

THE INTRODUCTION AND MANAGEMENT OF INNOVATIVE CONSTRUCTION PROCESSES AND PRODUCTS

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To gain competitive advantage, companies have to innovate and improve continuously. Exploiting innovative products and processes requires effective management. Construction organisations should exhibit specific characteristics to stimulate new technology and to overcome the expected barriers to innovation. This paper draws together several aspects of the management and introduction of innovative processes and products within a quality management framework. The implementation of innovation requires rational decision making when considering a company's projects and the uncertainties inherent in innovation. This may be aided by a decision system which simulates the benefits of short-term flexibility and efficiency for project based work to verify long-term performance and to achieve the desired step changes.

Keywords: Construction technology, decision system, innovation.

INTRODUCTION

Evolution is a natural process - any industrial sector will suffer if it fails to develop and change. The development of technological innovations can be used to obtain a competitive advantage, pursue new markets and improve productivity (Yates 1994). Innovative technology carries considerable unknown risks and creates a greater need for co-operation among businesses, government and individuals. Todd (1996) reported that managing technological change and the resulting challenges to strategic, economic, financial, material and human resource management, constitute management objectives. According to Noori (1990), the management of new technology should link engineering, science and management to address the planning, development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organisation. The acceptance of any innovation in construction often only comes after very significant advantages of this innovation on several projects, MacLeod (1998). This paper reviews the innovation framework and suggests the need to simulate its implementation required to construction step changes.

DEFINITIONS

The term 'innovation' has a number of related meanings. It is defined as 'the introduction of something new' or 'a new idea or device', Arditi (1997). Laborde

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(1994) defined “New technology” as a product or process that a company has not previously used in their construction operations. “Innovation” is therefore seeking, recognising and implementing a new technology to improve the functions a company performs. What may be considered as a new technology to one company, may not be to another. Conversely, invention is the process by which a new idea is discovered or created. Creativity forms something from nothing while innovation shapes that something into products and services, Farid (1993). ‘*Process innovations*’ are advances in technology that enable a greater output per unit of input, or as defined by Tatum (1989a), they are improvements in construction methods designed to accomplish usual construction operations or to improve the efficiency of a standard operation. These contrast with product innovations, which result in a qualitatively superior product. ‘*Product innovation*’ is the new idea which turns into a new component of a constructed product that has economic, functional, or technological value, Nam (1989). Simply, innovation takes place when a new approach replaces a set pattern of traditional and accepted processes or products.

There are three groups of innovation: incremental innovations, radical innovations and revolutionary innovations. Arditi (1997) reported that incremental innovations are the gradual processes which steadily improve products and/or processes. Radical innovations introduce totally new products or processes, whereas revolutionary innovations cause significant economic changes. Incremental innovations are much more common than radical and revolutionary innovations. Innovations may be caused by the incremental nature of innovations that take place in feeder industries, such as the construction equipment industry. It has been argued that competitive performance depends not simply on success with a single innovation, but success with a sequence of innovations and post-innovation improvements. This approach involves a shift in perspective - from treating innovations as isolated, discrete events - to treating them as an evolving flow of developments in a technological agenda, Arditi (1997).

INNOVATIVE CONSTRUCTION APPLICATIONS

Pries (1995) recorded 290 innovations in the building industry, analysed from publications of two Dutch professional journals that investigated the level of innovation in the construction industry during the period 1945-1992. The majority of innovations which emerged were included in the smaller enterprises (approximately 75 per cent). Smaller enterprises were more often involved in process innovation and the larger firms in product innovation. The results show that incremental innovations are most common. Innovative construction applications could be classified as follows:

1. Design innovations such as a ‘High-Strength Concrete’ project with non-standard structural design, Nam (1991). In this project, the long-term working relationship between the project partners fostered innovation and the building regulatory officials contributed as members of the design team.
2. Construction method innovations such as using up/down construction (which allows superstructure and substructure work to progress concurrently), Tatum (1989 a). Another example is that of a tall building project, Cushman (1992), in which technology was transferred from one area (non-seismic zone) to another (high seismic zone). These examples show how companies require ‘specific mechanisms’ to transfer any successful results of an innovation to other projects and the need to overcome the barrier of traditional procurement to innovation.

