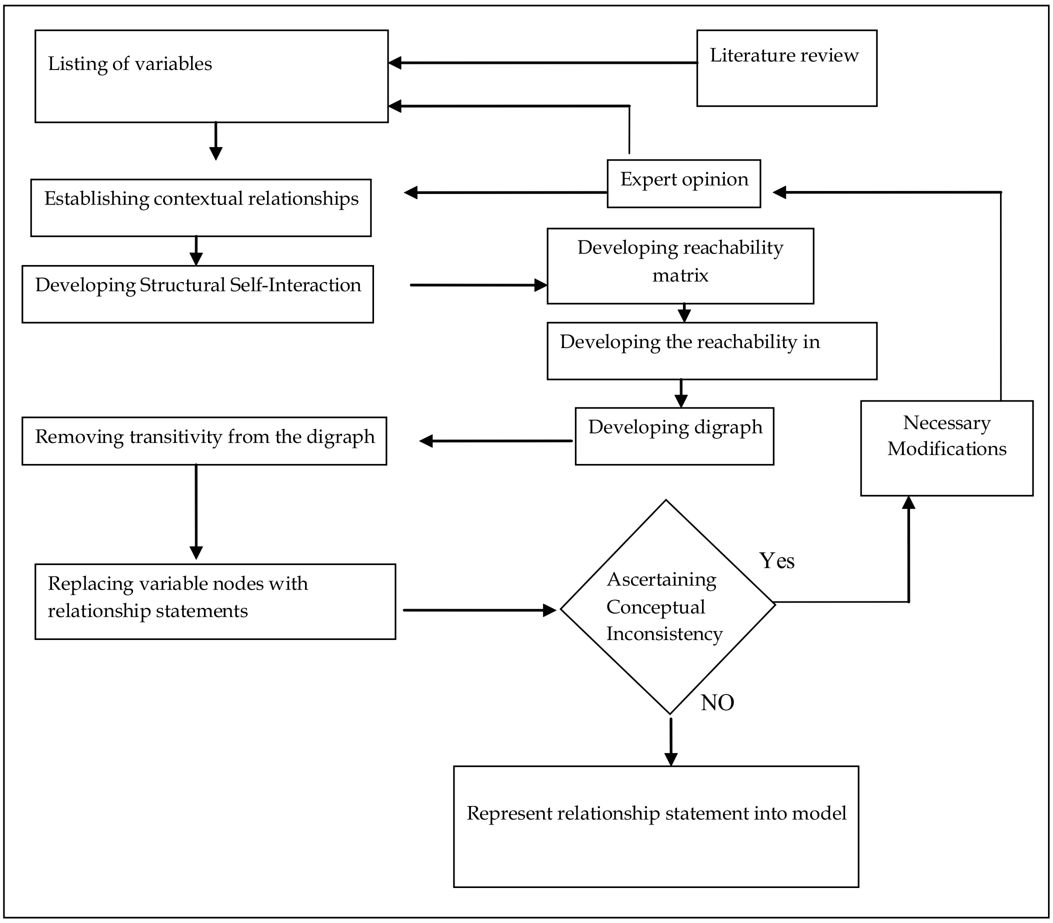

Figure 1: Flow Diagram for ISM-based Model

Table 2: Initial Reach-ability Matrix (IRM)

Enablers	1	2	3	4	5	6	7	8	9
1.Project Related Factors	1	1	1	1	1	1	1	0	0
2. Project Management Factors	1	1	1	0	1	1	1	0	1
3. Procurement Related	0	0	1	0	0	0	0	1	0
4. Client Related	0	1	1	1	1	1	1	0	0
5. Design Team Related	1	1	1	1	1	0	1	0	1
6. Contractor Related	0	1	1	1	1	1	1	1	0
7. Project Manager Related	0	0	1	1	1	1	1	0	1
8.Business & Work Environment	1	1	1	0	0	1	1	1	0
9.Other H.R Related	0	1	0	1	1	1	1	0	1

