An empirical test of causal relationships of factors affecting ICT adoption for building project management: An Indian SME case study

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Published in:
Construction Innovation

DOI:
10.1108/14714171011037174

AN EMPIRICAL TEST OF CAUSAL RELATIONSHIPS OF FACTORS AFFECTING ICT ADOPTION FOR BUILDING PROJECT MANAGEMENT – AN INDIAN SME CASE STUDY

Vanita Ahuja[1], Jay Yang[2], Martin Skitmore[3], Ravi Shankar[4]

ABSTRACT

Purpose: Building project management (BPM) requires effective coordination and collaboration between multiple project team organizations which can be achieved by real time information flow between all participants. In the present scenario, this can be achieved by the use of Information Communication Technologies (ICT). This paper presents part of a research project conducted to study the causal relationships between factors affecting ICT adoption for BPM by Small and Medium Enterprises (SMEs).

Design/Methodology/Approach: This paper discusses Structural Equation Modeling (SEM) analysis conducted to test the causal relationships between quantitative factors. Data for quantitative analysis was gathered through a questionnaire survey conducted in the Indian construction industry.

Findings: SEM analysis results help in demonstrating that an increased and matured use of ICT for general administration within the organization would lead to: an improved ICT infrastructure within the organization; development of electronic databases; and a staff that is confident of using information technology (IT) tools. In such a scenario, staff would use advanced software and IT technologies for project management (PM) processes and that would lead to an increased adoption of ICT for PM processes. But, for general administration also, ICT adoption would be enhanced if the organization is interacting more with geographically separated agencies and senior management perceives that significant benefits would accrue by adoption of ICT. All the factors are inter-related and their effect cannot be maximized in isolation.

Originality/Value: The results provide direction to building project managers for strategically adopting the effective use of ICT within their organizations and for BPM in general.

Paper Classification: Research Paper

KEYWORDS: Information Communication Technology, project management, structural equation modeling, SEMS, India

INTRODUCTION

Building projects involve collaborative working between multiple enterprises. Projects are managed by project managers, architects and contractors on behalf of the client/owner or by

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the clients/owners themselves depending upon the contract and type of project. Project Managers are required to facilitate the integration of work of all the agencies, while project team organizations may be geographically separated beyond national boundaries or, in the context of large countries, within national boundaries. The success of a construction project depends on a number of factors, and researchers have identified effective communication between the project team organizations as being important for successful projects (McIntosh and Sloan, 2001; Nielsen and Sayar, 2001). With geographical separation between project team members, effective communication can be achieved through ICT adoption. In a survey, it was also found that the construction organizations perceive that in the near future, the construction industry can not progress without adopting ICT tools (Frits, 2007).

However, literature indicates that despite many initiatives, ICT adoption by the construction industry is limited and less effective as compared to other sectors such as the automotive or the aerospace industry (Dehlin and Olofsson, 2008; Wilkinson, 2008; Ruddock, 2006; Adriaanse et al., 2004). Standalone applications for bookkeeping and 2 dimensional drawings are generally accepted. But, more advanced applications such as 3 and 4 dimensional modeling, GPS and Internet technology are still only incidentally applied (Frits, 2007), though these are essential tools for ICT adoption and construction information is primarily exchanged by conventional human communication, printed drawings (Pena-Mora and Tanaka, 2002) and other documents. A majority of the organizations in the Architecture, Engineering and Construction sector are Small and Medium Enterprise (SME) (Wilkinson, 2009; Katranuschkov et al., 2001) and have specific requirements for effective adoption of ICT. Thus, the strategic adoption of ICT by the construction industry is defined by the strategic and operational requirements of the SMEs. But, understanding of the project context and the nature of communication between organizations is an essential prerequisite in analyzing and designing ICT in an effective way (Adriaanse et al., 2004). Also, for successful and effective introduction of new technologies special care has to be given to the step-by-step process, where acceptance and dedicated adoption by personnel is of a decisive importance (Frits, 2007). Thus, the issue of ICT adoption by SMEs would require a clear understanding of the management and communication processes followed by the SMEs of each distinct regional area or country.

This paper presents the results of a research project conducted to test the causal relationships between factors affecting the extent of ICT adoption by SMEs for building project management (BPM) in India. The correlation between factors can be measured by Pearson *r*, but this does not allow any statements to be made regarding the cause-and-effect relationship between factors (Stewart and Mohamed, 2004). Also, when there are multiple factors that influence one another and the problem occurs in a chainlike fashion, it is necessary to identify the multiple, contextual crucial factors that are associated with the problem, rather than establishing any single cause-effect relationship (Sekaran, 2000). Thus, a structural model of causal relationships between the factors affecting ICT adoption by SMEs for BPM was tested through the Structural Equation Modeling (SEM) technique as SEM enables concurrent testing of the hypothesized causal relationships for the entire model (Meyer and Collier, 2001).

