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Chandran Rekha Jetty
MSRIT Bangalore, India, architect.solution@gmail.com

VENKATA SUBRAMANI
MSRIT Bangalore, India, Rvs_vlb@yahoo.com

INNOVATION MANAGEMENT IN ARCHITECTURE ENGINEERING AND CONSTRUCTION INDUSTRY (INNOVATION CHARACTERISTICS AND DIFFUSION)

[1]CHANDRAN REKHA JETTY & [2]VENKATASUBRAMANI

[1] Scholar Anna University, Coimbatore, School of Architecture, MSRIT Bangalore, India
[2]VLB Janakiammbal College of Engg. and Tech. Coimbatore, India
E-mail: architect.solution@gmail.com, Rvs_vlb@yahoo.com

Abstract—In AEC industry the success of technological developments in uptake and usage can be improved if the conditions of innovation diffusion within project organizations, parent organizations, matching of technological innovation with the perceived needs and preparedness for change on the part of the industry and the broader AEC industry are better understood and brought into play. This paper shall provide an overall snapshot & supposition of how AEC industry today approaches to innovation in design with respect to architectural, structural, and services; innovative use of it in design & construction; construction methods & processes, procurement methods, construction technologies; modern & innovative approaches to collaborative working, project delivery, facilities management, construction and project management, information & knowledge management; novel construction planning & scheduling methods; theoretical, conceptual, organizational & human aspects of innovation in AEC industry.

Keywords- *AEC: architectural engineering and construction*

I. INTRODUCTION: AEC INDUSTRY

Every AEC project is by definition an innovation project initiated by the demands of the client. Every new AEC project has its specific new requirements depending on the demands etc. Existing knowledge, technical and other, is combined to form something new. This is exactly the definition of architectural innovations. The problem in the AEC process is that it is far from being an optimal innovation process. The total working and environmental cultures are very different and constitute radically different climates for innovation. This exploratory research is carried out based on semi-structured interviews with practitioners from many sectors and interpretations of innovation are found to be dramatically different between others and AEC. Unlike Engineering sector AEC sector emphasizes on process innovations than technical. The traditional outlook and repetition of same innovations continue to persist. On exploring the source of the innovation beginning with creation, implementation, characteristics of innovation, and relevance of context for innovation it is found that there exists a dichotomy between the different industrial contexts for innovation, based on the technology available.

Pattern of 'widening' is seen in Indian AEC industry, where small new firms with its low barriers to entry, project-by-project timeframes and plethora enter the industry and disrupt the established models of production, wiping out the profits associated with previous innovations. By accessing the degree of

Technological innovation the AEC industry would house, create conditions that allow for frequent innovations in AEC products, design, manufacturing and production to increase the value of the product to the client; Innovations leading to newer technologies must lead to innovative design solutions with new perspective of managing both innovative technologies and connected innovative design solutions.

II. INNOVATION AND INNOVATION MANAGEMENT IN AEC INDUSTRY

It is different from invention as an invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice. Innovation requires set of theories and processes. The innovation process is starting from the array of sources and leading to the benefits of innovation while taking into consideration the constraints. To do this we require innovation management, which are the set of systematic processes that organizations use to develop new and improved products, services and business processes. It involves harnessing the creative ideas of an organization's employees by creating the right culture for innovation, soliciting and encouraging employees' submission of ideas, and developing new products and solutions.

Innovation management is the intermediate stage between the knowledge management and the intellectual property management stages, where the resources are processed into marketable products. We require a new theory of Innovation; it's relation to creativity and its management. Innovation is not just R&D. It involves successful exploitation of new ideas that involve design, marketing, brand development and many other factors. New ideas and concepts come