Table 3: Final Reachability Matrix (FRM)

Enablers	1	2	3	4	5	6	7	8	9	Driving Power
1.Project Related Factors	1	1	1	1	1	1	1	1	1	9
2. Project Management Factors	0	1	1	0	1	1	1	1	1	7
3. Procurement Related	0	0	1	0	0	0	0	1	0	2
4. Client Related	1	1	1	1	1	1	1	1	1	9
5. Design Team Related	0	1	1	1	1	0	1	0	1	6
6. Contractor Related	0	1	1	0	1	1	1	1	1	7
7. Project Manager Related	0	0	0	0	1	1	1	0	1	4
8.Business & Work Environment	1	1	1	0	0	1	1	1	0	6
9.Other H.R Related	0	1	1	0	1	1	1	0	1	6
Dependence	3	7	8	3	7	7	8	6	7	

Table 4: Iteration 1

Factors	Reachability	Antecedent	Intersection	Level
1	1,2,3,4,5,6,7,8,9	1,4,8	1,8	
2	2,3,5,6,7,8,9	1,2,4,5,6,8,9	2,5,4,8,9	
3	3,8	1,2,3,4,5,6,7,8	3,8	I
4	1,2,3,4,5,6,7,8,9	1,4,5	4,5	
5	2,3,4,5,7,9	1,2,4.5,6,7,9	2,4,5,7,9	
6	2,3,5,6,7,8,9	1,2,4,6,7,8,9	2,6,7,8,9	
7	3,5,6,7,9	5	1,2,3	
8	1,2,3,6,7,8	1,2,3,4,6,8	1,2,3,6,8	
9	1,5,6,7,9	1,2,4,5,6,7,9	1,5,6,7,9	

The final reachability matrix is obtained by incorporating the transitivity's as enumerated in Step 4 of the ISM methodology. This is shown in Table 3. In this table, the driving power and dependence of each barrier are also shown. The driving power of a particular barrier is the total number of barriers (including it) which it may help achieve. The dependence is the total number of barriers which may help achieving it. These driving power and dependencies will be used in the MICMAC analysis, where the barriers will be classified into four groups of autonomous, dependent, linkage, and independent (driver) factors.

Level Partitions

The reachability and antecedent set for each barrier is found out from final reachability matrix. The reachability set for a particular variable consists of the variable itself and the other variables, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is given the top-level variable in the ISM hierarchy, which would not help achieve any other variable above their

Table 5: Iteration 2

Enabler	Reachability	Antecedent	Intersection	Level
1	1,2,4,5,6,7,9	1,4	1	
2	2,5,6,7,9	1,2,4,5,6,9	2,5,6,9	
4	1,2,45,6,7,9	1,2,4,5,6,7	1,2,4,5,6,7	
5	2,4,5,7,9	1,4,5	4,5	
6	2,5,6,7,9	1,2,4,6,7,9	2,4,6,7,9	
7	5,6,7,9	1,2,4,5,6,7,9	5,6,7,9	**II**
8	1,2,6,7	1,2,4,6	1,2,6	
9	1,5,6,7,9	1,2,4,5,6,7,9	1,5,6,7,9	

Table 6: Iteration 3

Enabler	Reachability	Antecedent	Intersection	Level
1	1,2,4	1,4	1	
2	2	1,2,4	2	**III**
4	1,2,4	1,2,4	1,2,4	
5	2,4	1,4	4	
6	2	1,2,4	2	**III**
8	1,2	1,2,4	1,2	
9	1	1,2,4	1	**III**

own level. After the identification of the top-level element, it is discarded from the other remaining.

Variables from Table 4, it is seen that Procurement related factors (Factor 3) is found at Level I. Thus, it would be positioned at the top of the ISM model. This iteration is continued till the levels of each variable are found out. The identified levels aids in building the digraph and the final model of ISM. The barriers, along with their reachability set, antecedent set, intersection set and the levels, are shown in Tables 4–8.

