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Structural Equation Model for Assimilation of Robots in the Construction Industry

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ABSTRACT: Construction industry in India has investment about INR 50 trillion in 12th Plan in infrastructure, thus indicate large potential; however industry faces many weakness which makes construction a complex industry but adoption of robot can help it to overcome its weakness. Stage Adoption Model (SAM) considers that secondary adoption and assimilation isiterative and has six stages. During this paper author developed fifteen factors as a measurement models that influence assimilation stages of robot in construction. These fifteen factors are tested for validity and then used for develop a structural equation model for assimilation of robot in construction industry in SAM model.

Keywords: Construction Industry, adoption, infrastructure construction, India, SAM

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I. INTRODUCTION

The Construction industry plays an important role in socioeconomic development of a countries and India is no exception. Indian government planed an investment of around INR 50 trillion during 12th Plan in infrastructure (Valecha, and Arora 2012).Construction industry is a complex industry and has much weakness, which include: slow speed, stagnancy in technology, fragment nature, has complex products which are rooted in ground at site, products has large cost, and also has safety concerns. Robots shown their usefulness in manufacturing industry and hence can also help construction industry to solve issues through improvement in productivity, quality, safety etc., robots can also improve company image and competitiveness of firms, a reduction in labor cost and number is also observed. Though adoption has many definitions but here adoption means use of new technology at the levels of firm, group and individuals; also paper considered StageAdoption Model (SAM) which is developed by (Jain and Phadtare, 2013). Since it is most recent and takes care of many limitations of other models and has a dynamic in nature. During SAM primary adoption at group level along with secondary adoption is considered, it also considers consequences of adoption. As various factors that influences primary adoption is considered in (Jain, 2017); this paper focuses on secondary adoption of robots in construction industry. As per SAM secondary adoption and assimilation is iterative and paper considers six stages of it. These stages include: initiation stage; adoption stage; adaptation stage; acceptance stage; Routinization stage; and infusion. Figure 1 shows these stages.

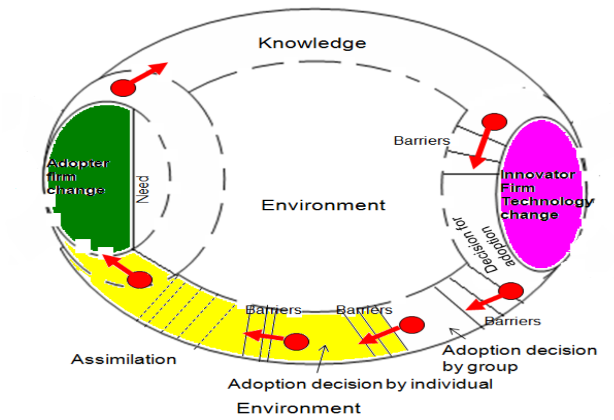

Figure 1: Factors influencing assimilation are considered in this paper (shaded area of the model).

During paper survey technique is used for primary data collection through a Questionnaire and it is administered personally. Snowball sampling is used for data collection and a total of 154 respondents are considered. During study fifteen factors are identified that influence six stages of assimilation; these are tested for reliability, convergent validity, and then used for developing Structural Equation Model for assimilation of SAM. Data is analyzed through AMOS 7.0 package. Following section will consider literature review, research methodology, data analysis and conclusion.

II. LITERATURE REVIEW

During this section various factors that influence the assimilation phase of SAM are considered. There are six stages in assimilation i.e. initiation stage; adoption stage; adaptation stage; acceptance stage; Routinization stage; and infusion. Following section consider various factors which influence these stages.

2.1 Initiation stage:

In this stage active and passive scanning of organization problems / opportunities along with solution are undertaken. Pressure to change comes from organizational need (pull) and technological innovation (push) or both. A match is found between an innovation and its application in the organization. (Cooper, &Zmud, 1990; Suzana, and Johan, 2007). Various factors influences this stage, these include: manager help (Gallivan, 2001); Criteria based choice between automation and conventional method (Hastak, 1998; Gokhale, and Hastak, 2000); Barriers at Initiation stage (Mahbub, 2008).

