MODELS OF CONSTRUCTION INNOVATION

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ABSTRACT: Construction innovation offers the potential for significant company, industry, and societal benefits. The objective of this paper is to present five models of construction innovation, which can provide a basis upon which companies can select and implement the innovations. Based upon current management and economic theories of innovations, the models reflect the unique conditions of constructed facilities, including the scale, complexity, and longevity of the facilities, as well as their organizational and social contexts. The innovations are differentiated by their degree of change from current practice, and their links to other components and systems. The five models are incremental, modular, architectural, system, and radical innovations. Using this categorization of innovations, companies can plan their implementation activities with respect to timing of commitment, coordination among the project team, special resources, and level of supervisory activity. Examples of construction innovations in each category are discussed.

INTRODUCTION

Although the generally accepted perception of the construction industry views innovation as a rare occurrence, in actuality it occurs consistently throughout the sectors of the industry (Dibner and Lemer 1992; Johnson and Tatum 1993; Slaughter 1993a). In addition, companies within the industry are interested in innovative technologies and designs, whether relating to materials, components, systems, methods, equipment, management, or other related areas. The objective of providing this framework of models of construction innovation is to guide selection and implementation activities by construction companies. Using the concepts presented here, it is hoped that a construction company could more effectively plan and carry out a strategy to identify, acquire, develop, and implement construction innovations.

To establish a common basis for discussion, innovation is clearly distinguished from invention. Invention is a detailed design or model of a process or product that can clearly be distinguished as novel compared to existing arts. Innovation, on the other hand, is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change (Freeman 1989). In contrast to an invention, an innovation does not require a detailed design or physical manifestation, and it does not have to be novel with respect to the existing arts, but only to the creating institution. While an innovation could also be an invention, an invention is not an innovation unless it has actually been used.

BENEFITS FROM CONSTRUCTION INNOVATIONS

Among the many macroeconomic benefits attributed to innovation are, most commonly, an increase in economic growth (Schumpeter 1934) and an increase in productivity (Schmookler 1952). While there is significant disagreement about the rate at which construction productivity and efficiency have been increasing over the last few decades, there is undeniably room for improvement. Indeed, the White House Committee has released ambitious goals for the improvement in the provision of construction activities ("National" 1994), and other countries have identified similar goals (Latham 1994).

Innovation can also be associated with market growth, through the provision of new or improved products and services, and reductions in the cost of production. In construction, improved components and technologies are constantly appearing. For example, the current security and communications subsystems in buildings are significant improvements over those existing even ten years ago. Mechanization of many construction tasks has reduced the cost of construction through decreasing the labor hours required. New markets can also emerge based upon innovations, as with the construction of high technology industrial facilities and Class 1 clean rooms for semiconductor manufacturing.

Construction-related innovations can also have significant social benefits (Seaden 1996). When the cost of constructed facilities is reduced, the facilities themselves become more affordable, and, therefore, more accessible to a greater proportion of the population. Improvements in the efficiency of residential construction to improve the quality of life for citizens is a focus of many national construction programs. In the same way, reducing the environmental impacts of construction-related activities through innovations provides social benefits regionally, as well as globally.

In particular, for construction, innovations often increase the technical feasibility of construction undertakings. Projects or facilities that may appear to be beyond the current technological frontier can become possible. For instance, the design for the Normandy Bridge extended by 60% the perceived maximum feasible length for a cable-stayed bridge (Shimizu 1997). Other research has demonstrated the preponderance of construction-related innovations that are new solutions to identified problems or technical constraints (Becker 1991; Dibner and Lemer 1992; Bruce et al. 1995).

Innovations may also provide significant benefits that cannot be adequately measured in direct monetary savings and gain, but can, nonetheless, add to a company's competitive position. For both the innovators and the early users of the innovations, certain intangible benefits can be obtained from innovations, such as improved reputation, ease of work, and attraction of promising new hires. These intangible benefits can often be more important for the early use of innovations than the expected dollar savings, as examined in the adoption of new information technologies for construction (Ramcharan 1997).

MODIFICATION OF INNOVATION MODELS FOR CONSTRUCTION

Innovation as a field of study has existed for several decades, focusing primarily on the manufacturing sector of national economies (Tushman and Moore 1988). However, certain key differences distinguish construction from manufacturing activities, and the nature of these differences can provide insights into how the existing innovation models and theories must be modified to reflect the characteristics of the construction-related activities. Specifically, constructed facili-

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ties are large, very complex, and long lasting, and they are created and built by a temporary alliance of disparate organizations within an explicit social and political context.

