A PROPOSED "MODEL FOR ADOPTION" OF HIGH TECHNOLOGY PRODUCTS (ROBOTS) FOR INDIAN CONSTRUCTION INDUSTRY

S. Jain[1] and Dr. M. Phadtare[2]

[1&2]*National Institute of Construction Management And Research,*
Balewadi, Pune, India
(Corresponding author: sjain2704@yahoo.co.in)

A PROPOSED "MODEL FOR ADOPTION" OF HIGH TECHNOLOGY PRODUCTS (ROBOTS) FOR INDIAN CONSTRUCTION INDUSTRY

ABSTRACT

Construction industry is considered as labour intensive, having shortage of skilled labour, unsafe with large number of industrial accidents. Construction industry requires high technology automation products (Robots) for improving productivity, safety, quality etc. Robots are developed by various countries in different areas like demolition, earthwork, bridge, tunnels, road work, underwater works, trenches and piping, maintenance etc. however they are still not used to their full potential by construction industry. Hence in this paper, the authors propose a "model for adoption" of robots in construction industry. This model considers how a construction firm will adopt full scale robots like manually controlled machine, tele-controlled machines, computer controlled machines and cognitive robots and assimilate them through various stages.

KEY WORDS

High technology products, robots, construction industry, adoption, India, SAM

INTRODUCTION

Construction industry similar to manufacturing has long history (Sebestyan, 1998) and plays an important role in socio-economic development, requiring to be studied properly (George, 1990). Many researchers considered construction as: labor intensive (Jen-Chi, 1994); dangerous industry, facing labor shortage (Wu, 1996); technologically stagnant, fragmented, negligible R&D, perceived by customer as slow and costly (Jones, and Saad, 2003); complex products requiring heavy integration; low standardization; (Chang, and Lee, 2004); design and assembly of objects fixed-in-place (Ballard, and Howel, 1998). Some researchers consider construction as a flow (Koskela, 1992), loose coupling system (Dubois, and Gadde, 2001) or as new product development process (Cooper et.al. 2005).

Infrastructure construction in India is growing at a rapid rate and investments in roads could account for 80% of the total investments. However revenue growth of firms lacks order book growth. That indicates that execution cycle is getting longer (Mukherjee, and Shori, 2008). (Report on Indian Infrastructure, 2011) observed main weaknesses in Indian infrastructure firms as: low level of domestic expertise; shortage of skilled labor; low mechanization and limited use of modern technological equipment. Robots are developed in many areas like demolition; earthwork; bridge work; road work; tunneling; under water works; trenches and piping; maintenance; material management etc (Report on robots and automation machines 1998). Many researchers have considered various perceived benefits of automation as productivity increase, quality improvement, work / labor saving (Jen-Chi, 1994; Wu, 1996), cost reduction, increase in company image, increased competitiveness and time saving (Wu, 1996). Construction industry in India would benefit by the adoption of robots and get a solution to its weakness such as slow speed, labour productivity, lower safety and quality. This will also result in construction industry becoming more cost efficient and competitive. India has scientific temperament but lacks in use of robots (Deb 2008) however hardly any research is done in the area of robots in Indian construction industry. The benefits of automation on one hand and lack of research on other hand motivated researchers to explore the adoption process of robots in India. The main objective of this paper is to develop a model for adoption of robots. The proposed model will show the adoption process in detail so that adopting firm and innovator firm will work together to help adopting firm to adopt the cognitive robots and assimilate them through various stages.