Here manager help is indicated through Strong and clear communication message of top manager; high level of resource committed **(**Gallivan, 2001); and gap between technology supply and demand **(**Won, 2002).Criteria based choice between automation and conventional method can be indicated by Need based criteria; Technical criteria; and Safety / Risk criteria (Hastak, 1998; Gokhale, and Hastak, 2000). Barriers at Initiation stage include: Underdeveloped automation products (Mahbub, andHumphreys, 2005; Mahbub, 2008); Highly fragmented R&D resources; and Low R&D investment **(**Won, 2002).

2.2 Adoption stage:

During this stage rational and political negotiations will ensure to get organizational backing for implementation of decision to get investment in resources for accommodation of implementation effort (Cooper, &Zmud, 1990; Suzana, and Johan, 2007). This stage is influenced by Organizational attributes (Won, 2002); External critical success factors (Rahman etal., 2003) and Barriers (Tabak, and Barr, 1999).

Here Organizational attributes which help adoption stage are indicated by: Repetition or common design (Mahbub, and Humphreys 2005; Mahbub, 2008); Risk reduction through large number of projects; and Large R&D support (Won, 2002). External critical success factors include: Competitive strategy used for market differentiation where organization cultivates to establish unique position and sets the organization apart from others in a particular market niche; Market condition through the analysis of the market place in which an organization operates or has interest in developing a position; and Political environment where the political forces influences project decisions, community development and fiscal policy (Rahman et al., 2003).Barriers include: Administrative barriers; Communication barriers; Cognitive barriers; Political barriers; and Barriers originating from mere resistance to change (Tabak, and Barr, 1999).

2.3 Adaptation stage

In this stage organizational procedures are revised and new processes are introduced that require a good understanding of current practices as well as need for restructured to exploit full potential of new technology; also there is a need for organizational members to be trained in both the new procedures and applications (Cooper, &Zmud, 1990; Suzana, and Johan, 2007; Statnikova, 2005). This condition is similar to the horizontal fit of new technology at the capability level which implies integration between business processes and people's individual and social behavior (Cabrera, et al 2001). Various factors which influence this stage include: managers support (Gallivan, 2001); improvement in organizational structure, improvement in technical applications, improvement in employee enhancements and improvement in process benchmarking; (Rahman, et al 2003); role of supplier (Wong, et al 1998).

Here manager support can be indicated by: Clear massage (Gallivan, 2001); Support other than money only (Statnikova, 2005); Retraining of construction workers (Yang, 2008; Mahbub, 2008; Suzana, and Johan, 2007); and Helping in Site upgrading skill (Mahbub, 2008). Role of supplier include: Reduce state of knowledge gap (Kouki et al., 2006); Improve compatibility of technology; and Improve trial-ability of technology (Yang, 2008; Wong et al.,1998). Improvement in organizational structure is indicated by: Single point responsibility for all phases of construction (Mahbub, and Humphreys, 2005; Mahbub, 2008); Greater interaction and coordination between workforce (Wong et al., 1998); and Proper communication and education techniques (Ronie et al., 1993). Improvement in Technical application are indicated by: RFID systems(Korteweg, 2007; Ronie,2008; Wang et al., 2004; Yang, 2008; Calis et al., 2011; Hwang, and Liu, 2011; Dios et al.,2011; Cheng, and Chang, 2011; Huang, and Tsai, 2011; Ali, and Amin, 2011; Grau et al., 2009); Using computers to reduce data fragmentation(Howard et al., 1989; Roger, 1994); and Computer integrated construction systems(Yasuyoshi, and Roozbeh, 1993). Improvement in Employee enhancements are indicated by: Labor concern; Low to middle manager concern; and Union concern (Ronie et al., 1993).Improvement in Process Benchmarking is indicated by: Cost of use consideration for use of machine in construction process during design phase (Slaughter, 1997); Toyota Production System (TPS) (Thomas et al., 2010); and Problem identification based on process criteria in traditional construction (Derek, and Khaled, 2003).