Data collection for the analysis was gathered through a questionnaire survey conducted in the Indian Construction Industry. The evolution of Indian Construction Industry was almost similar to the construction industry evolution in other countries: founded by Government and slowly taken over by enterprises. Around 16 percent of the nation's working population depends on construction for its livelihood and the industry employs over 30 million people. It contributes more than 5 percent to the nation's GDP and 78 percent to the gross capital formation. The Indian construction industry comprises 200 firms in the corporate sector. In addition to these firms, there are about 120,000 class A contractors registered with various government construction bodies. There are thousands of small contractors, which compete for small jobs or work as subcontractors of prime or other contractors (wikepedia.org, 2007). Apart from the contractors, the industry involves organizations of other specializations like Architects, project managers, consultants etc. Most of the class A contractors, sub-contractors and other agencies can be categorised as SMEs. The expectation was that there would be an industry level initiative for studying the factors affecting present ICT adoption in the industry, and its further development for future requirements. However, the literature review did not reveal the existence of any such industry-wide initiative and highlighted the importance of this research, as a survey has reported that it is not just the big organizations writing the new Indian growth story but entrepreneurs leading the SMEs are also contributing in good measure (Indiapressagency.com, 2006).

FACTORS AFFECTING ICT ADOPTION FOR BUILDING PROJECT MANAGEMENT

Peansupap and Walker (2005) state that ICT diffusion success could be perceived in terms of factors that influence technology adoption and the way in which successful adoption of technology by potential users could be sustained. They classify the factors affecting ICT diffusion in an organization as static and dynamic, where static factors, e.g., technological characteristics and communication channels, fundamentally affect initial ICT diffusion, and dynamic factors, e.g., motivation, training and technical support, sustain ICT diffusion changes.

People, who are a part of different project team organizations, manage projects and the project team organizations are a part of the construction industry. Thus, factors are required to be studied at the three levels of industry, organization and people and the following section summarizes the literature study for factors at these three levels.

In a survey conducted to assess the status of ICT adoption in the Australian construction industry, it was found that the annual turnover of an organization has an effect on the uptake of ICT and ICT training performance for an organization (Kajewski et al., 2004). Ruddock (2006) also reports that smaller firms tend to be less ICT intensive than large firms. Partly because large firms have more scope for improving communication flows within the organization and partly because large firms also invest more in ICT than small firms as ICT investment is risky and uncertain, which may be more difficult for small firms to bear. This factor highlights the relevance of the research study discussed in this paper as it studies ICT adoption by SMEs.

Liberatore et al. (2001) have identified the improved capabilities of PM software as enablers of effective ICT adoption and an area for future research. Thus, IT tools or PM software adopted for PM processes have an effect on ICT adoption for BPM.

In an organization, effective communication is linked to the integration of work units across organizational levels (Green, 2001). The communication systems of the organization should integrate all its project sites and the head office general administration team into similar ICT capabilities, ICT infrastructure and systems generally across the whole organization. Thus, it is hypothesised that the level of ICT adoption for general administration works affects ICT adoption for PM processes.

Using the Internet as the communication platform facilitates the speedy transmission of information and also reduces the cost of communication with overseas construction sites as compared with traditional information handling methods (Tam, 1999). Thus, increased geographical separation between project team members is an important factor driving ICT adoption for BPM.

Researchers have discussed expected benefits of ICT adoption at organization and project levels. Some of the discussed benefits are:

- improved operational efficiency of an organization, and improved quality and reduction in project time (Dehlin and Olofsson, 2008; Ruddock, 2006; Gunasekaran et al., 2001; Barney, 1991)
- increased profit levels (Gunasekaran et al., 2001)
- sustainable competitive advantage (Henderson et al., 1999; Powell et al., 1997)

But, it has been found difficult to evaluate these benefits (Ruddock, 2006) and many of the traditionally used appraisal approaches have been found inadequate. As a result, the investment in ICT is too often assumed to be negative since the benefits are not properly evaluated, included and weighted against the costs and risks the investment is expected to generate. It does not only have an influence on individual projects but also, in the long run, on the motivation to innovate and introduce new ICT tools in the construction industry (Dehlin and Olofsson, 2008). This aspect is a barrier for effective adoption of ICT. Some of the other identified barriers are suggested to be deficient understanding and lack of knowledge about the possibilities of ICT, unsuccessful implementation into project organizations and limitations of software functionality (Dehlin and Olofsson, 2008). Thus, in the absence of an accepted evaluation method, the benefits and barriers of effective ICT adoption are primarily perception-based and these perceived benefits and barriers determine the extent of ICT adoption by the construction industry.

Researchers have grouped the benefits of IT for construction PM according to the different perspectives involved:

- enhanced productivity, business expansion and risk minimization (Peters, 1994 as cited in Love et al., 2004)
- tangible or intangible (Serafeimedis and Smithson, 2000)
- strategic, tactical or operational (Irani and Love, 2001)
- economically measurable, measurable or non-measurable (Andresen et al., 2003)
- informational, automational and transformational (Stewart and Mohamed, 2004)

- System quality, Process quality, Information quality, System use, User satisfaction, Individual impact and Project impact (Lindfors 2003, DeLone and McLean 1992 as cited in Dehlin and Olofsson, 2008).

In this research, with the focus on ICT adoption for BPM, the perceived benefits are categorized according to:

- Measures of project success
- Effective team management
- Effective use of technology
- Increased organizational efficiency

The perceived barriers have been categorized as those related to:

- Technology
- Projects
- Organization
- Industry

Managers require a road map for strategic adoption of ICT. But, its implementation will inevitably be unsuccessful if the organization's culture is not properly aligned with, and supportive of an overall business strategy (Schneider 2000). So, ICT implementation should become a business objective of the construction industry and should give equal prominence to technology, people and processes involved in construction projects. Only in such a scenario will it be adopted by the industry as a whole. The strategic and cultural factors are qualitative and have been studied separately through qualitative analysis.

