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1.1 Introduction to research area

Adoption is defined by various researchers in many ways. Also there are many theories that are used in adoption. These theories include: innovation and diffusion theory; need based theory of adoption; organizational and economic theories of change; actor-network-theory; theory of reasoned action; theory of planned behaviour; decomposed theory of planned behaviour. There are various models developed based on these theories. These models include: Rogers model; Technology acceptance Model (TAM); Technology-Organization-Environment (TOE); Unified Theory of Acceptance and Use of Technology (UTAUT). These models were used by many researchers to develop combined models. (Sarker et al., 2005) developed a model for group adoption; (Huh, and Kim, 2008) considered factors for post adoption. (Gallivan, 2001) observes many limitations of most of basic models; that these models were good in individual adoption however lack in organizational adoption. He considered that organization adoption had many stages. He also considered that whenever there were complex technologies and users had high knowledge burden traditional models were least effective. He also developed a model which showed importance of secondary adoption / assimilation of technology. Hence there are many models in adoption; however these models mainly considered information technology related areas. Adoption model in construction is needed.

1.2 Rationale for proposed research

Construction is an economic sector similar to manufacturing (Sebestyan, 1998). Construction plays an important role in socio-economic development hence requires special attention (Ofori, 1990). (Ngowi et al., 2005) argued that construction industry was not much affected by industrial revolution in 18th century. Many researchers and scholars considered construction as: labour intensive (Hsiao, 1994); dangerous industry, facing labour shortage (Wu, 1996); backward, technologically stagnant.
fragmented, negligible Research and Development (R&D), perceived by customer as slow and costly (Jones, and Saad, 2003); low in co-ordination and communication, unstructured learning process (Cooper et al., 2005); complex products requiring heavy integration; low standardization (Chang, and Lee, 2004); design and assembly of objects fixed-in-place (Ballard, and Howel, 1998).

However many researchers considered that construction had developed much. (Ngowi et al., 2005) considered that construction industry developed from traditional labour intensive to modern methods. This was known as industrialization of construction. Industrialization of construction can be done from: prefabrication and mechanization. Prefabrication was based on industrial manufacturing of building component off site or near site. Mechanization was an important factor in technological advancement of construction. After sufficient mechanization, construction could be done by robots (Ngowi et al., 2005). (Koskela, 1992) observed that construction follows the manufacturing industry. Conversion model worked very well in manufacturing but not in construction. As construction had many flow processes. If these flow processes were neglected in construction, there would be lot of wastage. Hence construction flow must be improved before implementing the development in construction. (Dubois, and Gadde, 2001) observed that construction industry as a whole appears as a loose coupling system. They identified the pattern of coupling in construction industry. This pattern includes: tight coupling embedded in loose coupling in the permanent network of firms and six different aspects of the behaviour of firms are termed as loose coupling. A strong community of practice completed the pattern of couplings. This pattern seemed to favour short term productivity but hamper the innovation and learning. (Dorée, and Holmen, 2004) tried to test the couplings framework’ through a case study. Case study considered Dutch contractor. Contractor had successfully built a series of bridges that shows technical progress. They suggested amendments in frame work proposed by (Dubois, and Gadde, 2001). (Cooper et al., 1998; Cooper et al., 2005; Kagioglou et al., 1998) observed that product development process in manufacturing could be used as reference point for defining and understanding the design and construction process. They developed a process protocol. (Aouad et al., 1999) improved process model that supported the life cycle of construction projects. (Ajamian, and Koen, 2003) argued that Traditional stage-gate\textsuperscript{TM} (SG) considered little uncertainty associated with the technologies. This stage gate was not able to manage high risk technologies during new product development. As per (Ajamian, and Koen, 2003), technology
stage-gate\textsuperscript{TM} (Tech SG) process was needed to manage tech development effects where there were high uncertainty and risk. Main purpose of technology stage gate process was to bring science and business inputs in technology discovery process. It helped to better select and allocate resources and reduce development time in the technology development. Main difference between traditional and tech SG was opaqueness of gates. As in traditional SG these gates were transparent as process was well defined. However in technology SG project team could see only first stage and know probable final outcome. Other stage gates were opaque. Technology team could see other gates also once they would pass through changes in first stage (Ajamian, and Koen, 2003).