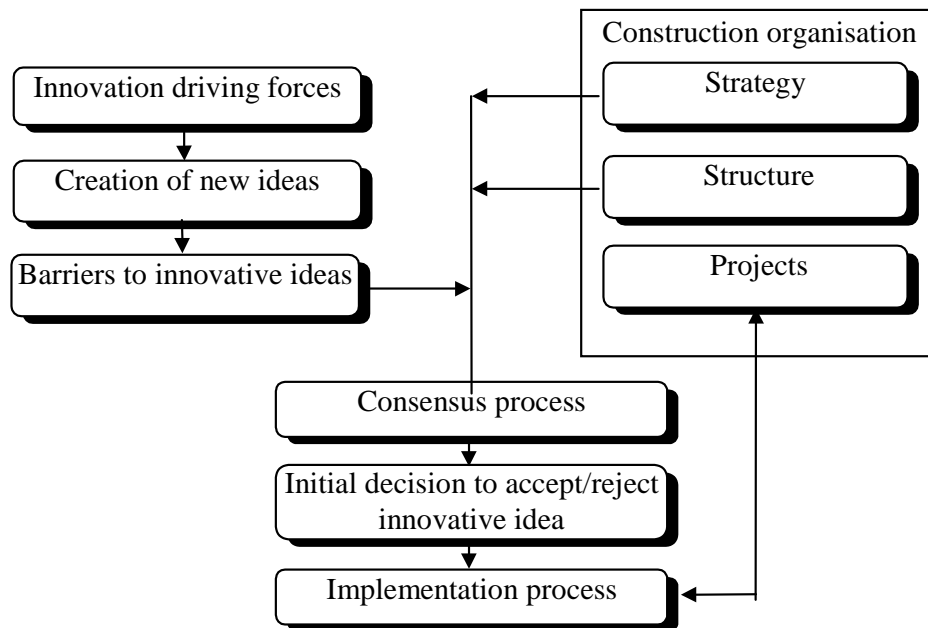


Figure 1: The dynamic framework of innovative construction organisation

3. Technology or equipment innovations such as upgrading existing computer aided design and computer integrated engineering systems, Hansen (1996). This study highlighted opportunities to innovate when there is no apparent problem. Successful innovation requires a long-term view of markets. The companies concerned funded their upgrades from on-going or committed projects when performance was slightly above target by using slack resources. Arditi (1997) reported an increase in the rate of innovation in construction equipment over the last 30-years despite a continuous and moderate decrease in technological life. This supports the concept of market driven incremental innovations.

INNOVATION PROCESS

For innovation to take place, an environment that stimulates new ideas must be created, and this remains the responsibility of management. Tatum (1987) reported that the characteristics of innovative processes are chaotic, individually motivated, opportunistic, customer-responsive, tumultuous and interactive during development.

Several models have been developed to represent the innovation process: Tatum (1987) and Tatum (1989 b), De La Garza (1991), Laborde and Sanvido (1994), Boles (1995), Kraft (1997) and MacLeod (1998). The process can be represented by a sequence phases with interrelations among them (see figure 1). Detailed descriptions for this framework are presented in figures 2 to 6. These phases are combined with the major organisation elements to explain the dynamic framework of innovative organisations. Company size, type of innovation, and breadth of innovation that may arise on a specific project or company-wide affect innovations. Large companies are more able to afford new investment for innovation and tolerate the risks associated with adopting them, whereas smaller companies are more likely to value technology and have less complex decision-making processes. Laborde and Sanvido (1994) considered the company size factor when building their innovation model.