from sources like patents, customers, staff, designers, academics, competitors, other markets and even nature. Innovation involves novelty, risk, experimentation and failure. Key to innovation process is "management of all these factors". Successful exploitation involves useful ideas through to development and implementation. Although during innovation process many stray ideas are parked or let go, some fail implementation. Innovation process is a continual dynamic process where ideas are transformed into value. Innovation is also defined as 'the effective generation and implementation of a new idea which enhances overall organizational performance'. Implementation is primary to Innovation. Merely being creative, developing and producing ideas, processes, services or products is not sufficient. At implementation stage AEC industry is generally tardy in adopting new ideas. The construction industry is basically conservative in its approach to innovation. Due to many reasons, new ideas must exhibit substantial advantage before they are accepted for implementation. Competitive or adversarial forms of procurement result in parts of industry lead proactive demand for innovation, where others reactively supply innovation, but this is unsustainable where short-term goals/responses can preclude development of a long-term innovation strategy. R&D in AEC industry has relatively low profile lacking serious continual investments (0.75 of the value of total output of the industry) and preventing take-up of innovation. Research and development in management innovations such as partnering, highlighted in the recent report 'Rethinking Construction', and its forerunner 'Constructing the Team', indicate how non-adversarial, long-term strategies can be of use.

III. FACTORS THAT AFFECT AEC INNOVATON

The construction industry in most countries is dominated by a large number of very small participants, who have limited resources to undertake innovation (McFallan, 2002). This sort of industry structure requires the existence of strong industry relationships if innovation opportunities are to be maximized

AEC industry innovates for client but if the client does not want innovation in their product, the industry will not push for it that besides government policies affect innovation. For example, garbage disposal mechanisms, environment controls like noise and dust pollutions etc., these have promoted ancillary and subsidiary industries to AEC core industry. Variables such as organizational size, structure, culture and attitude to innovation all have a significant impact. In addition, top-level encouragement is generally lacking for successful implementation of new practices besides the inhibitors of innovation like "fear of unknown and territorialism", "not invented here syndrome" unlike other industries whose inhibitors/enhancers both are instability, size, current technology, organizational culture, legal and business laws, budgets, and time. Interesting, even with "unstable climate of the sector" the inhibitors are not "instability". For AEC, instability is stability (right environment). Large organizations have greater pool of people for innovation. AEC seeks blame-free culture, Managerial and organizational to foster and promote innovations. AEC industries stress on the impact of innovation on environment as being very high. Innovations are brand builders of any organizations products and image.

Traditional approaches to the management of construction projects have also been criticized as tending to dampen conditions for innovation. Koskela and Vrijhoef (2001) seek complete revision of the theory of construction management, which they see as currently deficient. A number of researchers have elaborated on the problems caused by traditional management approaches. Winch (2000) has suggested that the allocation of hierarchical roles has important consequences for innovation.

Conservatism in Indian AEC industry can foster an unwillingness to innovate or implement "change". This unfortunate trend could be due to imbalance between the perceived value of innovation and the changing priorities of stakeholders specially those who are interested in the process/outcome during design and construction programme. It is therefore necessary to assess and ascertain the role and importance of innovation in relation to its 'value' in Indian AEC industry. Stakeholders' perception on value of innovation change over time. This variability implies that innovation restricted to a few particular work-stages may discount the influence of adjacent activities. The national initiative to understand how innovation actually takes place in the AEC industry is lacking by rising question to stakeholders about their role in the decision to innovate and whether their perception on innovation is withstood or accepted by the industry. This generic information is vital in providing an informative contextual study of how the AEC industry innovates currently and a framework within which further studies of innovation in particular sectors of the industry can be carried out on which are based the innovation management decisions.

IV. CONSTRUCTION PROCESS CHARACTERISTICS

Construction process literature shows that (i) the industry is fragmented & (ii) there are limited contacts between the various professional networks in the building projects. (iii) the Project contacts are short-term oriented.

(i) **F**ragmented: There are many relatively small companies in AECI. In India, almost 90% of all building companies have no more than 8-10 employees, @10% of the companies are medium-sized firms (10-100) employees. Thus, fragmentation and especially the segregation of design and construction activities are the main barriers to an improved performance of the industry and innovations.

(ii) **P**roject-based contacts: On studying the operations and behaviors of firms as a means to dealing with complexity. Industry as a whole is featured as a loosely coupled system. The pattern of couplings builds on two interdependent layers: tight couplings in individual projects & loose couplings based on collective adaptations in the permanent network. Thus, the characteristics of the industry seem to favor short term productivity while hampering innovation & learning. The survey revealed that one of the prime factors hampering the diffusion of innovation in the housing industry is the lack of information transfer between projects. This information transfer must be based on unambiguous evaluations and an innovation champion is needed in order to implement the innovation successfully.

