APPLICATION OF ICT BENEFITS FOR BUILDING PROJECT MANAGEMENT USING ISM MODEL

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Abstract

Construction is the second largest industrial activity is the Indian economy, employing over 31 million people. The construction projects require effective collaboration and coordination among the diverse project participants, that which exhibits a unique set of characteristics such as fragmentation, multidisciplinary, development, substantial financial commitment, varying complexities, long time spans, and a large number of geographically separated stakeholders involved at all the stages of the projects. Construction projects are managed by designated Project Managers, Architects or Contracts on behalf of the client or by the clients themselves depending on the contract and the project type. Project managers are required to integrate the efforts of all the stakeholders for required coordination for successful project management. Information Communication Technology (ICT) has influenced project management practices by the way of introducing and implementing newly developed management tools and the latest technology. Interpretive Structural Modeling(ISM) is a systematic application of graph theory in such a way that theoretical, conceptual and computational leverage is exploited by efficiently constructs a directed graph, or network representation, of the complex patters of relationship among the elements. In the present study an attempt is made to identify the strategic benefits, their level and interdependency for the project team organization using ICT and to develop ISM model for all the categories of benefits. For the present study MICMAC analysis is used to analyze the drive power and dependence power factors and by which 14 independent / Driven / Linkage benefits were obtained out of 31 benefits.

Key Words: *Construction, Project Managers, Collaboration, Benefits.*

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1. INTRODUCTION

Construction projects require effective collaboration and coordination among the diverse project participants and can be done effectively by means of communication between all the project participants. This type of co-ordination and effective communication is crucial in order to achieve quality standards and to reduce the cost of production effectively. Construction projects are managed by designated officials like Project Managers, Architects or Contractors on part of the Client or by the Clients themselves depending upon the contract and the project type. Such good and responsive communication is important to monitor and control projects' activities according to the specific plans and thereby to achieve required project goals. Hence, the efficiency of the project manager lies in the way he communicates, evaluates and explains the feedback to the rest of the project team during each stage of the project life-cycle and determines how efficiently a project's goals will be achieved.

Communication or data handling often takes about 75% to 90% of project managers' time in the construction industry. ICT is required not only to free up project managers for more decision making tasks but also to deliver the required levels of 'consistency and reliability' of information in the construction supply chains because use of incorrect or incomplete data can compromise the scheduled completion of a project and lead to wastage of resources Multi enterprise scenario of construction projects requires collaborative use of ICT by all the project team organizations for managing a project that is to be planned before the start of the project.

In the present day, ICT is being adopted for construction project management, but, till date, a perfect and sustainable methodology has not been developed and presented for the construction industry to examine the potential contributions of information management strategies in efforts to reduce overall project schedule and cost. This inability to quantify process improvements and uncertainty of benefits from process and cultural changes has become one of the primary barriers for effective implementation of ICT in construction project management. As a result of this the benefits of ICT adoption are primarily perception based and not quantifiable that specifically defines the extent of ICT adoption by the construction industry. Certain benefits are said to drive other benefits and certain benefits out of the driven ones are dependent on some other benefits. Construction professionals need to understand this aspect of driving power and dependence relationship between the benefits to plan strategic adoption of ICT for building project management.

Interpretive Structural Modeling (ISM) falls into the soft operations research (OR) family of approaches. Soft OR methods can be used to augment traditional quantitative methods that do not exactly replace traditional tools and

techniques. ISM is a tool that which highly helps all different groups of people in structuring their collective knowledge. ISM is a systematic application of graph theory in which theoretical, conceptual, and computational leverage is exploited to efficiently construct a directed graph, or network representation having a complex pattern with contextual relationship among a set of elements. It also helps to identify the structure within a system of related elements and also may represent the information either by a digraph (directed graph) or by a matrix, ultimately resulting in a "directed graphic representation of a particular relationship among all pairs of elements in a set to aid in structuring a complex issue area".

1.1 Objectives of the Study

1. Identifying the strategic benefits for the project team organization and developing ISM model for all categories of benefits.
2. Identifying the level of benefits and interdependency for evaluating the most independent and driving benefits for the total project.