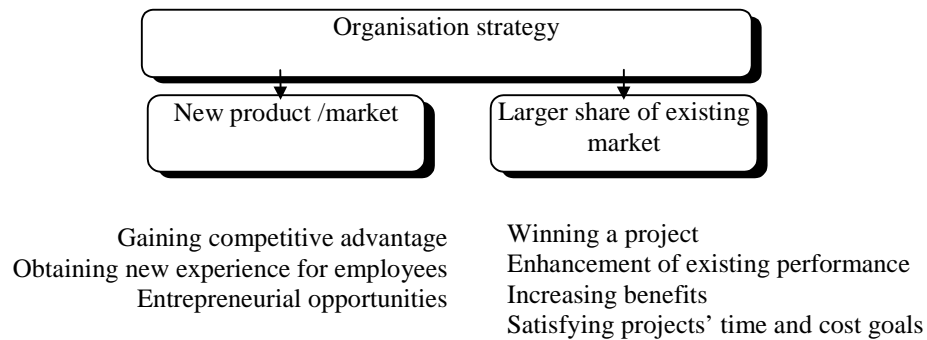


Figure 2: Main organisation strategy

Organisation strategy

Competition based on advanced technology and an ability to innovate requires long term strategic planning. Figure 2 classifies this strategy into two areas. These goals are directed to innovation in all aspects. The construction industry is highly competitive, volatile, attracts low margins and is subject to increasingly stringent standards. These factors make success difficult to achieve without innovation.

Organisation structure

Organisational structure and environment are the main factors that define the success of innovation. Figure 3 shows the main components of these factors. To create a climate conducive to innovation, short-lines of communication between senior management and project teams, with effective information flows to identify and resolve problems resulting from new technologies, should be present. This climate should expect some failures and accept the risks inherent in innovative processes. An innovative structure and culture should establish supportive policies and priorities, including long-term viewpoints, implicit vertical integration, emphasis on planning mechanisms, broad views of risk, flexibility through open project teams and use of slack resources. Decentralisation, informal decision-making, project organisation, management committees and project reviews enhance the team culture necessary for innovation. Because innovative improvements may be generated by any employee as ‘technical innovator’, Winistorfer (1996) stated that empowerment-allowing decisions to be made at the most appropriate level in an organisation have an important role.

Organisational ability to enhance competitiveness can foster innovation. Strong and unbiased management commitment to select technologies that best support project goals is one of these abilities. This can be fostered by establishing designers’ knowledge of technology. Because this knowledge is dynamic and fragmented the rate and scope of innovation depends on how this knowledge is managed, Nam (1992). Continuous learning is essential if innovation and adoption of new technologies are to be accepted, Lansley (1996). Stability of employees for a period of time reduces training costs and focuses experience, but a lack of varied experience also produces a lack of creativity, flexibility and is less innovative, Winistorfer (1996). Integration among project partners, owners, designers, contractors and suppliers also motivates innovation. This integration appears to be more helpful if achieved as early as possible so that there is adequate time to assess inherent risks (Tatum 1984 and Nam 1992).

Innovation teams

The success of innovative processes often requires the creation of an innovation team. The role of this team is to keep the organisation in tune with technological advancement, expend energy and take risks necessary to make innovations happen, Tatum (1989). An individual will have to be identified to champion or manage the process to completion. In this connection, Winistorfer (1996) described four key categories of individuals: ‘Technical Innovator’, ‘Business Innovator’, ‘Chief Executive’ and ‘Product Champion’. These champions do not exist in all construction firms. However, line managers may assume the roles of champion, but this often takes second place in the face of other problems and opportunities. Nam (1992 b) suggested an *integration champion*, who facilitates inter-organisational co-operation and learn-