The physical scale of the components and the completed facility establish certain operational constraints that affect the development and use of innovations. For instance, activities to assemble the components are performed primarily at the final location of the facility. Off-site fabrication and assembly activities in shops and controlled environments are limited to the space available and to the transportation requirements of the unit. Therefore, innovations that require controlled environments or conditions during implementation may be limited in their application. Second, when an innovation is tested, the most reliable results are obtained from full-scale prototypes, since the scale effects for built facilities can be significant. Full-scale tests can be expensive and time-consuming, and only a few facilities in any one country have the capacity for these tests.

The complexity of facilities introduces another operational constraint on the development and use of innovations. Most facilities consist of a number of different systems which interact with each other as well as with the specific environment, and these interactions are not comprehensively characterized. Introducing an innovation may create perturbations throughout the other systems that may often be difficult to trace definitively. Unlike a manufacturing product where the set of interactions can often be constrained, constructed facilities interact with an open set of components and systems, and with the environment itself.

A third factor differentiating constructed facilities from manufactured products is their longevity of use. Most public facilities have a specified design life of at least 50 years, and often longer. Certain critical infrastructure systems, such as aqueducts, have functioned for hundreds of years. Therefore, construction innovations must be assessed not only within the original installation context, but also over a very long time period. For this reason, the potential for failure and the failure mode for an innovation must be explicitly considered, as well as the strategy for extracting, repairing, or modifying the innovation within the facility through several decades.

The organizational context of construction innovations differs significantly from a great portion of manufacturing innovations. Construction innovations exist within a temporary alliance among independent organizations concentrated on a single project. After the project is completed, the alliance is dissolved. Unlike traditional manufacturing organizations, which have a set of permanent in-house resources for design and implementation, construction projects most often split the design, fabrication, and implementation activities among many different parties. In addition, manufacturing companies often have a fairly stable set of suppliers from whom they obtain components and other inputs. In construction, the set of suppliers are selected for each project and are often not repeated on future projects. Innovations that require even small modifications in other components, systems, or activities require a degree of interorganizational negotiation that is beyond the normal manufacturing requirements.

A final factor for the modification of existing innovation models for application to construction is the social and political context of constructed facilities. Because constructed facilities directly influence the safety, health, and well-being of the population, all portions of a facility's life cycle (design, construction, operation, and decommissioning) are circumscribed by codes and regulations. Design of a facility has to be conducted within the guidelines, and often to detailed specifications, established through significant experience and codified in rule making. The construction itself is conducted in many parts of the world within strict safety and environmental guidelines, monitored through frequent inspections, and enforced through strong fines and penalties. The operation is also overseen through frequent inspections and documented performance tests. Decommissioning requires activities and oversight similar to those for design and construction, with the added constraints of long-term liability for environmental conditions. Manufactured products, in contrast, are most often evaluated with respect to their performance and not prescribed in their design and fabrication, even for products, which, like automobiles, may have significant health and safety impacts. In addition, liability is more often borne by the manufacturing company or the industry sector as a whole, rather than the individual designers, workers, or supervisors, as is common in construction.

For the effective development of models of construction innovation, the combination of the attributes of constructed facilities (scale, complexity, and durability of the facilities, together with the organizational and sociopolitical contexts) influences the nature of the innovation and how it is developed, acquired, and implemented. These factors create an environment that differs from the context often assumed for manufacturing innovation models. For example, many of those models assume that the innovations are generated by an internal research and development (R&D) organization that chooses from among a set of promising research pathways (Nelson and Winter 1982), and that the innovations can be exploited through large scale mass production (Abernathy and Utterback 1978).

MODELS OF CONSTRUCTION INNOVATION

Although many theoretical models of innovation exist, the objective here is to provide a set of models that responds to the nature of the construction industry and the activities of specific construction companies. The organizing principles for these models are (1) the magnitude of change from current state-of-the-art associated with the innovation; and (2) the expected linkages of the innovation to other components and systems. These two attributes can combine to provide insight into effective implementation strategies and potential sources of these types of innovations.

Incremental and Radical Innovations

The two ends of a spectrum of innovation models can be defined as incremental innovation and radical innovation (Marquis 1988). Incremental innovation is a small change, based upon current knowledge and experience. In contrast, a radical innovation is a breakthrough in science or technology that often changes the character and nature of an industry. While incremental innovations occur constantly, radical innovations are rare and unpredictable in their appearance and in their impacts. For incremental innovations, the impacts are predictable within a fairly narrow range, and the interactions with other components and systems is expected to be negligible. A radical innovation creates a new way of understanding a phenomenon and formulating approaches through which to solve problems (Nelson and Winter 1977; Dosi 1982). All previous linkages and interactions may be irrelevant for a radical innovation, not only with respect to the systems, but also the ties among organizations.