Robots as High Technology Automation Products:

(Mahabub, 2008) considered, sophistication of technology application to defining mechanization, automation and robotics. As per her one end of spectrum is mechanization which involves equipping the process with machinery whereas robotics is on the other end of spectrum is most sophisticated. Task specific, dedicated robots perform discrete tasks with the help of computer and artificial intelligence. Mechanization helps in automation of processes which are not only supported by machine but also with a program which regulates machines. Japan industrial robot association (JIRA) defines robots as per degree of autonomy as: Manual handling devices; Fixed sequence robots; Variable sequence robots; Playback robots; Numerically controlled robot; Intelligent robots (Rick, and Gerard de, 2002). (Van Gassel, and Maas, 2008) considered a mechanization graph in which energy and control provided by equipment and various mechanization phases are observed. Results showed that mechanization phases can be represented as a chain in which traditional method can be mechanized in phases as from hand tools; manually controlled device; Tele-controlled devices (remote control devices); pre programmed devices (computer control devices); and cognitive robots. (Best, and Valence, 2002; Dev, 2008) also observed that modern Robots are developed through many generations. In this paper thus robots are considered with four generations as manually controlled machine, tele-controlled machines, computer controlled machines and cognitive robots.

Definition of Adoption:

Many researchers considered adoption as full use of innovation (Rogers, 1962). (Sarosa, 2007), "A*doption is a physical acquisition of technical artifacts or a commitment to implement innovation with an emphasis on decision to adopt and commitment of use."* (Zaltman, Duncan, and Holbeck, 1973), observed that *"two staged adoption process may be multi stage if intermediate level of adoption approval is required – for example if after senior management adopts the innovation, it must then be approved at the division or workgroup level, before end users have the opportunity to adopt it."*(Gallivan, 2001. p 53-54). (Mark, and Poltrock, 2004) also agree with multi level adoption and observed that adoption can be at various levels as: Individual level adoption, work group level adoption and organizational level adoption. Hence adoption is defined in this paper as: "Use of new technology along with three levels i.e. firm level; group level and individual level".

Models of Adoption:

Many researchers developed different models of adoption: Roger's model initially developed in 1962 then revised through 1972, 1995 and 2003 considers individual adoption (Jansma, 2003). TAM developed by Davis (1989) for individual acceptance of information technology. TAM provides explanation of determinants of computer acceptance by user (Al-Qeisi, 2009). He observes that TAM derived from TRA has extension like: TAM 2 developed by (Venkatesh and Davis 2000) to explain perceived usefulness and usage intentions in terms of social influences and cognitive instrumental process (Al-Qeisi, 2009). TAM3 developed by (Venkatesh, and Bala, 2008) considers another organizational issue: how managers from an organization make informed decisions about interventions which lead to greater acceptance and effective utilization. TOE model by (Tornatzky, and Fleisher, 1990) considers three elements i.e. technology context, organizational context and environment context. Unified Theory of Acceptance and Use of Technology (UTAUT) developed by (Venkatesh et al., 2003) for a synthesis to reach a unified view of user's technology acceptance as Information Science or IT researchers (Al-Qeisi, 2009). Though TOE model considered organization adoption, it has limited variables and cannot capture complex inter organizational interactions (Kurnia, and Johnston, 2000). There is no model of adoption for high technology products (Robots) in construction.

Proposed "Model for Adoption" of High Technology Products (Robots):

For developing the new model for adoption, researchers considered (Gallivan, 2001) model as base for many reasons. Firstly it considered limitations of all basic models. Secondly it is the recent one. Thirdly it considers importance of secondary adoption. Fourthly it also considers classification matrix for Information System (IS) technology which shows that locus of adoption may be individual or organizational. In this matrix first cell is for traditional adoption. Second cell is for organizational mandate. Third cell is for knowledge burden. Fourth cell is for organizational mandate and knowledge burden. As construction products are highly complex requiring heavy integration as well as automation and robots technology lead to high knowledge burden lies in fourth cell of classification matrix. However (Gallivan, 2001) framework has many limitations these are improved in proposed framework. Firstly (Gallivan, 2001) considered mainly about secondary adoption and organizational assimilation process. However in case of automation and robotics there is not much research done. As per (Sahin, 2006) Rogers's model is used for primary adoption and the sequence of knowledge-persuasion-decision can be changed to knowledge-decision-persuasion when group adoption is considered. Since work group is also very important in construction TAG model developed by (Sarker, Valacich, and Sarker, 2005) is integrated in proposed framework. This integration will elaborate various factors influencing group adoption. Secondly though (Gallivan, 2001) framework shows three types of uses i.e. extended use, integrated use and emergent use, their causes have not been properly explained. In proposed framework research for post adoptive use behavior by (Hsieh, and Robert, 2006) is considered. As per them, routinization stage results in routine use of technology and infusion stage results in emergent use and extended use. (Huh, and Kim, 2008) observed that early adopter of product may not be early adopter of next generation of product. Adoption of next generation depends on the post adoption use by adopter, especially innovative use and extended use in high technology products. Since Robots are high technology products they will be adopted in generations. Hence in this proposed framework this post adoption is considered. Lastly though (Gallivan, 2001) framework considers the feedback loop between consequences and secondary assimilation to show continuity, fails to focus on consequences. In this research these loops are considered as: Routine use positive feedback motivates the group decision of adoption whereas extended use positive feedback motivates firm level.