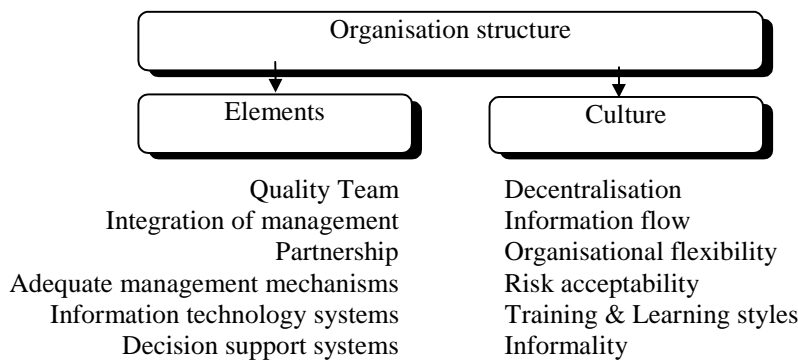


Figure 3: Organisation structure

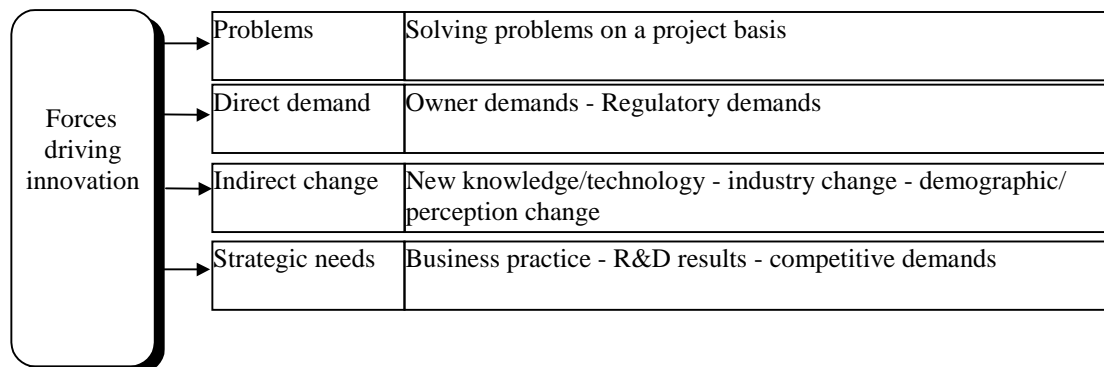


Figure 4: Innovation driving forces

ing, to ease this function. Technology gatekeepers, who link between organisations and sources of technology, identify, monitor and evaluate any improved or new technologies used by other companies may also be effective (De La Garza 1991).

Driving forces

Problems that cannot be solved by current technology prompt innovations (see figure 4). Owners demand not only safe and economic products, but also more functional facilities and aesthetic criteria (Nam 1992). The high standard of regulatory demands may cause design and construction teams to innovate to fulfil these regulations. Changes in the construction environment, any related science, engineering, industry and society may have a significant effect on the construction industry if these are to be adopted. Support of strong R&D programs can achieve the strategic goal of gaining a more significant business market share. New construction technologies can stem from adopting new approaches from any internal or external sources of industry. New ideas

could partially or completely change existing applications and may be classified into any of the innovation groups previously mentioned.