Examples of incremental and radical innovations within construction can illustrate the models. A recent incremental construction innovation is a full-body safety harness for fall prevention made from material similar to a mountain climber's gear, an incremental improvement over the waist-level safety belts. As new construction regulations increase the requirements for workers to "tie off" when they are working off the ground, the construction equipment manufacturers have re-

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sponded to make their harnesses more flexible to accommodate the workers' movements and to provide support over a greater length of the body in case of a fall (Korman 1997). A radical innovation in construction from over a hundred years ago was the introduction of structural steel. Its appearance was unexpected and changed the type of buildings and structures that could be designed and built. A whole new industry of steel manufacturing and fabrication emerged, as well as new components and systems linked to the new structural forms and systems (Elliott 1994).

The sources of incremental and radical innovations differ as well. Incremental innovations most often appear within the organization that has the knowledge base upon which to develop improvements (Marquis 1988). These organizations in construction can include all parties in the value chain, from suppliers and manufacturers for their own products, to contractors and workers in the materials, methods, and management they use, to the owners and occupants related to the performance of the facility. Radical innovations, on the other hand, often appear from outside an existing industry and are often based upon scientific or engineering research. They may be introduced into an industry through any number of avenues, but most often involve the entrance of new companies and organizations into an industry.

Modular and Architectural Innovations

The distinction between modular and architectural innovations is made on the region of the change and, specifically, the degree of interaction with other components or systems. Modular innovation entails a significant change in concept within a component, but leaves the links to other components and systems unchanged. Architectural innovation, on the other hand, involves a small change within a component, but a major change in the links to other components and systems (Henderson and Clark 1990). This distinction has important implications for the implementation of these innovations. Modular innovations may be developed within an organization and implemented with a minimum of negotiation with parties involved in the development or selection of other components, whereas architectural innovations require change and modification in the set of interacting components and systems (Afuah and Bahram 1995).

An example of a modular innovation is a new machine that automatically ties the wire for reinforcing bars in cast-in-place concrete ("Talon^2" 1996). To mechanize this activity is a significant change in concept, and involves many novel and patented devices, but it does not change any of the other components, methods, or materials related to cast-in-place concrete. A recent innovation that can demonstrate the concept of an architectural innovation is self-compacting concrete (Okamura et al. 1995). This concrete uses standard available materials in the cement, admixtures, and aggregate, but controls their size and homogeneity to the extent that the vibration stage of placing the concrete is eliminated. In addition, the cured concrete appears to have improved performance in durability, impermeability, and strength. Therefore, while the new concrete has only relatively minor changes within the basic technical field of concrete composition, it has major implications in the linkages to construction activities through the elimination of the consolidation phase and increased rates of placement.

In construction, it appears that modular and architectural innovations can come from a variety of sources. Modular innovations may be developed within organizations that have control over and responsibility for the module, or they may be introduced through a new entrant into the industry. Because architectural innovations require changes in the linkages to other components and systems, the developer of an architectural innovation is most often a company that does not have a vested interest in maintaining the existing linkages. However, in order for an architectural innovation to succeed, the originator and users of architectural innovations must understand the required changes in the linkages. In manufacturing, architectural innovations most often appear from new entrants to an industry, in the form of new manufacturing companies. In construction, preliminary analysis indicates that architectural innovations may well originate in the field (e.g., general and specialty contractors) rather than manufacturers and suppliers (Slaughter 1993b).

System Innovation

System innovations are identified through their integration of multiple independent innovations that must work together to perform new functions or improve the facility performance as a whole. For this type of innovation, the linkages are explicitly among the innovations, as well as often entailing changes in the links to other components and systems (Cainarca et al. 1989). The innovations often come from a variety of different sources, and must be explicitly connected and modified among the components of the systems. As noted previously, constructed facilities are complex systems, which are characterized by the integration of a changing set of components and systems that must interact to perform the overall function and meet conditions of the environmental context over time. System innovations appear with a relatively high degree of frequency in the construction industry (Hutcheson et al. 1996; Kangari and Miyatake 1997), since systems are reconfigured for each project, which provides an opportunity to incorporate a set of innovations that can complement each other to achieve new functions or levels of performance.