Robots are used in various countries as follows: (Feldmann, and Koch, 2000) observed that building industry in Germany had four areas for automation in construction. These areas included: production of building materials; prefabrication; the process at the building site; and supply process of the building. They considered main opportunities for automation as: increase in quality; reduction of costs; improving schedule and humanization. Some of main moderators were lack of mass production; low wage workers; investment; building site conditions; and weather conditions. They tried to experiment with three different degrees of automation. These included: manual, semi automatic and fully automatic system. Results showed that part automation found better choice on today’s building sites. It relieved the user from monotonous activities in construction. It also integrated the worker into the work routine. Economy was improved by: fast specifying the working points; omission of ladder or scaffold; setting of robot removed the use of mechanic and gave highest work accuracy. However there were certain disadvantages as: bringing the heavy devices to working area and high training expenditure for operating robots and high investment costs. For a successful development and use of automation, configuration of the devices was more critical (Feldmann, and Koch, 2000).

(O’Connor et al., 2000) observed that technology was used more during the front end and design phase in United States (US). However during construction management and construction execution, lower use of technology was seen. Hence there was a large scope for improvement through use of technology. As per them infrastructure projects were more variable and involve significant higher level of Integration and Automation (IA) technologies. Small, medium and large projects differed in use of technology (O’Connor et al., 2000). (Haas et al., 2000) observed
importance of foreman in construction project in US. They considered various current practices of foremen level task for automation. These included: interpreting plans and drawing; locating updated drawings; materials, tools, and equipment procurement; time reporting; short interval scheduling. They considered three classes for foreman level task automation. Class 1 included time reporting; accessing other information; communication with others on a project; accessing the latest drawing revisions; and visualizing future and present work through Three-dimensional (3D) drawing. Class 2 included ordering tools; locating tools; locating scaffolding; recording job progress; locating materials and ordering materials. Class 3 included ordering equipment; ordering scaffolding and locating equipment (Haas et al., 2000). (Miroslaw, 2000) tried to consider some of latest development in robotics technologies in US. He argued that population of robots had increased and their application areas were also increased in recent time. New types of devices emerged such as tiny micro robots and robots with multiple arms or legs. He also observed that fear of robot replacing employees also reduced. Employment increased by training people in robotic, research for human robot collaboration interfaces, robot mobility and navigation in unknown surroundings, and better robot intelligence. Robotics applications in the construction industry had been researched, explored and prototyped for the last two decades. He considered main requirements of practical uses of robots in challenging environments such as construction site. These include: ability of robots to move around, sense the environment, process the data and information received and reason based on available information. American laboratories developed some robots such as: All-Terrain Robot Line from I-Robots. It could operate in heavy terrain. I-Robots Inc supplied wireless communication based on R232 standard. They had on board computers, scanners, vision systems, joysticks and navigation sensor for heavy terrain locomotion (Miroslaw, 2000).

(Ting, and Jin, 2000) considered that integrated construction automation processes could solve labour shortage in Singapore. Automation of works of site erecting of prefabricated components would make the construction process more industrialized as a whole. (Gregory, and Ward, 2000) considered that most important factor in robotic implementation in construction was labour response in Singapore. They observed that construction had started using robots since past two decades which gave a new realm of mechanization and management in construction. They argued that in order to identify tasks best suited for automated construction, different levels of automation were important. Each category of robots could be divided based
on complexity as mechanization, robots, mechanized construction system and fully automated construction. Mechanization was the lowest level of robotics and automation. It included tools which were commonly used on project sites. Mechanization often required guidance of human labour and these devices substitute mechanical power for human. The main advantages of mechanized devices were that it reduced the human strain however still needed high level of skill of person. Robot could be an apparatus that could perform part of its entire task without direct human supervision or guidance. Robots might have some laser or other method of tracking used as a guide; they may also include artificial intelligence. Here human effort was required to input information into the apparatus. Guidance might be done physically or through remote control. Supplies for robots task might be loaded individually. Some robots might perform more than one task or may handle variety of materials. Mechanized construction system was one step further than robots. This system referred to a group of robots which performed separate and distinct tasks. However these were integrated or sequent to perform a larger activity. Human workers were still required to complete construction. They were helped by a number of robots rather than one designed for a single task. But it was more costly, and required more maintenance. Fully automated construction was still in research level. In this level no human workers were required. Fully automated construction sites would be arranged like travelling manufacturing plants. It required a higher level of consistency of surroundings. This could be more used when construction was done within a structural box (Gregory, and Ward, 2000).