Barriers to innovation

Applied management literature suggested that barriers to the adoption of new technology might come from a number of sources: financial resources, building codes, procurement procedures, unexpected risks, construction markets and resistance to change. The accompanied high initial cost of innovation for the construction industry as a project-based business, is considered a barrier to innovation. Building codes and standards are written in general terms and interpreted by local officials for specific applications. This interpretation may restrict potential innovators from transferring and modifying new technology, Cushman (1992). The interpretation may also act as a catalyst for innovations and improve products and processes, such as environmental regulations to reduce noise, Arditi (1997). The Technology Foresight Panel on Construction (1995) reported that procurement procedures and standard specifications, used by large organisations and government, are often disincentives to innovation. Rosenfeld (1994) noted that the imbalance between risk and profit by traditional procurement procedures gives the prime beneficiary from successful innovations to the owner and any failure of an innovation to contractors or designers. Songer (1996) and MacLeod (1998) suggested that the feature of the design-build process of early involvement of contractor knowledge fosters construction solutions and motivate designers to innovate. Nam (1992) suggested some non-contractual project integration approaches to foster innovation, including: owner's involvement and leadership; establishment of long-term business relationships between organisations; employing integration champions; and the professionalism of project participants. Risks increase as more resources are committed to innovation. Capital intensiveness makes risk-aware decision-makers invest in structures built through mainstream, well-tested designs, materials and methods, rather than innovative ways, (Skibniewski (1992) and Rosenfeld (1994)). The extensive, unstable, highly fragmented and geographically dispersed construction market's characteristics create an uncertain climate for investment in innovation, especially for small companies, (Technology Foresight Panel on Construction 1995). Construction companies are also dependent on the electronics, machinery and chemical sectors for technical system innovations. Nam (1988) described construction as a system locked to any attempt to change the status quo. The perception of a locked system explains why construction innovation that is technologically superior does not often follow the route that diffusion theorists, economists or engineers may anticipate. The system players include various owners, craft unions, subcontractors, local governments that enforce obsolete building codes and interest groups and coalitions that have stakes in construction technology development. The dynamics and friction among these parties that slow the rate of innovation are too complex to measure in quantitative terms.

Consensus process

Kraft (1997) emphasised the importance of building a consensus process (see figure 5) to support innovative ideas and overcome pitfalls. Managers of consensus plans should specify the groups involved within proposed innovations and include a scope of work, a schedule and an estimate of resources. Testing the validity of an innovative idea and potential application range come first in this process. New ideas should serve human needs and have acceptable planning functions as good as, or better than, other available alternatives. This phase should evaluate the availability of the

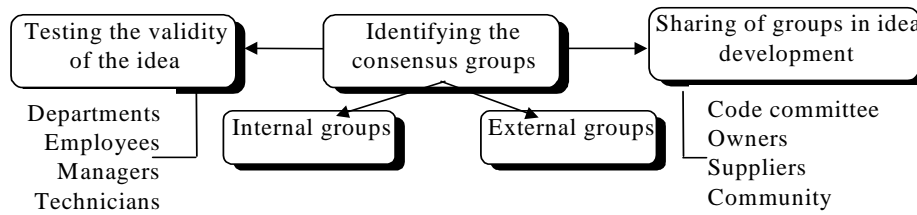


Figure 5: Consensus process

facilities required, expected changes for the management system and the degree to which overall strategic objectives will be achieved. It is also important to assess the impact of indirect fundamental research, expected lost ideas and efforts due to filtration of ideas. Replacing existing technology with new or using both concurrently, as well as the negative effects or technology down created by innovating should be considered. Providing detailed descriptions of the development process to those involved and feedback from them are important. The consensus process (figure 5), should consider organisational structures and features that affect innovation. This phase ends with the initial decision to accept or reject the innovative idea, figure 1.

Implementation phase

Many problems may arise during implementation as resource implications need to be assessed. Figure 6 demonstrates the sequence of these phases. Experimentation may

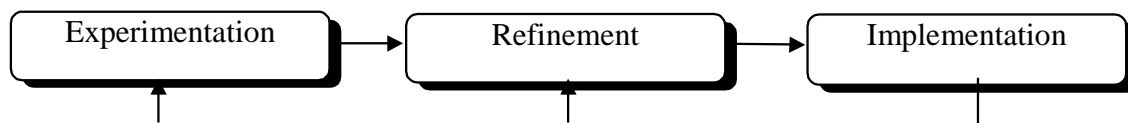


Figure 6: Implementation process

include the conceptual design of a pathfinder project or a beta-test plus technical and economic feasibility studies. This phase is quantitative and includes technological and economical risk analysis, Boles (1995).