ICT adoption by project managers and team members is defined by the factors affecting their perceptions as well as the factors affecting decision making at the organization level. Similarly, ICT adoption by an individual organization is also defined by the factors affecting ICT adoption at the industry level, since it represents its national construction industry. Thus, causal relationships between all the identified factors need to be studied. While researchers analyzing the benefits from ICT use and investment have tended to concentrate their assessment at the firm/organization level, studies at the industry level have been scarce (Ruddock, 2006).

Above discussed literature study and understanding of the construction industry helped in the identification and categorisation of the factors involved at the levels of industry, organization and people. These are summarised in Table 1.

Table 1: Factors Affecting ICT Adoption for Building Project Management

Industry Level Factors	**Organization Level Factors**	**People Level Factors**
Strategic issues	Strategic issues	Perceived benefits
Industry drivers	Turnover of the organization	Perceived barriers
Cultural factors	Cultural factors	Cultural factors
Available technology	Geographical separation of project team organizations	Training
Training and education	Use of ICT for general administration	
	IT tools utilised for PM processes	

RESEARCH METHOD

The identified factors are qualitative as well as quantitative and a mixed methods approach combining qualitative and quantitative methods was adopted to study the factors. This paper presents a part of the quantitative analysis component of the research. Six factors are quantitative factors: Turnover of the organization; Geographical separation between project team members; Perceived barriers; Perceived benefits; Use of ICT for general administration; and Use of advanced IT tools for individual PM processes. The causal relationships between these quantitative factors and their effect on the final factor 'use of ICT for BPM' were studied through quantitative analysis.

Data collection for the analysis was gathered through a questionnaire survey conducted in the Indian Construction Industry. The unit of analysis for the survey was an organization managing building projects and the sample population was the SMEs in the Indian construction industry. Three groups of organizations were included in the sample: builders, including contractors who construct and manage their own projects; PM consultancy organizations, which are formally appointed as project managers on building projects; and architectural organizations, which manage small to medium size building projects, as project managers are not formally appointed on many such projects. Targeted respondents were the senior level executives in the organizations. Survey was conducted across India to minimize the regional bias. Survey sample was selected from the Yellow Pages and the Notified lists of Professional bodies and falls under the group of Purposive Sampling,

The questionnaire for the survey comprised four sections. Section I contained questions that assessed organization size in terms of turnover and staff strength; the organization's area of expertise and primary mode of project execution; project team structures in terms of geographical separation of project team organizations; ICT maturity of the staff and the organization; and the mode of communication adopted for general administration. Section II contained a tool for mapping the BPM processes adopted by the organizations; an assessment of software applications adopted for these processes; and ICT adoption for each identified PM process. Section III assessed the project managers' perceptions of benefits, barriers, enablers and industry drivers affecting ICT adoption for BPM. Section IV provided the data regarding the respondents' profiles. In a study of ICT usage evaluation model for the construction industry, Dehlin and Olofsson (2008) assessed the expected benefits through a four level process, taking inputs from collective experiential knowledge of a multi-disciplinary evaluation group and data from earlier evaluations or any other relevant available information. To understand the extent of benefits achieved by ICT adoption, they were quantified in monetary terms and classified in three grades: 1 - 'Most likely'; 2 – 'Likely'; and 3 – 'Unlikely', depending on the likelihood of benefit being realized. A similar approach was used in this study for quantitative assessment of perception based factors. Qualitative perceptions analysis was converted into quantitative values with the help of a five point Likert scale. On this scale, 1 and 5 corresponded to 'not important' and 'most important' respectively, whereas 3 corresponded to 'moderately important'.

The questionnaire was subjected to pre-testing through a pilot survey. The pilot survey respondents were selected from the same population in which the main survey was to be conducted. It was undertaken to test the potential response rate, suitability and comprehensibility of the questionnaire and the questionnaire was forwarded to 11 organizations. Responses were received from 7 organizations, leading to a response rate of about 64%. Later, each respondent was interviewed on the basis of the questionnaire, with an objective to improve the questionnaire with respect to the content, form, sequence of questions, spacing, arrangement and physical appearance of the questionnaire, so as to get the desired response from the respondents. Primarily the questionnaire remained the same. But, in some questions respondents had given multiple answers, which showed that for the processes indicated in those questions, respondents were using multiple options. Such questions were modified to understand the percentage of each option utilized by the respondents. The modified questionnaire was forwarded for the main survey.

Questionnaires were mailed to 372 organizations. 153 responses were received. 4 responses were partially incomplete and were considered as missing cases. Thus, 149 usable responses were received, representing a response rate of 40.05%. Out of the 149 responses received, 75 (50%) were from Builders, 49 (33%) from Project Management Consultancy organizations (PMCOs) and 25 (17%) from Architectural organizations.