(Wang, and Su, 2000) observed that government of Taiwan was interested in automation and planned a long term plan. This plan provided guidance for the automation of various industries including construction. Plan of government included: investing more money; adopting tax reduction and interest subsidy of loan. They observed that large construction firms were more willing to adopt new construction automating techniques and equipments. They suggested that automation could be used more effectively if top firms were encouraged to use the construction automation. If small or medium constructors could merge or strategically join together to become bigger ones the benefits of using automation and information technologies could be more evidential (Wang, and Su, 2000).

(Hasegawa, 2000) considered various Japanese research projects on automation in construction. These included: Automated weather-unaffected building
construction system; unmanned tele-earthwork system; automated tunnel construction system. He observed that the research was done in automation of construction work since 1980. Results are not fully achieved due to lacking in research theme. He suggested solutions included: conceptual change of construction; rationalization of the construction industrial structure; full scale utilization of new advanced technologies. Conceptual change in construction work included changing the image of construction as site work only. Rationalizing of the industry can be done by integrating planning, design, fabrication and assembly process. Rationalization of construction industry structure was done through technological progress in sub contractors. In full scale utilization of new advanced technologies included use of Information Technology (IT), Global Positioning System (GPS), Computer Aided Drawing/design (CAD) etc. in construction industry (Hasegawa, 2000). (Kaneta et al., 2000) argued that PM / CM (project management / construction management) replaced previous procurement methods in Japan. They argued that Japanese construction industry valued efficiency so as to reduce competition and protect Japanese market. However the traditional system was not effective in era of international exchange and information technology. New technologies like robotics were neglected by traditional firms (Kaneta et al., 2000).

(Balaguer, 2000) consider house-building construction like bricklaying robots and modular assembly robots in European Union (EU). He also tried to find future possibilities of massive introduction of automation. He observed that brick laying robot were precise and suitable for heavy duty. However, very small numbers was sold due to three main barriers. These barriers included: high cost; high sophistication of the robot control system; necessary of using special parts, and materials. As per him modular houses reduced the assembly time and transportation costs. However use of conventional cranes for assembly would reduce the advantages. It could be improved by using modular house assembly robots. These robots may also have many barriers. These barriers included: standardization of the modules connectors; manufacturing tolerances of modules; modification of cranes control (Balaguer, 2000).

(Deb, 2008) considered that though India had scientific temperament, she failed to catch-up the progress from industrial revolution. India started using numerically controlled machines and computer controlled machines in both public and private sectors during seventies. In the next decade new manufacturing
technologies like CAD, Computer Aided Manufacturing (CAM) and Flexible Manufacturing Systems (FMS) along with robotics were developed with help of various universities. Production Engineering Department at Jadavpur University had automation and robotics laboratory. Institution of Engineers, Calcutta organized first National conference of production engineers on robotics and robot application. Bhaba atomic research centre also developed a 6 axis multipurpose robot in 1984. This robot weighed 300 kg and could move 10 Kg load. However there was very little development of automation in construction (Deb, 2008).