2.4 Acceptance stage

In this stage members of organization are included to commit to innovation's usage in organizational work (Cooper, &Zmud, 1990; Suzana, and Johan,2007). It is similar to the horizontal fit of new technology at the infrastructure (architecture) level that implies integration between organizational technology, organization structure and people (including the set of managerial practices which regulate the relationship between organization and its members). For an organization to successfully adopt, a new technology must be adapted by its structure and human resources (Cabrera, et al 2001). This stage is mainly influenced by Collective belief and perception of individuals which can be indicated through Social influences from peer usage (Gallivan, 2001; Everdingen, and Wierenga, 2002; Klooster, 2008); and individual attributes (Gallivan, 2001).

Here Collective belief and perception of individuals is indicated by: Customer influence (Gallivan, 2001; Klooster, 2008); Cultural norm which allow their learning and carrier development (Gallivan, 2001); Adequacy of information (Suzana, and Johan, 2007); and demonstrated and Perceived benefits of technology (Wu, 1996). Individual attributes are indicated by: Personal flexibility ; Shorter job tenure; Low seniority (Gallivan, 2001); Young age; Larger aptitude to learn new technology (Mahbub, 2008); Less Communication problems due to change in language; and Similar Values of users (Sillars, andKangari, 1997).

2.5 Routinization stage:

In this stage usage of technology application is encouraged as a normal activity and the organization's governance system are adjusted so as to account for the robot application and use of robot is no longer perceived as something new (Cooper,&Zmud, 1990; Suzana, and Johan, 2007). This stage leads to routine use (Hsieh, and Robert, 2006) and hence robot is used on routinely in construction. Routine use is indicated by: Management expected tasks from robot; Management expected features of robot (Hsieh, and Robert, 2006); and Demonstrated and Perceived usefulness of technology (Klooster, 2008).

2.6 Infusion stage:

Here organizational effectiveness is obtained through use of robot in more comprehensive and integrated manner for supporting higher level aspects of organizational works and it is used to its full potential (Cooper, &Zmud, 1990; Suzana, and Johan, 2007).

III. RESEARCH METHODOLOGY

Survey is done for 154 samples and data is collected from 96 construction firms that are located pan India along with projects. These firms are divided based on annual turnover as: INR 0-10Cr; 10-100 Cr; 100-250 Cr; 250-500 Cr; 500-1000 Cr; 1000-2500 Cr; over 5000 Cr. Sample are also divided based on position in firm i.e. CEO/Top managers, project manager, and users. Detail of sample is shown in figure 2 and 3.