Formation of ISM-based Model

From the final reachability matrix, the structural model is generated. If the relationship exists between the Factors j and i, an arrow pointing from i to j shows this. This resulting graph is called a digraph. Removing the transitivities as described in the ISM methodology, the digraph is finally converted into the ISM model as shown in Fig. 2. It is observed from Fig. 2 that project and design team related factors of construction projects (Factor 1 and 5) are very significant factors for the critical success factors in construction industries as it comes as the base of the ISM hierarchy. Procurement related factor (Factor 3) is the critical success factor on which the effectiveness of the critical success factors depends; This factor has appeared at the top of the hierarchy. The project and design team related factors of critical success in construction projects (Factor 1 and 5) leads to the client, contractor and business and work environment (Factor 4, 6 and 8), which results project manage-ment and other H.R factors pertaining to CSF of construction projects (Factor 2 and 9). A good project management and other H.R factors should be in place before project manager related factors are considered (Factor 7) and finally it will result into effective procurement of goods.

Table 7: Iteration 4

Factors	Reachability	Antecedent	Intersection	Level
1	2,4	4	4	
4	2	1,2,4	2	**IV**
5	2,4	4	4	
6	2	1,2,4	2	**IV**
8	2	2,4	2	**IV**

Table 8: Iteration 5

Factors	Reachabity	Antecedent	Intersection	Level
1	4	4	4	**V**
5	4	4	4	**V**

MICMAC Analysis

The MICMAC principle is based on multiplication properties of matrices (Sharma *et al.*, 1995; Raj *et al.*, 2007).The objective of the MICMAC analysis is to analyze the driving power and the dependence of the variables (Mandal and Deshmukh, 1994; Faisal *et al.*, 2006). This is done to identify the key variables that drive the system in various categories. Based on their driving power and dependence power, the variables in the present case, are classified into four categories as follows:

1. Autonomous variables: These are the variables having weak driving power as well as weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may not be strong.

2. Dependent variables: This category includes those variables which have strong dependence but weak driving power.

3. Linkage variables: Variables which have strong dependence as well as strong driving power are known as linkage variables. These variables are unstable also. Any action on these variables will have an effect on others and also a feedback effect on themselves.

4. Independent variables: They have strong driving power but weak dependence power. It is generally observed that a variable with a very strong driving power called the 'key variable' falls into the category of independent or linkage variables.

Table 9: MICMAC Analysis

	9			1						
Driving Power	8									
	7							2,6		
	6						5,8	9		
	5		IV			III				
	4								7	
	3		I			II				
	2									
	1									
		1	2	3	4	5	6	7	8	9
		Dependence								