The proposed **S**tage **A**doption **M**odel (SAM) consists of three parts i.e. primary adoption; secondary adoption along with assimilation; and consequences post adoption i.e. need for next generation purchase of robots. Primary adoption consists of four stages i.e. organization need; organizational knowledge; adoption decision at firm level; adoption decision at group. During primary adoption top managers play a critical role. Once the adoption decision is taken at firm level, it is mandatory to use robot in firm. Primary adoption leads to secondary adoption where individual adoption is important and is determined by managerial intervention, subjective norms and facilitating conditions. The process between secondary adoption and assimilation is iterative and has many levels. Assimilation process has six stages i.e. initiation; adoption; adaptation; acceptance; Routinization; and infusion. Once the technology is started to be used in firm, three types of uses will emerge i.e. routine use, extended use and emergent use. These uses will motivate firm for further use of robots. On one hand positive feedback from routine use will motivate group for further use of robots in next activities while on the other hand positive feedback from extended use will motivate firm for use of robots further. In the proposed model, post adoption is also considered as extended use and emergent use of technology leading to purchase of next generation product. This makes the model a dynamic model leading to adoption of robots in various stages as shown in figure 1.

Hypothesis:

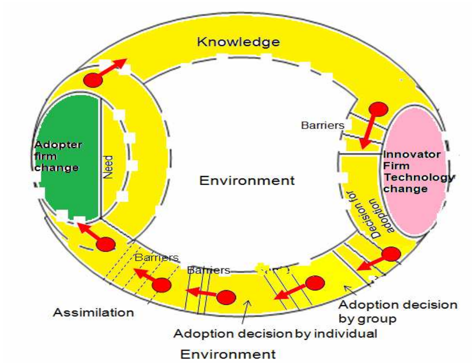
H1: Organizational need will lead to organization knowledge gathering about the robots.
H2: Organizational knowledge gathering will lead to adoption decision at firm level.
H3: Adoption decision by firm level will lead to adoption decision by group.
H4 Organizational adoption decision will lead to increase in managerial interventions
H5 Group adoption decision will lead to improving in subjective norms.
H6: Managerial interventions lead to adoption decision by individual.
H7: Subjective norms lead to adoption decision by individual.
H8: Adoption decision by individual leads to initiation stage of assimilation of robots in construction.
H9: Initiation stage of assimilation leads to adoption stage of assimilation of robots in construction.
H10: Adoption stage of assimilation leads to adaptation stage of assimilation of robots in construction.
H11: Adaptation stage of assimilation leads to acceptance stage of assimilation of robots in construction.
H12: Acceptance stage of assimilation leads to routinization stage of assimilation of robots in construction.
H13: Routinization stage of assimilation leads to infusion stage of assimilation of robots in construction.
H14: Routinization stage of assimilation leads to routine use of robots in construction.
H15: Infusion stage of assimilation leads to extended use of robots in construction.
H16: Infusion stage of assimilation leads to emergent use of robots in construction.
H17: Emergent use of robots leads to next generation purchase of robots.
H18: Extended use of robots leads to next generation purchase of robots.