Structural Equation Modeling (SEM)

SEM is an extension of the general linear model and is a family of statistical techniques which incorporates and integrates path analysis and factor analysis (NCSU, 2006). It allows the evaluation of entire models simultaneously - bringing a more macro level perspective to the analysis. SEM consists of two components, a measurement model and a structural model (Meyer and Collier, 2001). In the hypothesized model, the measurement model includes the relationships between the factors and the questionnaire items (indicators) that operationalise the measurement of those factors. It assesses how well the observed variables (indicators) reflect the unobserved or latent variables (factors). A structural model statistically represents the hypothesized structure and depicts the causal relations between the latent variables (factors).

Research model

The factor 'Turnover of the organization' cannot be standardized for the three groups of surveyed organizations and was tested for each group separately. The causal relationships between the remaining five quantitative factors and their effect on the final factor were studied through the SEM analysis. Table 2 lists the macro variables studied. The literature review and an understanding of the construction industry helped in the identification of additional micro variables, which were further divided into measurable dimensions. Hypotheses HR1, HR2, HR3 and HR4 of the causal relationships between the quantitative factors involved were formulated as illustrated in Fig. 1.

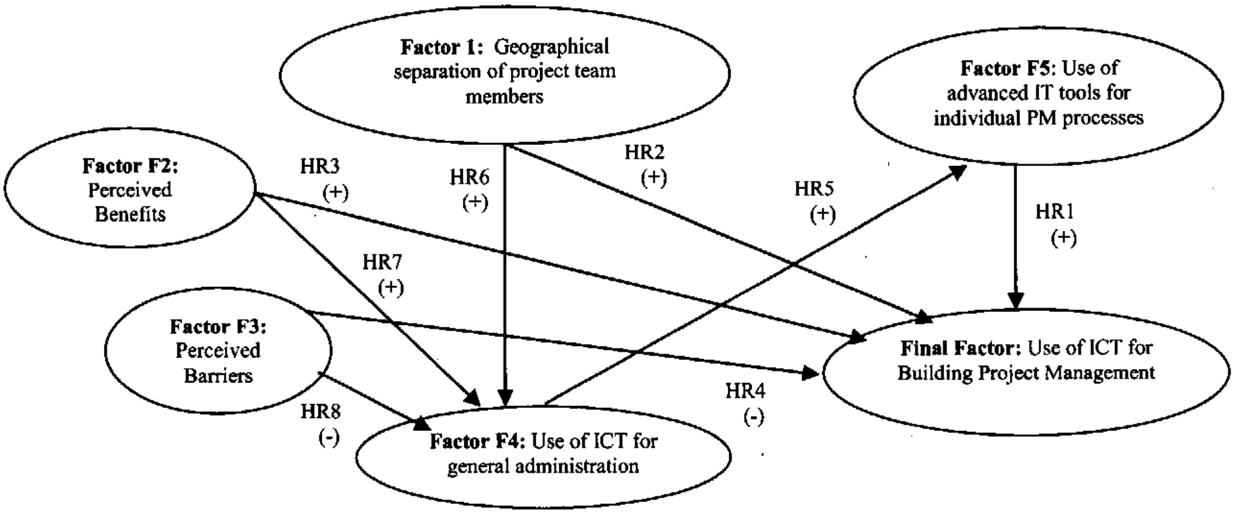

Fig. 1: Structural Model derived from the Hypotheses of Causal Relationships

Further 31 important perceived benefits of the use of ICT for BPM were identified from the literature and categorized under four groups as discussed earlier in the paper. An Interpretive Structural Modeling (ISM) technique was used to analyse the relationship between these benefits and to understand the dependence and driving power of each benefit with respect to other benefits. The analysis and results are discussed in detail in a separate publication (Ahuja et al., 2009a).

The developed ISM model shows that organization and technology related benefits have high driving power and these are 'strategic benefits' for the project team organizations. Thus, organizations need to give more attention on strategically increasing these benefits from the application of ICT. Also, if the use of ICT for general administration works is mature (with appropriate IT tools included in the working framework and team management issues planned at the earlier stages of the project), then project-related benefits would be achieved by default. In addition, the four groups of benefits are interrelated and cannot be achieved in isolation (Ahuja et al., 2009a).

The results of the ISM analysis led to the formulation of additional hypotheses concerning causal relationships. The effect of 'ICT adoption for general administration works' on 'ICT adoption for BPM' was tested through the increased use of IT tools or software for individual PM processes, thus, leading to the formulation of hypothesis HR5 (Fig. 1).

The relationships between the three factors - 'geographical separation between project team members', 'perceived benefits of ICT adoption' and 'perceived barriers for effective ICT adoption' and the factor 'ICT adoption for general administration works' was also tested. Thus, three additional hypotheses HR6, HR7 and HR8 were formulated (Fig. 1).