An example of a recent system innovation is the zone module construction method for large, coal-fired power plants ("Zone" 1996). For this innovation, the plant is prefabricated in four large-side zone modules and one top module. Each module includes the structural elements, piping, equipment, electrical and control wiring, and other installed components. The top module acts as the lifting platform for the lower modules. This system innovation replaces on-site placement of each component with prefabrication of the whole plant, thereby minimizing on-site activities. It incorporates several specific independent innovations (e.g., split boilers and hydraulic lifting devices) and requires the integration of all the modules and their components, as well as the coordination of all activities related to design, fabrication, erection, and connection among each of the zone modules to ensure the performance of the facility as a whole.

Similar to the innovation sources for architectural innovations, the sources for system innovations are most often entities that do not have a vested interest in the current configuration of components, subsystems, and systems, but rather obtain significant benefits from the improved performance or new functions provided by the integration and complementarity of multiple innovations. The innovator also is able to exercise the technical competence and project responsibility and control to achieve coordination and cooperation across the system(s). The requirements to effectively develop and use system innovations often runs counter to common project delivery systems where control and responsibility are split among different organizations by specific tasks or technical subsystems.

Summary of Construction Innovation Models

The five types of innovation presented through the models can be ordered by their degree of required change from the current state-of-the-art or practice (Fig. 1). Incremental innovation is a small change, with impacts confined to the im-

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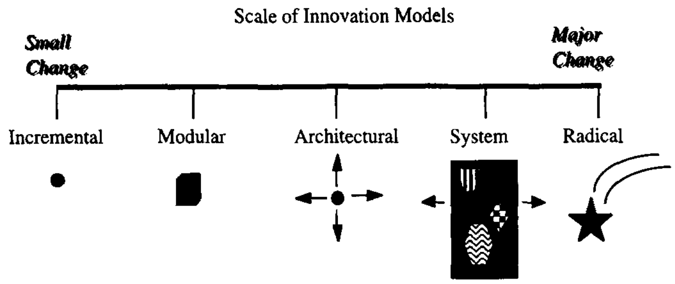

FIG. 1. Innovation Models for Construction

provement of the specific element or component. A modular innovation is a more significant change in the basic concept, but it also has limited impacts on other components or systems. Architectural innovations, on the other hand, may entail only a small change within a concept or component, but are strongly linked and interactive with other components and systems, and so require changes in the linkages or the linked units. With the system innovation, the linkages are among multiple innovations that must be integrated together and may require significant changes in other components and systems, as well as the linkages to those elements. A radical innovation is a new approach and causes major changes in the nature of the industry itself, appearing as a rare and unpredictable event, almost as a "shooting star."

For construction companies searching for innovation, the innovations may be quite close to home. The general categories of sources of innovation are research and development (R&D) organizations (e.g., universities and research and testing laboratories), manufacturers and suppliers, designers, contractors and workers, and the owner and occupants, both within and outside the construction-related industry.

Incremental innovations appear most often within the organizations that have the knowledge, experience, and control to affect the improvements, which can be any of the organizational types listed as sources. In construction, previous studies have indicated that incremental innovations are even more common in this industry than in other industries and often occur within the construction companies themselves (Myers and Marquis 1969). Modular innovations, likewise, originate within a technically competent organization, but because they involve an advancement in the general concept on which an element is based, they may more often appear in organizations with higher specialized technical capabilities, such as R&D organizations, and manufacturers and suppliers that support specialized development activities.

Architectural innovations may originate at any of the sources, but the modifications of the linkages requires an organization with knowledge of and control over the affected components and systems, such as the contractors and owners. System innovations require technical competence equivalent to that needed for modular innovations, as well as the knowledge and control equivalent to that needed for architectural innovations, combined with organizational authority to ensure collaboration and integration. With these requirements, the individual innovations may come from any of the sources, but the integrating source is more likely to be an organization with design and implementation capabilities, with strong relationships with or ties to the owner. Radical innovations, in contrast, will most likely be developed within organizations with strong scientific and engineering competencies, such R&D organizations, or in industries with high R&D concentrations and expenditures, such as materials and communications.

INCORPORATION OF INNOVATIONS WITHIN PROJECTS

The five innovation models can provide the basis for a strategy to incorporate innovations into specific projects. Using the attributes of the magnitude of the change and the linkages to other components and systems, companies can predict and plan for different types of activities depending upon the type of innovation involved. Although several models exist for implementing construction innovations (Tatum 1987; Laborde and Sanvido 1994), this approach will focus on the five models of innovation and specific activities and resources needed to use the innovations on specific projects.