H19: Positive feedback from Routine use motivate group to adopt robots more.
H20: Positive feedback from extended use motivate firm to adopt robots more.

Working of model:

(Elias, and Robie, 2000) observed pull and push scenario in which pull focuses on solving a problem by providing a technical answer to a market need and push focuses on identifying a market need to accommodate an existing technical solution. A dynamic balancing between technology push and market pull drives the speed and acceleration of technological change and in process creates market opportunities and competitive threats to existing technology. As per (Elias, and Robie, 2000) push and pull can be defined from either a technology or market point of view as: technology push; technology pull; market pull; market push. During adoption of Robots in construction, pressure for change in firms comes from organizational needs (pull) and technological innovation (push) or both (Copper, & Zmud, 1990; Ivkovic, and Nehlin, 2007). Hence factors which influence organizational need and technological innovation will drive the adoption process initially. Once adoption decision is taken by a firm, robotics technology is introduced to the adopting firm. As per (Cabrera, Cabrera, and Barajas, 2001) whenever a new technology is introduced for implementation it will affect the other sub systems of organization and hence either technology is to be designed to fit in organizational structure or organization structure has to be changed to fit demands of new technology. Technology has to fit vertical and horizontal levels (Cabrera, et al 2001). This is similar to technology pull condition and also market push situation which will influence implementation. Forces are shown as in Figure 2. After acceptance the users start using the technology for their tasks and if they find that new technology is easy to use they use it regularly which helps in extended use of technology. If users find more satisfaction and enjoyment by using technology they use it more innovatively leading to demand for improvement in technology features, creating a need for updating and thus leads to next generation. This need of technology leads to bottom up secondary adoption situation forcing a change in the form of organizational need (pull) for next generation product and this will continue the adoption process until full cognitive robots are adopted which is in line with findings/ observation of (Elias, and Robie, 2000). (Elias, and Robie, 2000) claim that market push and technology pull leads to radical improvement and sets standard for technology as shown in Figure 3.

Innovative firms want to modify high technology products in such a way that R&D costs will be recovered properly through life cycle of product. In this model various stage gates are considered. S1-S4 are the four stages of high technology products i.e. manually controlled machine, tele-controlled machine, computer controlled machine and cognitive robots respectively. Stage gate during new product development acts as decision points and represented by diamond shape. They serve as quality control checkpoint, providing a funneling of projects, pointing towards a path forward (Cooper, and Edgett, 2006). This paper considers G1 - G3 as three gates during product development. G1 is stage gate between manually controlled machine and tele-controlled machine. G2 is stage gate between tele-controlled and computer controlled machine. G3 is stage gate between computer controlled machine and cognitive robots. These technology stage gates are opaque in nature i.e. technology team can see at initial gate. Technology team can see other gates also once they will pass through changes in first stage (Greg, and Peter, 2003). This is shown in Figure 4.



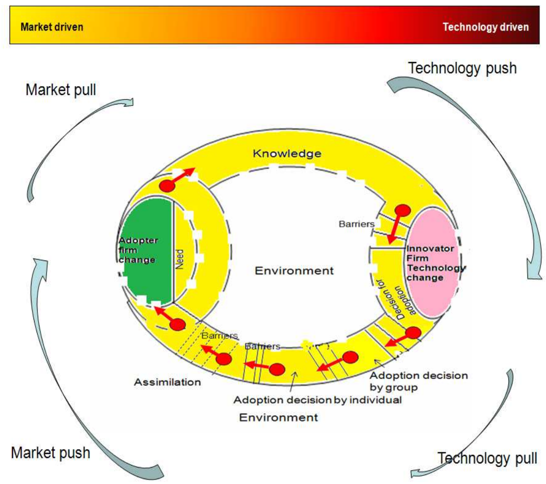
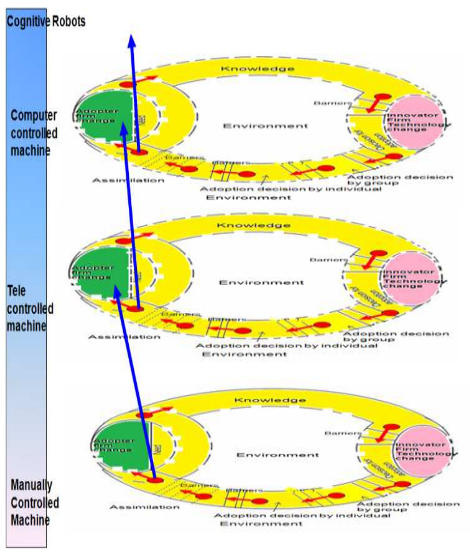