(iii) **S**hort term orientation: Vrijhoef en Koskela (2000) characterize the construction process as short term oriented. Unlike manufacturing, the `construction factory' is set up around the single product. Therefore every project creates a new product or prototype with little repetition. As a result, the construction supply chain is typified by short term organizations, instability, fragmentation, and especially by the separation between the design and the construction of the built object. Kumaraswamy (1998), wonders why the construction industry's short-term orientation did not lead to innovative managerial techniques.

***K**ey innovations actors:* Seaden and Manseau (2001) defined ten key actor types involved in construction who can undertake innovation activities: a) Building materials producers, b) Machinery manufacturers, c) Building product component manufacturers, d) Sub-assemblers (trade specialty and installers), e) Developers & facility assemblers (or main contractors), f) Facility/building operators who manage property services & maintenance, g) Architects & specifiers, h) Consultants & engineers, i) Providers of complementary goods & services such as transportation, distribution, cleaning, j) demolition & disposal. K) Institutional environment actors such as financial institutions and business/trade general labour regulations and standards.

Vrijhoef and Koskela (Vrijhoef and Koskela 2000) drew a supply chain based on a traditional construction supply chain with two more key actors: a) Residents, b) Principals. The total of different types of actors in the construction industry added up twelve. The characteristics mentioned so far specifically describe the traditional construction process. Since the 1990's several alternatives to the traditional construction process are in market (Briscoe and Dainty 2005): design & build contract, the private finance initiative, public private partnership, build, own, operate & transfer

V. INNOVATION DIFFUSION

Much literature on technical change and innovation focuses on creation & development, but it is not until it is used that any real gain is achieved (Stoneman, 2001, Hall, 2005). Diffusion is the process by which the innovation is communicated & spread over time among the members of a social system (Rogers, 2003). The diffusion of innovations have been studied from various perspectives: historical, sociological, economic and network theoretical (Hall, 2005). There are different models for analysing diffusion patterns Stoneman (2001), Tidd et al. (2001) and Rogers (2003).

The models aim to analyse and explain different perspectives of the diffusion process. Throughout the models' development, some common areas of importance for the diffusion process have emerged (Stoneman,2001): learning & information spreading; cost of acquiring new technologies & changes therein; performance of new technologies & changes therein; price expectations & change therein; technology expectations & changes therein; firm characteristics & their distributions; discount factors & attitude to risk; extent of product differentiation & changes therein; extent of first mover advantage & the economic return being an early adopter; impact of other firm's adoption upon users' & non-users' profits; extent to which realized profits generate new investments. One diffusion model is used to study the social networks in which the innovation (and diffusion) takes place.

The main reason is that diffusion occurs within a social system or network. Increased interaction around an innovation in a social network increase the rate of diffusion (Deroïan, 2002, Pittaway et al., 2004). The diffusion is affected by the structure of interaction, the existence of opinion leaders and change agents. The most prominent characteristic of opinion leaders is that they are more exposed to external communication. Change agents are often professionals with a technical degree from a university (Rogers, 2003). In some areas, professional institutions or associations act as independent change agents - so called innovation brokers (Winch, 1998).

The success of technological developments, in terms of uptake and usage, can be improved if the conditions of innovation diffusion within project organizations, parent organizations, and the broader AEC industry are better understood and brought into play. This includes the matching of technological innovation with the perceived needs and preparedness for change on the part of the industry. There is a unique and 'deeply embedded' culture of today's AEC industry and is endowed with its inherent resistance to

change. AEC industry's today necessarily must be able to change its existing culture.