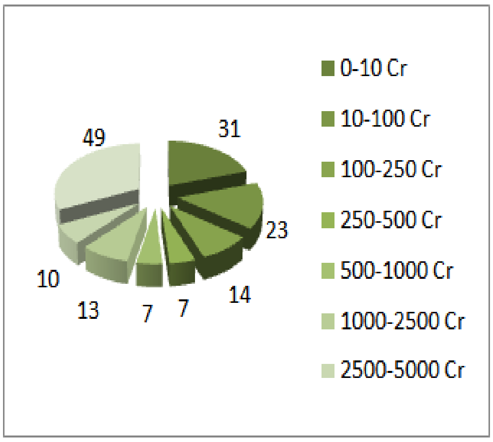

Figure 2 Respondent details as per Turnover of firms

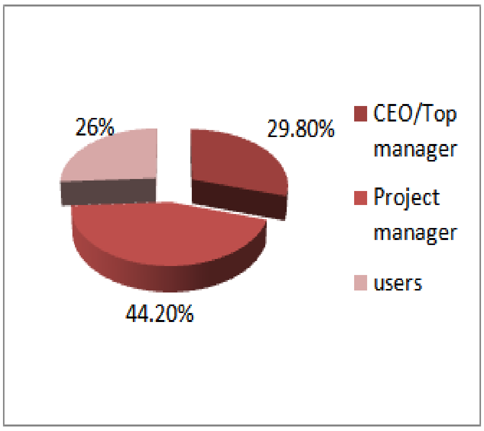

Figure 3 Respondent details as per position

Snowball sampling technique is used for primary data collection. Date is screened through KMO for sampling adequacy and Bartlett's Test of Sphericity for suitability of data for application of factor analysis techniques. The KMO index range of 0 to 1 is considered satisfactory for sampling adequacy. The Bartlett's Test of Sphericity should be significant ($p<.05$) for factor analysis to be suitable (Williams et al, 2010). Checking of reliability is done by Cronbach alpha and value must be equal to or greater than 0.7. SPSS 17 software is then used for factor analysis. Factors are developed as measurement model tested for Convergent validity which is assessed by composite reliability, average variance extracted (AVE) (Farrell, and Rudd, 2009; Yanamandram, and White, 2009; Liao, and Wang,2011; Yusoff, 2011). Here values needed for validity are for VE (more than 0.5); CR values (more than 0.7); and Cronbach α (more than 0.7). These factors are then used to develop structure equation model for assimilation.

IV. DATA ANALYSIS

The output of KMO and Bartlett's test as shown in table 1 and since all KMO values are more than 0.5 and significance values are 0.000, data is suitable for analysis of factors, and hence further analysis of measurement model can be done. Each of the fifteen factors passes the test of validity as their VE values exceed 0.5; CR values exceed 0.7 and Cronbach α exceed 0.7, hence convergence validity is established, as shown in table 2. These developed factors are then used for developing a structural equation model for primary adoption of robot as shown in figure 4. This model is found fit as CMIN/Df is 3.011 which less than 5 is (Paul, 2007).

V. CONCLUSIONS AND DIRECTION FOR FUTURE RESEARCH:

In this paper the main objective was to find various factors which influence assimilation phase of SAM and to develop a structural equation model for assimilation of robots. Here totally fifteen factors are found important for assimilation of robots. These developed fifteen factors have good reliability and convergent validity.

Here first factor is Manager Help in initiation stage in which three main indicators are found important i.e. Strong and clear communication message of top manager; high level of resource committed; and gap between technology supply and demand. Second factor is Criteria based choice between automation and conventional method in Initiation stage which has three main indicators, i.e. Need based criteria; Technical criteria; and Safety / Risk criteria. Third factor found is Barriers at Initiation stage which has three main indicators i.e., under developed automation products; highly fragmented R&D resources; and Low R&D investment.Fourth factor found is Organizational attributes help in Adoption stage which has three main indicators i.e., Repetition or common design; Risk reduction through large number of projects; and Large R&D support.Fifth factor found is External critical success factors helps in Adoption stage which has three indicators i.e., Competitive strategy used for market differentiation where organization cultivates to establish unique position and sets the organization apart from others in a particular market niche; Market condition through the analysis of the market place in which an organization operates or has interest in developing a position; and Political environment where the political forces influences project decisions, community development and fiscal policy.

Sixth factor found is Barriers important in adoption stage which has five main indicators i.e., Administrative barriers; Communication barriers; Cognitive barriers; Political barriers; and Barriers originating from mere resistance to change.

Seventh factor found is Manager support helps in adaptation stage of assimilation which has four indicators i.e., Clear massage; Support other than money only; Retraining of construction workers; and Helping in Site upgrading skill.Eighth factor found is Role of supplier in Adaptation stage which has three main indicators i.e., Reduce state of knowledge gap; Improve compatibility of technology; and Improve trial-ability of technology.

Ninth factor found is Improvement in organizational structure in adaptation stage which has three main indicators i.e., Single point responsibility for all phases of construction; Greater interaction and coordination between workforce; and Proper communication and education techniques.Tenth factor found is Improvement in Technical application in adaptation stage which has three main indicator i.e., RFID systems; Using computers to reduce data fragmentation; and Computer integrated construction systems.