Model specification

The hypothesized model is a recursive model. Details of the model specifications are shown in Table 2. The measurement of each of the factors was operationalised using a set of questions in the questionnaire, which are the indicators, or micro variables, and are attached

Table 2: Model Specification		
Factors	**Micro variables/Indicators/Manifest variables**	
	Label	**Description**
F1: Geographical separation of project team members	geo_sep1	Percentage of projects on which the organization has interacted with geographically separated agencies within India in last 5 years
	geo_sep2	Percentage of projects on which the organization has interacted with overseas agencies in last 5 years
F2: Perceived benefits of ICT adoption for building project management	ben_tete	Benefits related to effective team management and use of technology
	ben_orgp	Benefits related to increased organizational efficiency and measures of project success
F3: Perceived barriers for effective ICT adoption for building project management	bar_ind	Industry related barriers
	bar_teop	Technology, organizations and projects related barriers
F4: Use of ICT for general administration	ictgeni	Infrastructure maturity for use of ICT for general administration
	ictgenu	Extent of use of ICT for general administration
F5: Use of advanced IT tools for individual processes of Building Project Management	tim_too	IT Tools utilized for Project Time Management processes
	cos_too	IT Tools utilized for Project Cost Management processes
	adm_too	IT Tools utilized for Project Administration and Resource management processes
Final Factor: Use of ICT for Building Project Management	tim_ic	Extent of ICT adoption for Project Time Management processes
	cos_ic	Extent of ICT adoption for Project Cost Management processes
	ad_c_ic	Extent of ICT adoption for Project Administration and Resource management processes
Measurement Error Terms		
e1 – e14 attached with the manifest variables or indicator variables		
Disturbances		
d1 – d3 attached with the endogenous variables		
Covariances		
Covariance between all the exogenous variables is shown through double arrow curved lines		

with unique variances, i.e. this indicates the variance unexplained by the factors. Such variance is termed the measurement error (e_n). In the hypothesized model, 39 free parameters were estimated with 66 degrees of freedom.

DATA ANALYSIS

The model was tested on AMOS 5.0, software used for formulating, fitting and testing structural equation models to observed data. The input for the structural equation model estimation was the data file compiled in SPSS statistical estimation software and converted as a covariance matrix by AMOS for analysis. Maximum Likelihood Estimation, the method employed by most researchers and the default estimation method in most structural equation modeling software packages including AMOS is used. To make the absolute scores of the composite indicator variables comparable, standardization or normalization scoring techniques were used.

STATISTICAL RESULTS AND ANALYSIS OF HYPOTHESIZED MODEL

The data was tested for content validity, construct reliability, multicolinearity, linearity and multivariate normality. Model estimation calculates the weights of the causal paths between the factors and also calculates factor loadings between the factors and the indicator variables. Significance was defined as $p<0.05$ throughout. SEM was utilized as a confirmatory, as well as exploratory analysis technique. A systematic, iterative process was used to determine the paths and factors to be eliminated from the hypothesized model. Item elimination was based on path insignificance and theoretical determination. Based on these principles the hypothesised model was modified in three steps to arrive at the final model.

Table 3 shows the unstandardised regression weights or estimates for the path coefficients and factor loadings for the hypothesized model as well as for each modification and stadardised regression weights for the final model. Table 4 shows the covariance between the exogenous variables. Model fit indices were calculated and are reported in Table 6.

In Step 1 modification, the path from Factor F1 to Final factor (HR2) was deleted from the model as the regression weight or path coefficient for the path from Factor F1 to the Final factor was negative and was therefore not significant. In Step 2 modification, paths from Factor F2 to the Final factor (HR3) and Factor F3 to Factor F4 (HR8) were deleted as the paths from Factor F2 to the Final factor and Factor F3 to Factor F4 were not significant and the p levels were very high. In Step 3 modification, path from Factor F3 to the Final factor (HR4) and consequently Factor F3 was dropped from the model and the final model was achieved (Fig. 2). The final model had 29 free parameters with 49 degrees of freedom.

Analysis results for the final model (Step 3) are reported in the relevant tables. As seen in Table 3, all paths were significant. Unstandardised and standardised regression weights or estimates for the path coefficients and factor loadings are reported. The covariance between Factor F1 and Factor F2 was not significant, but the p value had improved considerably from the last iteration (Table 4). Estimate values of all the exogenous variables, the disturbances and the measurement errors were significant (Table 5). Values of model fit indices had improved and showed a good model fit (Table 6).

The revised model provides an acceptable fit to the data. But, with 29 free parameters, the required sample size was 145 – 290, while the actual sample size was 149. Thus, it is postulated that the results would have further improved if the sample size was increased.

Table 3: Regression Weights/Path Coefficients and Factor Loadings

			Hypothesized model	Modified Model-Step 1	Modified Model-Step 2	Modified Model-Step 3	
			Unstandardised	Unstandardised	Unstandardised	Unstandardised	Standardised
F. F4	<---	F. F1	0.876***	0.876***	0.854***	0.865***	0.753
Final F.	<---	F. F1	-0.028(p=0.817)				
F. F4	<---	F. F2	0.35***	0.352***	0.294***	0.304***	0.298
Final F.	<---	F. F2	0.042(p=0.604)	0.052 (p=0.467)			
F. F4	<---	F. F3	-0.18(p=0.334)	-0.186 (p=0.318)			
Final F.	<---	F. F3	-0.225(p=0.124)	-0.235 (p=0.096)	-0.181(p=0.089)		
F. F5	<---	F. F4	0.735***	0.732***	0.731***	0.727***	0.862
Final F.	<---	F. F5	0.692***	0.662***	0.677***	0.633***	0.865
geo_sep1	<---	F. F1	1.553***	1.549***	1.569***	1.581***	0.886
geo_sep2	<---	F. F1	1	1	1	1	0.736
ben_tete	<---	F. F2	1	1	1	1.045***	0.897
ben_orgp	<---	F. F2	0.971***	0.969***	0.984***	1	0.858
bar_ind	<---	F. F3	1.316***	1.315***	1.366***		
bar_teop	<---	F. F3	1	1	1		
ictgeni	<---	F. F4	0.913***	0.912***	0.917***	0.911***	0.798
ictgenu	<---	F. F4	1	1	1	1	0.875
tim_too	<---	F. F5	1	1	1	1	0.738
cos_too	<---	F. F5	0.906***	0.908***	0.910***	0.911***	0.671
adm_too	<---	F. F5	0.693***	0.690***	0.699***	0.677***	0.499
tim_ic	<---	Final F.	1	1	1	1	0.54
cos_ic	<---	Final F.	0.901***	0.902***	0.912***	0.9***	0.486
ad_c_ic	<---	Final F.	1.456***	1.456***	1.477***	1.482***	0.8