Four factors influence diffusion of innovation: the innovation itself; communication channels; time; and the social system. Creation, exploitation and successful implementations of innovation along the supply chain partners of AEC industry in terms of design, materials and construction all are equally important. Time required for diffusion depends on individual's acceptance or rejection of an innovation, rate of adoption both by system and individual. In contrast with other Engineering industries, AEC is characterized by shorter project time frames with very limited time to evaluate innovations, this result into fewer innovations and more failures, this does not promote attitude to future innovations. Diffusion also depends on social system that includes structure, norms, and the presence of influential individuals and a champion to ensure and facilitate diffusion since their ideas are quickly disseminated, enabling swifter diffusion of innovations, in turn allowing for the creation and development of further innovations. But, AEC initiatives result in feeling of Saturation thus the innovations are slow to catch on and generally ignored because it is not viewed as an innovative sector and this creates a problem for future innovations: the cycle is perpetuated. Even large volume of initiatives, result in marginal implementation. This affect is cascaded by the varying degrees of consolidation and fragmentation within the industries. In AEC, incremental innovations are not only common, but are also viewed equally important as radical innovations. This is partly due to rarity of radical innovations and the belief that culture change occurs through small-scale changes. Poor communication attributes to poor innovation diffusion within their companies. There exists significant gap between top-down encouragement, recognition of innovations, and the actual implementation of them throughout the company.

VI. INNOVATION AND PERFORMANCE IMPROVEMENT IN AEC INDUSTRY

Managing innovations efficiently and effectively along PDLC, supply chain and knowledge chain of the AEC industry synonymously increases productivity and paves way for newer innovations. There is a never-ending demand for performance improvement in the building industry. This imposes the need for better AEC professionals & effective innovation management. The busy practitioners take in and convert the information from contracts, plans, specifications, catalogues, research reports, websites etc. into knowledge when they are obliged – by contract or by law – to do so. The other way is to learn how the new practices make their life easier. Information and knowledge management is a prerequisite for performance improvements. We need to understand the current situation in order to propose better performance, and to convert effectively and efficiently information into knowledge in real building projects. Challenges of innovation, information Knowledge creation and knowledge transfer need to be addressed.

VII. CASE STUDY

The case study of the AEC industry revealed that, the definition of Innovation is understood differently by different organizations. The organizational, technical, technological processes, all are continually subjected to small scale minor to major changes that makes the distinction blur between "incremental innovation and continual improvement". If both are same then how should both be managed so as to make the organization as a whole "innovative". The terms inventions, innovations, knowledge creation, continuous improvement and continual changes are generalized with same meaning even when they are different. Innovation has more of marketing base than any other terminologies. Generally technical-radical innovations are favored. We see each day so many innovative AEC products but generally the Process innovation is favored against product innovation. Thus, there is apparent bias towards technical innovations is perhaps partly responsible for the noticeable divide between the supposedly 'innovative' industries, such as Electronics, IT etc, and supposedly 'less sophisticated' sectors such as AEC, where the opportunities for product innovation are very limited. Generally the context dictates innovation. The reality is much more complex with this unsolved dichotomy that will ensure the perceptions of technologically sophisticated IT sector and the "still primitive" AEC sector to continue to remain same.

VIII. CHALLENGES BEFORE AEC INDUSTRY

The challenges are the intense competition, increased pressures on style, delivery and price from owners, stringent regulatory standards. The questions are: Can they deliver a structure or building that brings lifetime values to the owners? Are they adopting new technologies fast enough? Are they able to accelerate market-driven innovations through integrated Product Development Life Cycle Management solutions?

IX. ICT & INNOVATION

Future development in AEC industry is dependent on determining new and improved ways of doing the business through the usage of ICT and Knowledge diffusion and Knowledge Transfer to all stakeholders in the AEC supply chain. Industry must rise above "mere familiarization" to "innovative user" of the tools and current systems besides technology itself. The successful implementation of ICT requires careful consideration to the 'human touch'. Therefore, it is necessary for AEC industry to use the best digital technologies to tackle the toughest design and construction projects. Firms such as Gehry Partners, Farnham and Pfile, and many others rely on our solutions to make their imagination a reality, on time and on budget. BIM and PDLCM solution lets clients see their facilities at different stages of completion thereby enabling AEC industry to complete projects

on schedule and at budget, regardless of the complexity.