Figure 1-Proposed "Model of Adoption" High Technology Products (Robots)- (SAM)

Figure 2-Various forces which drive Adoption process



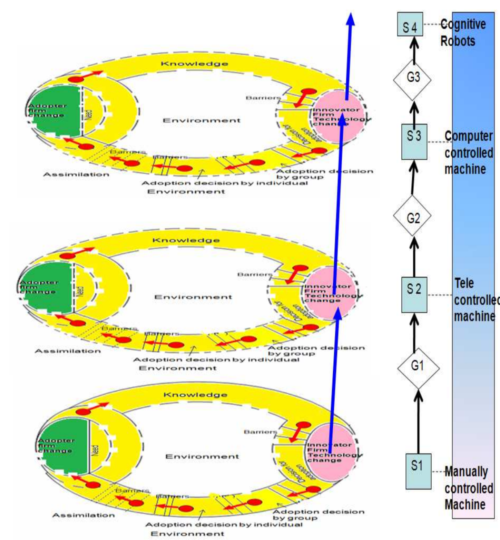


Figure 3-Changes in adopting firm need during for next level robots during adoption process

Figure 4-Technology changes in supplier firms adoption process

Research methodology:

Hypothesized statements are tested by using sample survey for their significance by SPSS software. Purposive sampling, especially snowball sampling is used as firms that use automation have rare population. Mailed questionnaire method is used for collecting data. Total 100 questionnaires were sent to various respondents having different positions out of which total 74 questionnaires were received totally filled and hence considered for analysis. Sample includes 18 top managers; 37 project managers and 20 users. A seven point scale is used in which respondents are required to indicate level of agreement to each statement by ticking their response. All hypotheses are tested by one tailed t-test and null hypothesis is considered as:

Null Hypothesis as H_o $\mu = 4$

And alternative hypothesis as H_1 $\mu > 4$

RESULTS

SPSS output for all hypothesis are as shown in Table 1, all t values are positive and large and all alternative hypothesis i.e. H1 to H20 are accepted.

Table: 1- Results of t-test of hypothesis

	statement	t	Sig. (2-tailed)	
H1	**OrgNed → OrgKow**	12.852	0.000	Significant
H2	**OrgKow → AdoFm**	9.454	0.000	Significant
H3	**AdoFm → AdopGp**	13.792	0.000	Significant
H4	**AdoFm → Magin**	17.593	0.000	Significant
H5	**AdopGp → SubNor**	13.015	0.000	Significant
H6	**Magint → AdopIn**	16.455	0.000	Significant
H7	**SubNor → AdopIn**	15.385	0.000	Significant
H8	**AdopIn → InitS**	12.963	0.000	Significant
H9	**InitS → AdoptS**	12.545	0.000	Significant
H10	**AdoptS → AdaptS**	13.373	0.000	Significant
H11	**AdaptS → AccptS**	14.803	0.000	Significant
H12	**AccptS → RoutS**	11.673	0.000	Significant
H13	**RoutS → InfuS**	13.336	0.000	Significant
H14	**RoutS → RouUse**	13.346	0.000	Significant
H15	**InfuS → EmrUse**	11.838	0.000	Significant
H16	**InfuS → ExtUse**	10.207	0.000	Significant
H17	**EmrUse → NPNextG**	15.739	0.000	Significant
H18	**ExtUse → NPNextG**	14.573	0.000	Significant
H19	**PFRoU → AdopGp**	18.937	0.000	Significant
H20	**PFExU → OrgNed**	20.125	0.000	Significant