Eleventh factor found is Improvement in Employee enhancement in adaptation stage which has three main indicators i.e., Labor concern; Low to middle manager concern; and Union concern.Twelve factor is Improvement in Process Benchmarking in adaptation stage which has three main indicators i.e., Cost of use consideration for use of machine in construction process during design phase; Toyota Production System (TPS); and Problem identification based on process criteria in traditional construction.Thirteenth factor found is Collective belief and perception of individuals in Acceptance stage which has four main indicators i.e., Customer influence; Cultural norm which allow their learning and carrier development; Adequacy of information; and Demonstrated and Perceived benefits of technology.Fourteenth factor is Individual attributes in

Acceptance stage which has seven main indicators i.e., Personal flexibility; Shorter job tenure; Low seniority; Young age; Larger aptitude to learn new technology; Less Communication problems due to change in language; and Similar Values of users.

There is one important relation is found i.e. improvement in process can help all stages of assimilation, as it has large correlations with factors that influences various stages of assimilation, i.e., Criteria based choice between automation and conventional method in Initiation stage (0.793); Manager Help in initiation stage (0.578); Organizational attributes help in Adoption stage (0.722); Improvement in organizational structure in adaptation stage (0.934); Improvement in Technical application in adaptation stage (0.885); Manager support helps in adaptation stage (0.865); Improvement in Employee enhancement in adaptation stage (0.828); Collective belief and perception of individuals in Acceptance stage (0.824); Individual attributes in Acceptance stage (0.813); and Routine use (0.72) during Routinization stage. Structural equation model for assimilation is also found fit; hence seller firms of robot and buying firms i.e. construction industry can use it. However thee are limitation of this study is also there i.e. study consider small number of firms and also sample size can be increased. This study cover Indian firms only; however it can extended to other countries also.

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Table 1: KMO and Bartlett's test

Sr. No	Stage	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	Bartlett's Test of Sphericity			Total Variance Explained
			Approx. Chi-Square	df	Sig	Cumulative %
1	Initiation stage	0.800	280.708	36	0.000	48.015
2	Adoption stage	0.866	515.215	55	0.000	56.722
3	Adaptation stage	0.888	1092.527	171	0.000	54.623
4	Acceptance stage	0.889	1103.635	78	0.000	58.944
5	Routinization stage	0.782	257.298	6	0.000	72.944

Table 2: Convergence Validity

	MHIS	CBCI	BarIS	OAtAS	ESFAS	BarAS	MSAdS	Rolsu	ImOS	ImTA	ImE	ImPB	CBUPA	IAAS	Rout Use
MHIS1	0.705														
MHIS2	0.738														
MHIS3	0.791														
CBCI 1		0.717													
CBCI 2		0.693													
CBCI 3		0.833													
BarIS1			0.882												
BarIS2			0.783												
BarIS3			0.804												
OAtAS1				0.807											
OAtAS2				0.825											
OAtAS3				0.632											
ESFAS1					0.651										
ESFAS2					0.939										
ESFAS3					0.628										
BarAS1						0.861									
BarAS2						0.897									
BarAS3						0.918									
BarAS4						0.867									
BarAS5						0.725									
MSAdS1							0.824								
MSAdS2							0.7								
MSAdS3							0.816								
MSAdS4							0.851								
RolSu1								0.871							
RolSu2								0.814							
RolSu3								0.977							
ImOS1									0.6						
ImOS2									0.906						
ImO									0.						

S3									901						
ImTA1										0.746					
ImTA2										0.874					
ImTA3										0.93					
ImE1											0.732				
ImE2											0.92				
ImE3											0.759				
ImPB1												0.784			
ImPB2												0.758			
ImPB3												0.696			
CBUPA1													0.771		
CBUPA2													0.728		
CBUPA3													0.906		
CBUPA4													0.744		
IAAS1														0.717	
IAAS2														0.832	
IAAS3														0.829	
IAAS4														0.754	
IAAS5														0.729	
IAAS6														0.758	
IAAS7														0.871	
MExTA															0.888
MExFA															0.941
DPUT															0.707
VE	0.556	0.563	0.679	0.577	0.567	0.733	0.64	0.792	0.664	0.728	0.653	0.558	0.625	0.618	0.725
α	0.79	0.786	0.873	0.823	0.77	0.931	0.846	0.916	0.828	0.871	0.839	0.763	0.86	0.917	0.877
CR	0.789	0.793	0.864	0.802	0.791	0.932	0.876	0.919	0.852	0.889	0.848	0.791	0.869	0.919	0.886