Feedback, iteration, and process documentation are shown throughout this phase. These may change any method completely, refine the present idea or require more experimentation.

DECISION-MAKING PROCESS TO INNOVATION

Evaluation and assessment of a new technology as well as decision analysis are integral to the innovation process. The inherent risk of applying any innovation slows down the process of introducing new technologies in construction. Many of these decisions (for example risk management and innovation decisions) are qualitative and subjective in nature, needing heuristic approaches. Risk, competitiveness and intangible benefits that have strategic significance for a given firm require analysis techniques other than traditional economics ones. Decision-makers face four potential barriers to the successful development of innovation: technical, financial, institutional, and public/perceptual. Decision tools may be built to help overcome these obstacles, (Wakeman 1997). Classification analyses, as tools for decision making, have been directed to define and assess the existing technology product and processes such as Tatum' framework (1988) and the computer database of Ioannou (1993). Trinh (1996) prepared a list of suggested attributes for assessing product and process complexity. Chang (1988) and Lutz (1990), each built an assessment decision

analysis model to prioritise identified innovative technologies using weighted factor models for technical, cost/benefits and risk assessment. Skibniewski (1992) proposed the Analytical Hierarchy Process (AHP) technique to compare the relative strength of one alternative against another. AbouRizk (1994) used the AHP method to simulate the risk factors involved in construction innovation and their impact on various company objectives. Ioannou (1996) studied the simulation of alternative construction methods affected by uncertainty factors external to methods of tunnelling in order to be compared on an equal basis. Chao (1995) proposed an approach to determine the acceptability of alternative technologies using neural network model.

Each of the above tools has its advantages and disadvantages, Touran (1990), Mohan (1990), Murtaza (1993) and Skibniewski (1997). However, the classification analyses are not appropriate when a decision-maker does not know the value of a certain attribute and may not have past data. The weighted factor models may give different results for the same application depending on the experts who apply them. Simulation is an appropriate alternative where the complexity of a process or system makes mathematical modelling infeasible. However, developing the simulation models requires highly computer facilities and efforts. The ability of expert systems and neural networks to combine factual knowledge with judgement, to handle incomplete and uncertain data and to communicate with their users, provides a special appeal to the construction profession. However, they also need certain types of historical data (which may not be available in construction innovation) to build the facts and rules of expert systems or to train a neural network.

Along with the above, simulation models may be more appropriate in dealing with risk, tangible and intangible factors of innovation problem. These models can be powered by developing an expert system to test or adjust the process during the simulation run.

CONCLUSION

The need to innovate should emerge from a construction organisation's strategies to enable it to gain the desired benefits and market share. The characteristics of partnering and integrated management can enhance a construction organisation's capability to innovate. Most of the successful examples of construction innovation have highlighted that more TQM mechanisms such as team works, leadership and information flow facilitate innovation. Construction innovation could be represented as a dynamic process within an organisation's strategies and structure. There are numerous models that have been developed to represent the innovation process within construction organisations. Within these models the decision analysis systems constitute pivot points for the innovation process. Many decision tools are available such as classification databases, weighed factor models, AHP, simulation models and artificial intelligence tools. The challenge for the innovation issues includes the exploitation of the benefits of short-term flexibility and efficiency for project based work to verify the long-term performance achieving the desired step changes. However, evaluating the process, especially the implementation phase which includes the transformation of innovation into reality, has only been partially studied. This phase deals with problems identified in early phases and includes new types of construction activity characteristics (i.e. experimentation, iteration, and refinement). A high portion of risk associated with innovation can be accommodated if a company can manipulate them within the overall short- and long-term views of its projects. Developing an innovative approach should make the management of risk and

uncertainty more achievable in practice if successful step changes are to be implemented. The need to achieve these step changes through innovative construction requires rationalising the implementation phase of innovation considering a company's projects and policy.

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