2. METHODOLOGY

Construction projects are of two categories, namely building construction projects and Engineering or Infrastructure projects for which the basic need is to study ICT adoption for both the categories of projects separately, where characteristics of supply chain issues, management procedures and contract conditions are different for both the categories of projects. In this study, variables are the perceived benefits of ICT adoption for building project management identified 31 important perceived benefits from literature and after discussion with the experts from the industry and academics. Considering the past experience, ISM technique has been used to analyze the relation between various benefits and to understand the dependence and driving power of each benefit with respect to other benefits. This way of analyzing each project, shall help the managers to decide, whether they are planning and proceeding with systematic ICT adoption procedure for achieving certain benefits to know the other driving benefits that should be achieved prior to the first and also the dependent benefits that would be achieved by default. It requires examination of all relationships between the benefits of ICT adoption rather than considering these benefits in isolation.

2.1 Benefits of Information Communication Technology in Construction Project

Benefits of ICT adoption for managing building projects and improving overall organizational efficiency have been discussed in the literature. Some of the identified benefits are: richer information to aid decision making, project information obtained quicker, improved communication, closer relationships, improved information flow, and greater management control (Hendrickson and Au, 1989; Root and Thorpe, 2001; Love et al., 2004).

Table 1: Perceived benefits of ICT adoption for building project management

Benefits related to measures of project success	
1	Projects completion as per the estimated time
2	Project completion as per the estimated budget
3	project completion as per the specifications
4	Life cycle concept becomes a competitive factors
5	Projects information obtained in real time
6	Richer information made available to managers
7	Less time spent in query and approval process
8	Effective change management
9	Reduced risk of errors and rework on projects
10	Effective concurrent construction management
11	A complete log of all communications maintained for tracking purposes
12	Effective material procurement and management
13	Effective contract management
14	"One-Source" documentation archive maintained for clients
15	Client satisfaction
16	Reduced administrative costs of document handling and distribution to multiple parties
17	Project managers spend more time on managerial works
Benefits related to effective team management	
18	Effective collaboration and co-ordination between project team members
19	Effective communication management between project team members
20	Greater management control
21	Effective joint decision making
22	Motivation of the work force
Benefits related to effective use of technology	
23	Increased information portability in the ICT environment
24	Reduced hard copy storage of documents / drawings
25	Flow of accurate information
26	Ease of retrieval of information
27	Improved capability of the system to cross reference to other correspondence
28	Multi locational availability of information
Benefits related to increase organizational efficiency	
29	Increase in overall organizational efficiency
30	Better information assessment and management with in the organization
31	Useful information compiled and disseminated to other projects

2.2 Interpretive structural Modeling

ISM is an interactive learning process technique in which a set of different directly and indirectly related elements are structured into a comprehensive systematic model. The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words. This model is a well-established methodology for identifying relationships among detailed stuff, which define a problem. For any complex problem under consideration, different number of factors may be related to problem. However, the direct and indirect relationships between these factors describe the situation more accurately than the individual factor taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships. The following are the steps involved in Interpretive Structural Modeling

Step 1: Identify the elements which are relevant to the problem. This could be done by a survey or group problem solving technique. The benefits which we presented in Table 1 are considered in this step.
Step 2: Establish a contextual relationship between elements with respect to which pairs of elements would be examined.
Step 3: Structural Self-Interaction Matrix (SSIM)

- *V* for the relation from factor *i* to factor *j* (i.e., factor *i* will influence factor j)
- *A* for the relation from factor *j* to factor *i* (i.e., factor *i* will be influenced by factor *j)*
- *X* for both direction relations (i.e., factors *i* and *j* will influence each other)
- O for no relation between the factors (i.e., barriers *i* and *j* are unrelated).
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Step 4: Reachability Matrix
The next step in ISM approach is to develop an initial reachability matrix from SSIM. For this, SSIM is converted into the initial reachability matrix by substituting the four symbols (i.e., V, A, X or O) of SSIM by 1s or 0s in the initial reachability matrix. The rules for this substitution are as follows:

- If the *(i, j)* entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the *(j, i)* entry becomes 0.
- If the *(i, j)* entry in the SSIM is A, then the (i, j) entry in the matrix becomes 0 and the *(j, i)* entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the matrix becomes 1 and the *(j, i)* entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the *(i, j)* entry in the matrix becomes 0 and the *(j, i)* entry also becomes 0.