***Significant at p<0.001 level (2-tailed)

Table 4: Covariance between Exogenous Variables

			Hypothesized model	Modified Model-Step 1	Modified Model-Step 2	Modified Model-Step 3
			Unstandardised	Unstandardised	Unstandardised	Unstandardised
F. F1	<-->	F. F3	0.077(p=0.137)	0.078(p=0.130)	0.069(p=0.161)	
F. F1	<-->	F. F2	0.079(p=0.238)	0.079(p=0.239)	0.08(p=0.224)	0.09(p=0.166)
F. F3	<-->	F. F2	0.262***	0.262***	0.247***	

***Significant at p<0.001 level (2-tailed)

Table 5: Estimates				
	Hypothesized model	Modified Model-Step 1	Modified Model-Step 2	Modified Model-Step 3
F. F1	0.587***	0.589***	0.582***	0.577***
F. F2	0.788***	0.789***	0.778***	0.732***
F. F3	0.287**	0.287**	0.281**	
d1	0.207***	0.208***	0.222***	0.224***
d2	0.12*	0.125**	0.121**	0.139**
d3	0.055(p=0.148)	0.058(p=0.113)	0.059(p=0.101)	0.073*
e1	0.418***	0.422***	0.402***	0.393**
e2	0.478***	0.477***	0.484***	0.489***
e3	0.466***	0.462***	0.469***	0.453***
e4	0.563***	0.558***	0.561***	0.547***
e5	0.741***	0.741***	0.738***	0.746***
e6	0.365***	0.364***	0.359***	0.361***
e7	0.239***	0.237***	0.24***	0.233***
e8	0.699***	0.699***	0.705***	0.703***
e9	0.754***	0.754***	0.753***	0.759***
e10	0.37***	0.371***	0.364***	0.357***
e11	0.207*	0.206*	0.217*	0.195*
e12	0.251**	0.252**	0.24**	0.262**
e13	0.495***	0.497***	0.468**	
e14	0.706***	0.706***	0.712***	
* Significant at p<0.001 level (2-tailed)				
** Significant at p<0.01 level (2-tailed)				
*** Significant at p<0.05 level (2-tailed)				

Table 6: Model Fit Indices				
Overall Model Fit Indices	Hypothesized model	Modified Model-Step 1	Modified Model-Step 2	Modified Model-Step 3
Chi-square	122.642***	122.681***	124.273***	78.72**
Normed chi-square	1.858	1.831	1.801	1.607
RMSEA	0.076	0.075	0.074	0.064
GFI	0.888	0.888	0.887	0.912
NFI	0.862	0.862	0.860	0.901
CFI	0.929	0.930	0.931	0.959
Parsimony ratio	0.725	0.736	0.758	0.742
** Significant at p<0.01 level (2-tailed)				
*** Significant at p<0.001 level (2-tailed)				

DISCUSSION

The final modified model is considered to be admissible. Standardized path coefficients with absolute values less than 0.10 indicate a "small" effect; with values around 0.30, a "medium" effect and those greater than 0.50, a "large" effect (Kline, 1998). In the model, all the indicators specified to measure a common underlying factor have high factor loadings on that factor, except the factor loading of indicator variable expressing 'use of IT tools for Project administration and resource management processes' (adm_too) on Factor F5, which is at 0.499 and the factor loading of indicator variable expressing 'use of ICT for Project cost management processes' (cos_ic) on the Final factor, which is at 0.486. However, these are also close to 0.5 and can be considered high. This determines the Convergent Validity of the model. Measurement errors and disturbances are very small. All path coefficients are positive and of high magnitude, except the path coefficient between Factor F2 and Factor F4 which is of medium magnitude. This implies that they contribute significantly to the achievement of 'use of ICT for BPM processes'.