Significant** at 99%
Source SPSS output

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS:

The proposed SAM model fills the gap as observed from the literature review. Secondly SAM considers adoption at all levels. Thirdly SAM integrates group adoption. Fourthly SAM considers proper sequence of steps leading to adoption process of robots in construction firm. SAM is a dynamic model as firm adopts robots through various stages. SAM also considers various technological changes in supplier firm during adoption process. This model helps both adopting firm and vendors. Adopting firm will fix their problems through technology adoption and vendors are benefited as they get a deep view for needs of customer firms. Hence firms which supply high technology automation products (Robots) can get a good Indian market which has a large potential. It is planned to invest 1$ trillion in Infrastructure construction in next five years in India (Report on Indian Infrastructure, 2011). The model does not explain the reasons for market pull and technology push and market push and technology pull during primary and secondary adoption respectively. Other limitation may be small sample size for testing hypothesis hence in future study can consider larger sample.

REFERENCES:

Al-Qeisi, K. I. (2009). *Analyzing the use of UTAT model in explaining an online behavior: Internet banking adoption.* (Unpublished PhD thesis), Brunel University.

Ballard, G., and Howel, G., (1998). *What kind of production is construction?* Paper presented at Sixth conference conducted by International group of Lean Construction, Guaruja, Brazil.

Cabrera, Á., Cabrera, E.F., and Barajas, S., (2001). *The key role of organizational culture in a multi-*

system view of technology-driven change. International Journal of Information Management, vol.21, num.3, p. 245-261.ISSN 0268-4012.

Chang, A.S., and Lee, K.P., (2004). *Nature of construction technology.* Paper presented at Twelfth conference conducted by International group of Lean Construction, Denmark.

Cooper, R., Aouad, G., Lee, A., Wu, S., Fleming, A., and Kogioglou, M. (2005). *Process management in design and construction (1st ed.)*. UK: Blackwell Publishing.

Cooper, R.B., and Zmud, R.W., (1990). *Information technology implementation research: A technology diffusion approach.* Management Science,36(2), pp.123–139.

Cooper, R.G., and Edgett, S.J., (2006). *Stage-Gate® and the critical success factors for new product development.* Retrieved from http:// www.stage-gaye.com

Deb, S. R. (2008). *Robotics technology and flexible automation (18th ed.)* New Delhi: Tata McHill publishing company ltd.

Dubois, A., and Gadde, L-E., (2001). *The construction industry as a loosely coupled system: Implications for productivity and innovativity.* Paper presented at Seventeenth IMP Conference, Oslo, Norway.

Elias, G.C., and Robie, I.S.R., (2000). *Davids vs Goliaths in the small satellite industry: the role of technological innovation dynamics in firm competitiveness.* Technovation 20 , pp. 287–297.

Gallivan, M.J., (2001). *Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework.* The DATA BASE for Advances in Information Systems - Summer 2001 (Vol. 32, No. 3), pp. 51-85.

George, O. (1990). *The construction industry: Aspects of its economics and management*. Singapore: University Press.

Greg, M.A., and Peter, A.K., (2003). *Technology stage-gate™: A structured process for managing high-risk new technology projects.* Retrieved from www.cioindex.com/nm/articlefiles/61127-tech**stagegate**.pdf

Hsieh, JJ Po-An, and Robert, JJ Po-An, (2006). *Understanding post-adoptive usage behaviors: A two-dimensional view.* Paper in Proceedings of Association for Information Systems AIS Electronic Library (AISeL), http://aisel.aisnet.org/digit2006/3.