During 12th five year plan total investment in infrastructure is US$1trillion (Rs. 50trillion) (Valecha, and Arora 2012). (Faridi and Basistha 2012) considered that Indian economy is expected to grow @ 8.2% during 2011-12. Based on projected Gross Domestic Product (GDP) a $1300billion is planned in various infrastructure sectors during a span of 8-10 years. Distribution of this investment is as: railways ($165billion); road ($150billion); mining ($70billion); thermal power ($50billion); hydropower ($15billion); airport (445billion), seaport ($25billion) and urban infrastructure ($780billion). As per them market value of equipment is over $6.5billion during 2014. Similarly as per (Report on construction equipment 2012) expected construction equipment market in 2016 may reach US$10billion from US$4billion in 2011. Growth of market is 20% annually. As per (Mukherjee, and Shori, 2008) revenue growth of infrastructure construction firms lacks order book growth. That indicates that execution cycle is getting longer (Mukherjee, and Shori, 2008). Main weaknesses in Indian infrastructure firms observed by (Report on India Infrastructure, 2010) are: low level of domestic expertise; shortage of skilled labour; low mechanization and limited use of modern technological equipment. (Mukherjee, and Shori, 2008) observed that complexity in the construction sector is rising and project sizes are increasing; industry has significant increase in employee costs due to manpower requirements and rising wages. Construction companies are getting more capital intensive and prefer to own their equipment rather than rent or lease (Mukherjee, and Shori, 2008).

Robots were developed in many areas like demolition; earthwork; bridge work; road work; tunnelling; under water works; trenches and piping; maintenance; material management etc (Report on robots and automated machine, 1998). Many researchers had considered various perceived benefits of automation as productivity increase, quality improvement, work / labour saving (Hsiao, 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. The benefits of automation on one hand and lack of research on other hand motivated researcher to explore the adoption process of automation in India.

1.3 Geographical coverage of research

Mumbai and Pune are the two most industrialized cites in Maharashtra; both the cities had grown in infrastructure. Researcher is resident in Pune hence it is convenient for him. Also both Mumbai and Pune are well connected through roads and other transportation systems. Hence in proposed study these two are selected. This will help in many ways as it save time, cost and energy of the research.

1.4 Research aims and objectives

This research is aimed to help adopting firm, supplier firm and beneficiary (ultimate customer/ client). Since this study provide a proper adoption process in infrastructure construction industry, adopting firm will be benefited by knowing requirements of adoption process. They will fix their problems through technology adoption. They also get a view what changes are required in firms to adopt high technology automation products. After adoption adopting firm will take advantage of higher productivity, labour saving, and improvement in company image, higher competitiveness etc. Supplier firm will also be benefited as they get a deep view for the needs of customer firms. Beneficiary will have advantage of good quality, more safety, saving in cost and time.

Hence in this study following research objectives are considered:

1. To study current status of use of automation in infrastructure construction in India
2. To study various strategies for adopting robots in construction in India
3. To develop various measures for various stages of adoption i.e. primary adoption; secondary adoption and post adoption
4. How high technology automation products (robots) can be adopted in its various stages like manually controlled machine, tele-controlled machine, computer controlled machine and cognitive robots?

1.5 Chapterization scheme

Chapter two shows a detailed literature review. This chapter stars with defining various areas. These included: adoption, high technology, automation, proposed definition of high technology automation product, and robots. A detail literature review is made of high technology industry characteristics and its need of development and factors influencing. Chapter also considered automation in construction and its advantages. A list of use of robots in various infrastructure constructions is considered. Chapter showed various theories and models that are used in adoption. These included basic models and combined models also. Chapter also showed various areas and products covered by these models. Lastly, the chapter identified the research gap.

Chapter three is regarding research methodology. Chapter begins with research approach used for current study. A proposed model for adoption of high technology products is considered. Chapter also shows research questions and hypotheses. Chapter included a detail of measurement model. This model shows all stages details along with factors and their measures. A sampling design is considered in chapter. This included: universe, sampling frame, sampling unit, size of sample, sample details, sampling procedure. Chapter also included details for primary data collection. It included: instrument used, its development, and pilot testing. Chapter also shows data collection method details, statistical test conducted and various tools/software that were used for data analysis.

Chapter four is regarding data analysis. Chapter begins with data screening. Chapter considered development of measurement for various stages. Initially first order reflective measures are developed. These measures are tested for reliability, various validities and model fit. Second order formative measures are developed by using these first order reflective measures. Chapter showed detail testing of hypothesis. Chapter also considered details of current status of automation in construction in India along with various strategies/drivers for adoption of robots in construction in India.
Chapter five is conclusion and recommendation. This chapter shows interpretation of results of data analysis. This chapter also showed various recommendations for future studies.

Chapter six includes all the references used in the study.

Chapter seven includes appendix which includes SPSS abbreviated codes details and various questionnaire used.