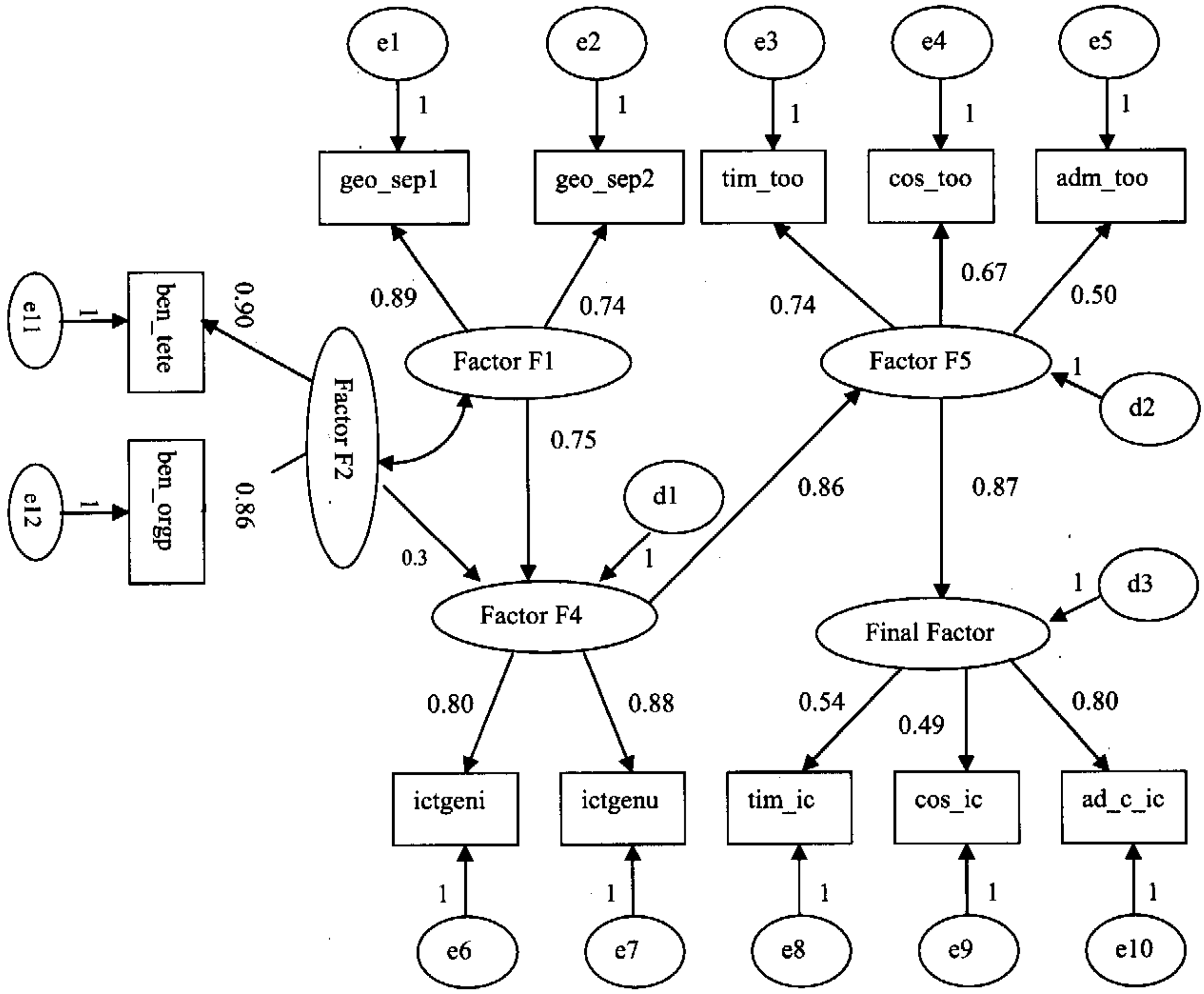

FIG. 2: Standardized Path Coefficients and Factor Loadings of Model Modification - Step 3 (Final Model)

The most important finding is that the 'geographical separation of project team members' and 'perceived benefits of use of ICT for BPM' do not independently increase 'use of ICT for BPM processes' as Hypotheses HR2 and HR3 are not supported by the model. But, these factors positively affect increased and matured use of 'ICT for general administration work' which leads to 'increased use of advanced IT tools and software for individual PM processes' as Hypotheses HR6, HR7 and further hypotheses HR5 and HR1 are supported by the model. *This validates the Interpretive Structural Modeling analysis results discussed earlier and provides direction to building project managers for strategically adopting effective use of ICT within their organizations and for BPM.*

The 'Perceived barriers' do not affect the adoption of ICT for general administration work by PM organizations as Hypothesis HR8 is not supported by the model. But, perceived barriers directly affect ICT adoption for PM processes, as organizations are not very sure of the benefits that can be accrued and whether all project team organizations would be able to adopt the same level of ICT. But the effect is not very significant and if the client requires ICT adoption for PM, it is adopted. Thus Hypothesis HR4 is not significantly supported by the model. The Final Structural Model is shown in Fig. 3. Refer to Fig. 1 for comparison with the hypothesized model.