Huh, Y.E., and Kim, S.-H., (2008). *Do early adopters upgrade early? Role of post-adoption behavior in the purchase of next-generation products.* Journal of Business Research 61, pp. 40–46.

Ivkovic, S., and Nehlin, J., (2007). *End user perception of managerial interventions in the later stages of assimilation: A case study of a CRM system implementation process.* (Unpublished master thesis), Lund Univercity.

Jansma, A. P., (2003). *Innovation and diffusion of information technology in non-competitive environments as typified by country and local Governments.* A thesis submitted to the faculty of graduate school of the University of Minnesota in partial fulfillment of the requirement for the degree of Doctor of Philosophy United State: UMI Microform 3078017, ProQuest Information and learning company.

Jen-Chi, H. (1994). *A comparison of construction automation in major constraints and potential techniques for automation in the United state, Japan, and Taiwan.* (unpublished master thesis), Massachusetts Institute of Technology.

Jones, M., and Saad, M. (2003). *Managing innovation in construction*. Landon: Thomas Telford Publishing.

Koskela, L., (1992). *Application of the new production philosophy to construction.* (Center for Integrated Facility Engineering) CIFE Technical Report # 72), Stanford University.

Kurnia, S., and Johnston, R. B., (2000). *The need for a processual view of inter organization system adoption.* Journal of Strategic Information System ,9, 295-319.

Mahabub, R. (2008). *An investigation into the barriers to the Implementation of automation and robotics technologies in construction industry*. (Unpublished PhD thesis), Queensland University of Technology.

Mark, G., and Poltrock, S., (2004). *Groupware adoption in a distributed organization: Transporting and transforming technology through social worlds.* Information and Organization, 14, pp. 297–327.

Mukherjee, S., Shori, T., (2008), *"India Infrastructure and Construction" Lehman Brothers, initiation to coverage sector view, Building Materials & Construction India Infrastructure & Construction.* Global Equity Research, Asia Ex-Japan, page 1-80

Report on robots and automation machines (1998). Robots and automated machines in construction. Publication Committee International association for automation and Robotics in Construction, IAARC.

Report on Indian Infrastructure (2011). *India Infrastructure Report Q1 2011 Including 5-Year Industry*. Business Monitor International, London.

Rick, B., and Gerard de, V. (2002). *Design and construction: Building in value (1st ed.)*. UK: Butterworth-Heinemann.

Rogers, E. M. (1962). *Diffusion of innovation.* New Yark: Free Press.

Sahin, I., (2006). *Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers'theory.* The Turkish Online Journal of Educational Technology, 6521 volume 5 Issue 2, ISSN: 1303.

Sarker, S., Valacich, J.S., and Sarker, S., (2005). *Technology adoption by groups: A valence perspective.* Journal of the Association for Information Systems, 6(2), pp.37-71

Sarosa, S. (2007). *The information technology adoption process within Indonesian small and medium enterprises.* (Unpublished PhD thesis), University of Technology Sydney.

Sebestyan, G. (1998). *Construction: Craft to industry*. London: E & FN Spon.

Tornatzky, L.G., and Fleischer, M. (1990). *The Processes of Technological Innovation*. Lexington Books, Lexington, Massachusetts, 1990. Cited on web http:/Technology-organization-environment framework - Theories Used in IS Research.mht

Van Gassel, F., and Maas, G. (2008). *Mechanizing, robotizing and automating construction process*. In C. Balaguer and M. Abderrahim (Eds), *Robotics and Automation in Construction* (pp. 43-52). Croatia: In-Teh.

Venkatesh, V. and Bala, H. (2008). *Technology Acceptance Model 3 and a Research Agenda on Interventions.* Decision Science, 39 (2), 273-312.

Wu, B. (1996). *Geotechnical design and construction automation in Taiwan.* (Unpublished master thesis), Massachusetts Institute of Technology.

Zaltman, G., Duncan, R., and Holbeck, J. (1973). *Innovations and Organizations*. New York: Wiley & Sons.