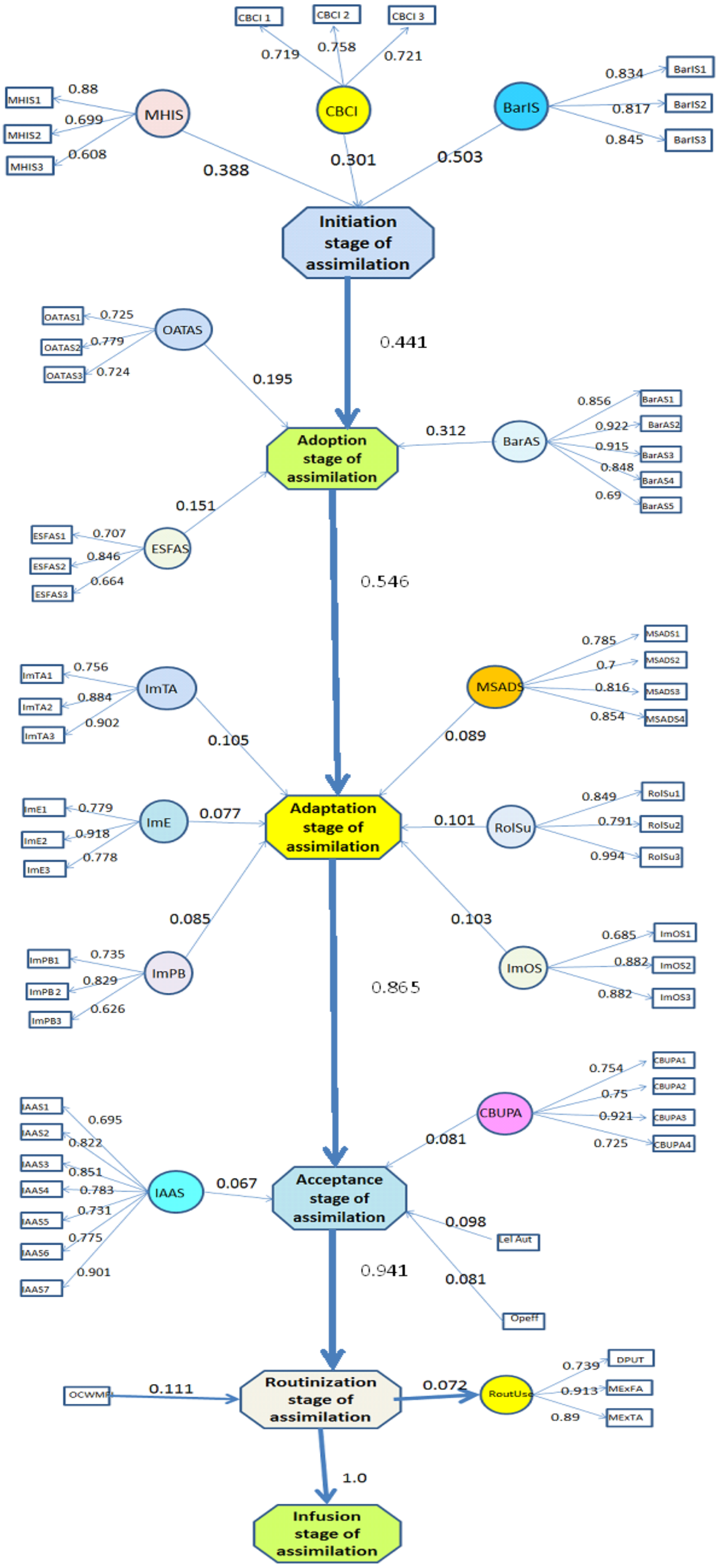

Figure 4 SEM for Assimilation of robots in construction