X. AREAS, TYPES AND CLASSIFICATION OF INNOVATION IN AEC INDUSTRY

Areas of Innovation are: design (architectural, structural, services, etc.), Innovative construction methods and processes, procurement methods, construction technologies, approaches to collaborative working, approaches to project delivery, Modern approaches to information and knowledge management, Approaches to Facilities Management, Approaches to Construction/Project Management, Use of IT in Design and Construction, Theoretical and Conceptual Aspects of Innovation, Organizational/human aspects of innovation in construction, Novel construction planning and scheduling methods. Innovation in the AEC industry has been categorized as "Product innovation" (development of construction materials or components); "Process innovation" (management of design and operations); "Service/procurement innovation" (advances in customer care, partnering etc.); "Information innovation" (IT, new methods of capturing, and/or using expertise or experience); "Technology transfer innovation" (new methods of sharing and/or exchanging developments). Importance level attributed to every type of innovation is dependent on individual circumstances of a design or construction problem. The stakeholders involved in the decision to innovate are architects, clients (and their agents), construction managers, engineers, facilities managers, main contractors, manufacturers/suppliers, quantity surveyors, and specialist sub-contractors/trade contractors.

Innovation ranges from incremental to radical. IT sector tends to consider radical innovations to be the most significant, whilst AEC relies more on incremental innovation to assist cultural change. Incremental innovations are those small-scale changes are carried out based on current knowledge. Impact of incremental innovations is marginal, minimal and predictable. They generally originate from within the organization may be partly due to customer feedback and others. Radical innovations are characterized by breakthroughs, large-scale change, unpredictable in appearance and impact with "out of box" thinking other originating from outside the current industry. They provide a new way of understanding the phenomenon and formulating approaches to problem solving and decision making. The scale of radical innovations means they are rare often resulting in patents, and by their very nature they frequently result in significant change.

XI. CONCLUSION

Visualization and Imagination has always been the force that fuels the Architecture, Engineering and Construction industry but imagination alone is not enough. Every great architect knows it takes more than imagination to create an architectural marvel. Structures and buildings must be functional and able to withstand loads coming from occupants, equipment, wind or earthquakes. They also have to be delivered to the owners on schedule. In an industry where 80% of the projects are over budget, AEC firms must find new way to manage their projects. To accelerate **market-driven innovations** they must rely more and more on BIM (Building Information Management) and PDLCM (Product development Life Cycle Management) solutions governed by AEC processes and address their challenges.

AEC firms must develop BIM and PDLCM solutions unique and customized to their culture, and that of the supply chain partners to ensure 1) That the innovation is managed all through the PDLC, by all stakeholders and supply chain partners. 2) Encourage their suppliers to increase engineering innovation while streamlining design-to-construction process across distributed teams. 3) Built on the same advanced technologies that have revolutionized Industrial Engineering Industries. Solutions must help customers advance the pursuit of innovation in AECI by integrating business process management with cutting-edge tools for design, engineering and construction planning. **T**he importance of fostering innovative practice in AECI has been widely acknowledged.

The optimum way of encouraging innovation is, however, likely to vary with the industry sector being considered and the uptake of any innovations is also likely to be variable. Despite the variability in innovation performance between the industry sectors, recurring patterns do indicate common ground among those organisations regarded as successful innovators.

The identification of the strategies already in use among high innovators is an aid in lifting the performance of the AECI in general. Survey results lead to several indicative strategies for the improvement of innovation performance in the various sectors of the Indian AECI. These are particularly useful for those sectors currently lagging in innovation performance. Contractors, suppliers and others who wish to improve their innovation performance may benefit from following some of the practices shown by the survey to be already in place in high innovator groups. These include: a) Raising general organizational skill levels with employee training programs and through the recruitment of new graduates; b) Maintaining a strong focus on profitability and therefore enabling an atmosphere where innovative activity can thrive; c) Actively monitoring developments within the industry at the appropriate level, locally and/or internationally; d) Having formal systems in place to capture project based learning's for ongoing use within the AECI; e) Providing a supportive atmosphere for staff who generate new ideas; f) Putting in place formal evaluation procedures to gauge the success of advanced technologies and practices as well as any negative repercussions they may have; g) Increasing both direct and indirect investment in Innovations and R&D; (h) Fostering linkages with research institutions and universities supportive to AECI-industrial innovations & research; (i) Adopting a broad range of technology, knowledge and human resources

strategies; and (j) Surveying a wide spectrum of sources of innovation ideas. The adoption of such innovative strategies needs to penetrate to all levels of the industry if the effect is to be significant and lasting.