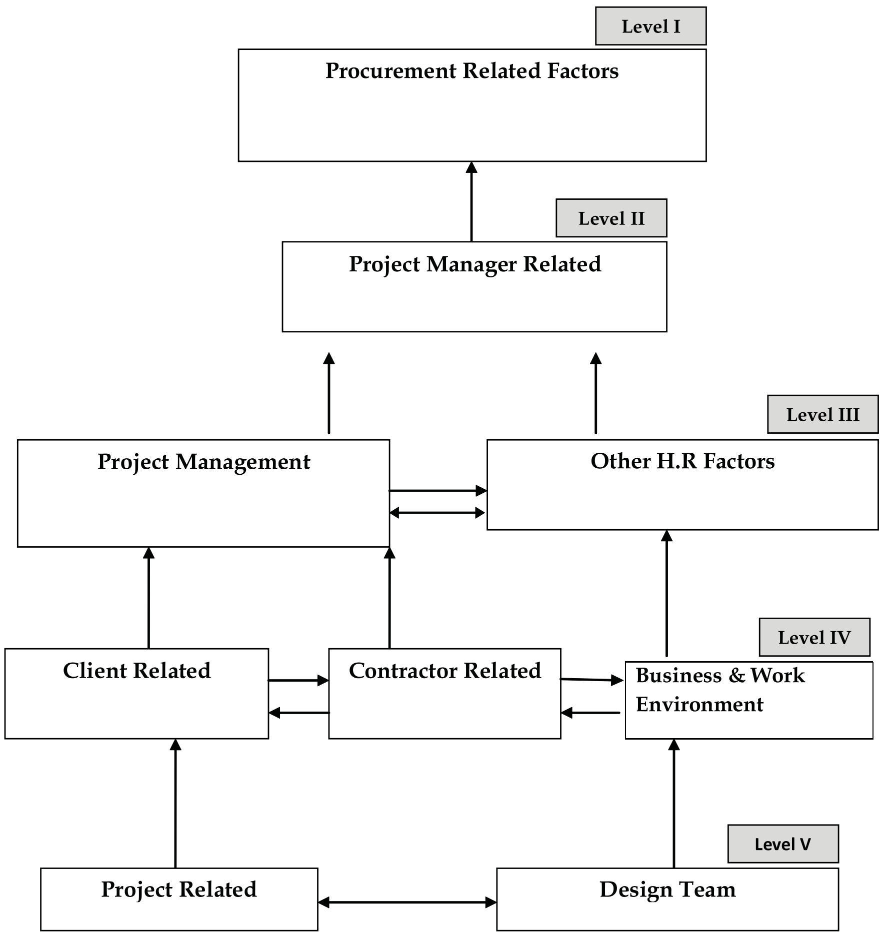

Figure 2: ISM based model for Critical success factors in construction industry

DISCUSSION AND CONCLUSION

The critical success factors pose considerable challenges For the managers in construction industries. Some of the factors have been highlighted here and put into an ISM model, to analyze the interaction between the factors. These factors need to be considered for the success of construction projects. The driver–dependence diagram gives some valuable insights about the relative importance and the interdependencies among the factors. This can provide valuable insights to the top management for proactively dealing with the critical success factors of the construction projects. Some of the observations from the ISM model, which give important managerial implications, are discussed below. Project and Design team related factors are one of the most important factors in the success of construction projects. From the ISM model, it is observed that project related, design team related and contractor related factors are at the bottom level of the hierarchy implying higher driving power. Therefore, top management should focus on developing strategies to create awareness about the use of critical factors so that the benefits of it can be reaped. It is also observed from the ISM model that two factors, namely, project management factors and client related factors have strong driver power and therefore, these are less dependent on the other barriers. Thus, it can be inferred that these are strong drivers and may be treated as the root cause of success in the project. To manage these successes, a comprehensive strategic plan for success factors should be initiated. The decision maker, of the companies could potentially target the success factors so that the desired objectives could be met. Despite the fact that the ISM model developed in this research is for the success factors prominently seen in the construction companies, some generalization of results are still possible. Thus, the identification of the critical factors affecting the implementation of construction projects assumes great importance. This can aid the top management in deciding the priority so that it can proactively take steps in considering these factors. The factors identified in the ISM model are quite generic and, with marginal adjustments, can be used for many other projects. Thus, the ISM-based model proposed in this paper for identification of critical success factors can provide the decision maker a more realistic representation of the success factors. A major contribution of this research lies in the development of critical success factors in construction projects. The utility of the proposed ISM methodology in imposing order and direction on the complexity of relationships among elements of a system assumes tremendous value to the decision makers. At the end, we examine the scope of further research. In this research, using the ISM methodology, a relationship model among the critical success factors in construction projects has been developed. But this model has not been statistically validated. Structural equation modeling (SEM), also referred to as linear structural relationship approach, has the capability of testing the validity of such hypothetical models. Thus, this approach can be applied in the future research to test the validity of this model. It is worth mentioning here that while comparing ISM and SEM, although SEM has the capability of statistically testing an already developed theoretical model, it cannot develop an initial model for testing. ISM, on the other hand, has the capability to develop an initial model through managerial techniques such as brain storming, nominal group techniques, etc. In this sense, ISM is a supportive analytic tool for the discussed situation.

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