The first consideration is the timing of the commitment to use the innovation. The commitment is the degree to which resources are assigned to the implementation of the innovation, and when an organization may publicly acknowledge its use of the innovation. The timing is with respect to the progress of the project, through the stages of feasibility analysis, conceptual design, detailed design, bid award, construction, and turnover. If the timing of the commitment to the innovation must correlate to other scheduled events (such as acceptance of bid), then the potential user of the innovation must collect adequate information, evaluate the innovation, and make a decision appropriate to the specific project in time to incorporate it into the project plans. On the other hand, if the innovation commitment can be made independently of the project schedule, the potential user can make that decision based upon other factors, such as the innovation being a solution to an emerging problem.

The degree to which use of an innovation requires implicit and explicit coordination among the members of the project team, including the client, designers, contractors, subcontractors, and other contractual parties, is the second consideration. Implicit coordination can include informal negotiation and collaboration to solve problems, exchange information, and coordinate activities, while the explicit coordination may include special provisions in the contract for design or construction changes, signatures for acceptance of risk or uncertainty, or a waiver of penalties for late project completion. If use of an innovation does not require implicit or explicit coordination, it can be implemented with ease, while significant explicit and implicit coordination among the team members may significantly complicate the implementation process.

The use of an innovation may require special resources (e.g., special equipment or trained personnel), and these resources may only exist within specialty companies. Therefore, the third consideration for the incorporation of an innovation into a specific project is the type and source of special resources. If the resources are difficult to obtain, the innovation may not be appropriate for many projects, or the benefits that are expected to accrue from the innovation may be captured by the supplier of the special resources through high fees. A company may decide to develop those special resources inhouse, such as through a training program, but the associated costs from internalizing the special resources that are needed may be greater than the benefits that are probable for a single project, and future applications may be uncertain. When an innovation does not require special resources, or when those resources can be found or easily developed within the company, the implementation of the innovation can proceed more smoothly and generally at a lower cost than innovations that need external special resources.

The fourth consideration is the nature of the supervision activities, including the organizational level at which the supervision is required, the type of supervisory activity, and the specific competencies of the supervisors. The organizational level of the supervision may differ by innovation type, since some innovations may require supervision only at the level of the performance of the task, whereas others may require supervision by the upper levels of the management structure. In the same way, the types of supervision may range from simple notification to active involvement and decision-making to

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TABLE 1. Specific Activities for Implementation by Type of Innovation

Types of innovation (1)	Timing of commitment (2)	Coordination within project team (3)	Special resources (4)	Supervision organizational level (5)	Supervision type (6)	Supervision competency (7)
Incremental	At any time	None	None	At locus of improvement	Notification	Specific product or process
Modular	At design/selection	None	For concept change	At design level	Notification, review	Technical competency
Architectural	At design-to-implementation stages	Among affected parties	For complementary changes	At affected system level	Notification, agreement, review	System competency
System	At conceptual design stage	With all project team members	For integration of set of innovations	At top engineering management level	Project scope, agreement, review	Technical and system competency
Radical	At technical feasibility stage	With top management from all involved organizations	For breakthrough	At top management level	Project objectives and scope	Specialized technical competency

strategy formulation of the company as a whole. The specific competencies can include supervisory knowledge and experience, and may be task-specific, or may need to include specialized scientific or engineering fields.

A critical point to make at this juncture is that an innovation is most usefully categorized for this discussion with respect to the implementing construction organization. An innovation that is categorized as "radical" to one field may be viewed as "modular" to a different area (Afuah and Bahram 1995). For example, a new mapping and surveying device, the Cyrax, uses a laser-radar transmission to measure the surfaces of a facility, and transforms those measurements into a three-dimensional CAD image during the mapping activity ("Lasers" 1997). It may well be a radical innovation to the industry that currently produces as-built facility measurements and drawings, since it will completely transform its activities, and possibly its composition of companies. On the other hand, for the construction company that will use the measurements and drawings for maintenance, repair, retrofit, and decommissioning projects, it is a modular innovation, since it is a change in concept, without requiring any changes in the use of the CAD images or other related construction functions.

The specific activities required for the five types of innovations can be presented as an increasing level of complexity corresponding to the degree of change associated with the innovation (Table 1). Incremental innovations can be committed to at any time in the project, since they do not involve major changes, but only small improvements. They also do not require explicit or implicit coordination within the project team, or special resources. The level of supervision is at the locus of the improvement (e.g., task level) and concerned primarily with notification, with supervisory competencies needed in the product or process being improved.