Government agencies must gear up to assist in fostering the innovation process. By acting through the medium of industry associations they can assist skill development. This would be particularly being useful because low innovator groups among supply chain partners are largely dependent on trade and industry associations for new ideas. Greater resourcing of education and training is also likely to assist in lifting innovation performance given the strong association between the spectrum of knowledge sources used and level of innovation performance. More effective targeting of tax and other measures to encourage R&D and innovations are indicated as requiring attention, given the current low uptake of these schemes in the AECI.

The primacy of general industry profitability in producing an atmosphere conducive to innovative practice IS far above to AECI. Sectors of the industry where financial security is least reliable are least likely to innovate or to create high level innovations, due to the risk of constrained resources tending to result in defensive practices and risk aversion. This in turn leads to an avoidance of new ideas and a stubborn adherence to current practice, therefore well-placed confidence in the success and security of AECI is seen as a prerequisite for innovative practice. Continued industry profitability, equitable distribution of the gains made through innovation and a regulatory system which allows for new solutions are all significant factors in the creation of an 'innovation-friendliness' in all sectors of AECI.

The nature of product and service innovation is evolving to reflect greater speed, interactivity throughout the process, and increasingly involves softer organizational and knowledge-based capabilities as well as hard technological issues. Consideration should be given to these changes in assistance service design and offering. **E**very firm that is part of AECI should have a strategic orientation toward innovation to ensure long-term survival in the global economy. **I**nnovation does not need to occur in an ad-hoc manner. AECI-SMEs may move toward planned processes that encourage innovation.

Look to various sources of information for ideas—inside and outside the company, locally and across the globe. One source of innovation is direct observation of how current, potential, or "expert" customers use or could use the product. Particular notice should be made of solutions to problems that customers may have with the product or with components/parts or processes linked to the building materials and products. So is with suppliers. Material Manufacturers claim success with hosting groups of customers or suppliers to provide input for future product and service innovations in AECI.

For AECI-SMEs that do not offer products or manufacture relatively low-cost building/Architectural and Construction materials, consideration should go toward how the capability or part can be moved up the value chain and become more complex or more integrated into the core technology of the end product (buildings and built environment). Creating a collaborative and integrated network of firms/organizations with different capabilities can help the development of new building/Architectural and Construction products as a single enterprise may not possess all the necessary resources and expertise.

Innovation in any product and service industry will inevitably require "soft" changes to organization. Attention should be paid to the role of human resources in the encouragement and fostering of innovation. New ideas often come from new hires with expertise in other industries. It is therefore important to pair the internal innovator with a process manager that has a track record of successful new idea introductions to move the innovation forward; the venture world has found that inventors do not always make the best business managers. **N**ew sources of innovation can be found in developments in informatics, in R&D-intensive areas such as nanotechnology, Sustainable Technologies, and in high value niches in recreation, lifestyle, built environment, and societal issues such as energy.

Innovation can involve the need for resources not directly devoted to Construction/production to finance it and the development or acquisition of new administrative capabilities such as intellectual property management or risk analysis. Emphasis should be placed on mitigation of these costs through government grants and program, university partnerships, state R&D programs, ventures with suppliers or customers, industry consortia and public-private participations. Assistance with initiation of basic planning of innovation processes. **A**ssistance with intellectual property issues through mechanisms such as preliminary searching of patent databases and matching with legal resources. **A**ssistance linking SME with universities and other innovation resources. **O**rganizational capability to develop, broker, and support multi-firm building product development networks. **F**acilitation of customer and supplier innovation sessions. **M**atching services linking company R&D efforts with grants or other financial resources. **F**inancial modeling capability to support company product and service innovation decisions.

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