Step 5: Level partitions
The reachability set for a particular variable consists of the variable itself and the variables it drives. The antecedent set shown in Table 2 consists of the variable itself and the variables on which it depends. Subsequently, the intersection of these sets is derived for all the benefits. The variable(s) for which the reachability and the intersection sets are the same as in the top-level of ISM hierarchy, as they would not help achieve any other variable above their own level. After the identification of the top-level variables, these are discarded from the other remaining variables (Ravi and Shankar, 2005). Then the same process is repeated to find out the factors in the next level. This process is continued until the level of each factor is found. These levels shown in Table 3 help in building the diagraph and the ISM model.

Table 2 Reachability and Antecedent Set.

Benefits	Reachability set	Antecedent set
1	1,2,15,20	1,5-13,15-21,23-28,30,31
2	2,15,20	1,2,4-9,11-13,16-31
3	3,15,20	3,5,6,8,9,11,13,16-21,23-28,30
4	2,4,15	4,6,7,16,17,19,21, 23-26,28,30
5	1,2,3,5,6,7,8,9,10, 12,13,15,16,18,19, 20,25,28,30,31	5,16-21,24,26,27
6	1,2,3,4,6,8,9,10,12, 13,15,16,18,19,20,28,30	5-7,16,17,21, 23-27,28,31
7	1,2,4,6,7,8,9,10,12, 13,15,16,18,20,28,30	5,7,11,16,17,19,21, 23-26,28
8	1,2,3,8,9,10,12,13, 15,16,18,20,30	5-8,11,16-19,21,23-28,30
9	1,2,3,9,10,13,15,20	5-9,11,16-19,21,23-28,30
10	1,10,13,15,20	5-12,16-19,21,23-28,30
11	1,2,3,7,8,9,10,11,12,13, 14,15,16,18,19,20, 23,25,28,30,31	11,17,21,26
12	1,2,10,12,13,15,20	5-8,11,12,16-19, 23-28,30
13	1,2,3,13,15,20	5-13,16-21,23-25,27-30
14	14,15,31	11,14,21
15	1,15,20	1-21,23-30
16	1-10,12,13,15-20,29,30	5-8,11,16,17,19,21,23-28
17	1-13,15-20,22,23,25,26, 28-31	16,17,21,24,26
18	1,2,3,5,6,7,9,10,8,12, 13,15,18,19,20	5-8,11,16-19,21,23, 25-28,30
19	1-5,7-10,12,13,15,16, 18-20,	5,6,11,16-19,21,23-28
20	1,2,3,5,13,15,20,	1-3,5-13,15-20, 23-28,30

21	1-19,21,23,25,27-31	21
22	2,22,29	17,22,26
23	1-4,6-10,12,13,15,16, 18-20,23,28,29,30	11,17,21,23
24	1-10,12,13,15,16,17,19, 20,24,25,28,30,31	24
25	1-4,6-10,12,13,15,16, 18-20,25,28,30	5,11,17,21,24-27
26	1-12,15-20,22,25-28,30,31	17,26
27	1,2,3,5,6,8,9,10, 12,13,15,16,18,19,20, 25,27,28,30,31	21,26,27
28	1-4,8-10,12,13,15,16, 18-20,28-31	5-8,11,17,21,23-28
29	2,13,15,29	16,17,21-23,28,29
30	1-4,8-10,12,13,15,18, 20,30	5-8,11,16,17,21,23-28,30
31	1,2,6,31	5,11,14,17,21,24,26-28,31

Step 6: Conical Matrix

A conical matrix is developed by clustering benefits at the levels achieved, across rows and columns in the final reachability matrix. The final reachability matrix is in conical form. Most zero (0) variables are in the upper diagonal half of the matrix and most unitary (1) variables are in the lower half. The ISM Model shall be framed.