Because modular innovations involve a change in a core concept, the associated activities for use require an earlier commitment, usually during the design or bid stages. Since many construction specifications define in detail acceptable components and processes, changes must be explicitly identified and agreed upon within the design scope. However, because modular innovations do not require changes in the linkages to other components and systems, it requires little explicit or implicit coordination within the project team. The special resources required are access to the innovation itself and to the related concept change (e.g., training to install and maintain a component embodying a modular innovation). The supervision required is, therefore, primarily at the design or bid levels and requires notification and review to ensure that the modular innovation will meet the project's requirements. The supervisor will have to possess some degree of technical competency in the core concept area to adequately evaluate the innovation and oversee its implementation.

Architectural innovations, on the other hand, may require fewer special resources, but a greater degree of commitment, coordination, and supervision. Architectural innovations often involve only a small change within a core concept, but major changes in the linkages to other components and systems. This apparent small degree of change may lead to a wider range of timing for commitment, from design to implementation, but often requires extensive explicit, as well as implicit, coordination among the members of the project team. If the required modifications for the architectural innovation requires new deliverables in either the performance of work or the components involved, the explicit coordination will include contract changes. At the least, the architectural innovations will require implicit coordination, with special resources associated with the complementary changes. The supervisory activities will be quite active, primarily at the implementation site for the full system being affected, and will entail notification, agreement, and constant review and revision activities to ensure the performance of the completed system. The supervisor's competence will have to be at the system level, including not only implementation, but operation.

System innovations require earlier commitment from more of the organization than is needed for architectural innovations. Commitment to a system innovation is made during the conceptual design phase, since it often involves new functions or increased levels of performance of the facility as a whole. The identification and implementation of the set of innovations and their integration into the system require the explicit and implicit coordination among the team from the earliest stages, with the special resources related to each of the innovations, and their integration. The risk associated with the use of a system innovation may require active supervision by top engineering managers, who are concerned with incorporating it into the project scope, obtaining agreements, and constantly reviewing its implementation and performance. These supervisors need technical and system competence to assess the complementary changes needed to effectively implement the system innovation.

Implementation of a radical innovation entails not only financial and project risk, but also the potential for technical failure. These innovations are often assessed well before a specific project is initiated and are explicitly considered during the technical feasibility analysis. Coordination for explicit and implicit cooperation will involve top management from all involved organizations, and requires special resources related to the scientific or technological breakthrough. The supervision will also involve the top management levels, because of the risk involved, and will relate specifically to the project objectives and scope. However, the top management will probably need to supplement their competencies with specialists in the specific scientific or technology area related to the breakthrough, to monitor the implementation process and adjust the activities or innovation accordingly.

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The categorization of an innovation into one of the five models (incremental, modular, architectural, system, and radical) can provide a basis for predicting the degree of change from standard practice associated with the innovation, and for planning the type of activities and resources necessary to effectively implement the innovation. The specific considerations are the timing of commitment, the degree of coordination within the project team, need for special resources, and the type and level of active supervision. In general, as the degree of change associated with an innovation increases, the activities and resources must increase as well.

CONCLUSIONS

Construction innovation offers the potential for significant company, industry, and societal benefits. As the demand rises for increasingly complex facilities, and the traditional sources of construction materials and labor shrinks, most construction-related companies are looking for design and technology innovations to improve their products and services, and decrease their costs. Owners and clients seek construction innovations to increase the technical feasibility of their desired projects and improve the performance of the completed facility, and governments encourage the innovations as a means to improve the efficiency of the industry and the cost-effectiveness of the facilities.

Five models of construction innovations are presented as a basis for construction companies to plan and carry out activities to effectively use specific construction innovations. These models are based upon current theories in management and economics but are modified to reflect the special conditions associated with constructed facilities, such as their scale, complexity, durability, and organizational and sociopolitical contexts. For the purposes of project incorporation, the five categories of innovation are differentiated with respect to their degree of change from current practices and their links to other components and systems.

Based on these models of innovation, companies can evaluate what they must do to implement the innovations. This framework can provide companies with a means through which to reduce the perceived risks of using construction innovations, and to thereby somewhat lower the barriers to innovation throughout the industry. In addition, developers of innovations can be made more aware of the level of commitment and change required to use their innovations and may be more willing to supplement the resources available to construction companies to aid their implementation and spread.

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