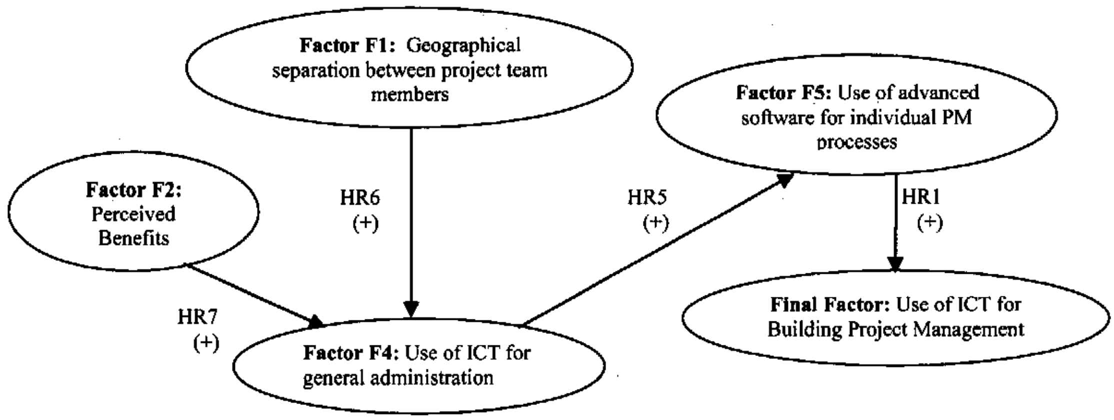

Fig. 3: Final Structural Model

The covariance, which is an unexplained association between exogenous variables Factor F1 and Factor F2 is not significant. However, the p levels improved with each iteration, so it could be assumed that, if the sample size is increased, this result would improve. The model fit indices show a good model fit to the data and the value of chi-square is significantly reduced in last two iterations.

The analysis of results helps us in understanding that an increased and matured use of ICT for general administration within the organization would lead to an improved ICT infrastructure within the organization, development of electronic databases and a staff that is confident of using IT tools. In such a scenario, staff would use advanced software and IT technologies for PM processes and that would lead to an increased adoption of ICT for BPM processes.

But, for general administration also, ICT adoption would be enhanced if the organization is interacting more with geographically separated agencies and senior management perceives that significant benefits would accrue by adoption of ICT. All the factors are inter-related and their effect cannot be maximized in isolation.

These results provide a road map to the project managers and construction organizations for strategically enhancing effective use of ICT for BPM. Results also show that it is important for the organizations to evaluate the benefits of ICT adoption accrued at organization and project levels, because perception of accrued benefits affects ICT adoption for general administrative works and for BPM and organizations should adopt latest IT applications, tools and technologies for general administration works and for BPM. This study is with reference to SMEs, and as studied in the literature survey, large organizations have higher adoption of ICT (Ruddock, 2006, Kajewski et al., 2004) and it has been found difficult to evaluate benefits of ICT adoption for the multi-enterprise construction industry (Ruddock, 2006). Thus, large organizations and national level bodies in the construction industry are required to take initiatives for:

- formulating appropriate methodologies for evaluating ICT investments in the construction industry, and
- increasing awareness of latest IT tools and technologies in the construction industry through seminars, conferences and training programs.

Since the data was collected from the Indian construction industry, the results are applicable to India. However, the results can be generalized to other countries after studying the extent and characteristics of similarities between the construction industries of these countries.

These results, combined with additional analysis conducted on the questionnaire survey data (Ahuja et al., 2009b), led to the formulation of a benchmarking framework for rating construction organizations for ICT adoption for BPM. The qualitative factors including strategic issues, cultural factors, issues concerning training of executives etc. as indicated in Table 1 were studied through case study analysis conducted in a sample of organizations in which the questionnaire survey was conducted. Quantitative analysis studied factors from a broad sample of organizations and provided results at industry and organization levels. Case study analysis studied the qualitative factors or the research variables at the level of the organization and projects to probe, explore and validate the results in more depth. Triangulation of qualitative and quantitative analysis led to the formulation of the protocols to be adopted at the levels of industry, organization and people for enhancing effective ICT adoption for BPM.

CONCLUSION

Building project management is a multi-enterprise effort and effective communication between project team members and within each organization is an important criterion for successful completion of building projects. The required communication between project team members can be achieved by adoption of ICT. The construction industry has been slow in adopting ICT and a direction is required for strategic adoption of ICT within the organizations that would lead to effective use of ICT for building project management (BPM).

This paper describes a research study conducted to study the causal relationships between the factors affecting ICT adoption for BPM by SMEs. Extensive literature survey helped in identification of factors at the three levels of industry, organization and people managing building construction projects. Structure Equation Modeling analysis was conducted to study the causal relationships between all the identified factors as this technique allows to concurrently test the hypothesized causal relationships for an entire model. Data collection for analysis was gathered through a questionnaire survey conducted in the Indian Construction Industry. The unit of analysis for the survey was an organization managing building projects and the sample population was the SMEs in the Indian construction industry. Analysis of the hypothesised causal relationships demonstrates that all the factors are inter-related and their effect cannot be maximized in isolation. 'Geographical separation between project team members' and 'perceived benefits of ICT adoption' positively affect 'use of ICT for general administration within the organization', which further leads to increased 'use of advanced IT tools and software for individual PM processes' leading to increased 'ICT adoption for BPM'. These results provide a roadmap to project managers and construction organizations for effective adoption of ICT within organizations and for BPM; identify initiatives to be taken by large organizations and national level bodies in the construction industry for facilitating SMEs in increasing effective adoption of ICT; and in further research component lead to the development of a benchmarking framework for rating construction organizations for their ICT adoption for BPM. Results are applicable to Indian construction industry and can be applied to other countries after due considerations.

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