Table 3 Level of Benefits

Level	Benefits		Types
1	1	Projects completion as per the estimated time	Projects Related
	15	Client satisfaction	Projects Related
2	2	Project completion as per estimated time	Projects Related
	3	Project completion as per specifications	Projects Related
3	5	Project information obtained in real time	Projects realted
	19	Effective communication management between project team members	Team management related
4	8	Effective change management	Projects related
	17	Projects managers spend more time on managerial works	Project related
	26	Ease to retrieval of information	Technology related
	30	Better information assessment and management within the organization	Organization related
5	4	Life cycle concept becomes a competitive factor	Project related
	13	Effective contract management	Project related
	20	Greater management control	Team management related
6	10	Effective concurrent construction management	Project related
	29	Increase in overall organizational efficiency	Organization related
7	9	Reduced risk of errors and rework on projects	Project related
	12	Effective material procurement and management	Project related
	22	Motivation of the work force	Team management related
8	16	Reduced administrative costs of document handling and distribution to multiple parties	Project related
	18	Effective collaboration and co-ordination between project team members	Team management related
9	6	Richer information made available to managers	Project related
	7	Less time spent in query and approval process	Project related
	31	Useful information compiled and disseminated to other projects	Organization related
10	14	"one-source" documentation archive maintained for clients	Project related
	23	Increased information portability in the ICT environment	Technology related
	25	Flow of accurate information	Technology related
11	11	All communications maintained for tracking purpose	Project related
	24	Hard copy storage of documents	Technology related
	27	Improved capability of the system	Technology related
12	21	Effective joint decision making	Team management related
13	28	Multi location availability of data	Technology related

2.3 MICMAC Analysis

The purpose of MICMAC analysis is to analyze the drive power and dependence power of factors. MICMAC principle is based on multiplication properties of matrices. It is done to identify the key factors that drive the system in various categories. Based on their drive power and dependence power, the factors, have been classified into four categories i.e. autonomous factors (Weak drive power and weak dependent power), linkage factors (Strong drive power as well as strong dependent power), dependent (weak drive power but strong dependence power) and independent (strong drive power but weak dependence power) factors.

The fig. shows the details about the nature of benefits which tells us about the driven or dependent or independent benefits.

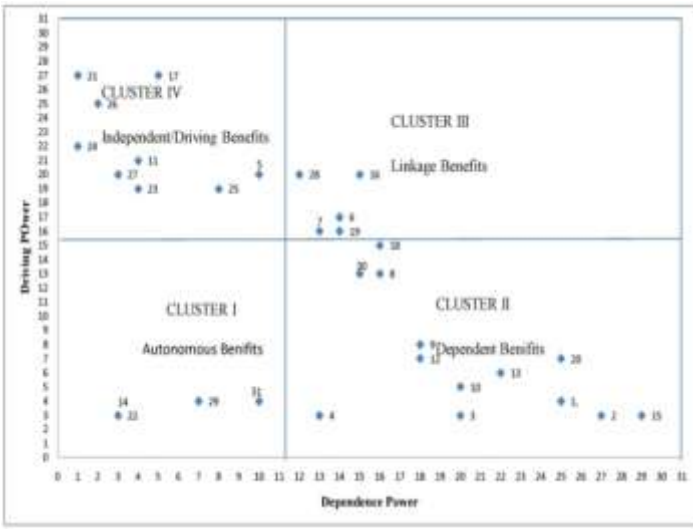

Fig 1: MICMAC Analysis.

3. RESULTS

The developed ISM model presents a hierarchical framework to evaluate the ICT benefits those shall be adopted for building project management.

The results can be summarized as follows.

1. The Structural Self Interaction Matrix shows the relation between the 31 benefits.
2. From Reachability matrix the no. of driven power, dependence power for each benefit is obtained and reachability set, antecedent set for each benefit is found.
3. From the 13 Iterations level of each benefit is obtained and shown below.
4. From the MICMAC analysis we got 14 Independent / Driven / Linkage benefits (5,6,7,11,16,17,19,21,23,24,25,26,27,28) out of 31 benefits. These 14 benefits reflect on the qualitative and quantitative completion of project.

Iteration	Level	Benefits
1	1	1,15
2	2	2.3
3	3	5,149
4	4	8,17,26,30
5	5	4,13,20
6	6	10,29
7	7	9,12,22
8	8	16,18
9	9	6,7,31
10	10	14,23,25
11	11	11,24,27
12	12	21
13	13	28

4. DISCUSSIONS

The Developed ISM model shows that the project related benefits are primarily at the top of hierarchy, team management related benefits are primarily in the middle and technology and organization related benefits are primarily at the bottom of hierarchy. The result indicates the Positive Net Value as driving nature of the benefits and negative Net Value as the dependent nature of the benefits and 0 indicates equal driving and dependent nature of the benefits.

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