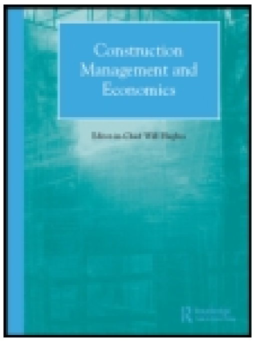

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Leaders and champions for construction innovation

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Leaders and champions for construction innovation

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Based on empirical studies of the role of key individuals in the processes of ten successful innovations in the US construction industry, this paper makes three principal arguments. First, effective leadership is essential for technological innovation – in particular in construction. Second, technological competence is an utmost prerequisite for effective leadership for construction innovation – regardless of the size of the firm. In other words, an entrepreneurial role as a technical champion in a small firm does not change even as the firm grows. Lastly, the role of technical champion can be delegated only with slack resources and adequate power. This paper also highlights conclusions and practical applications to increase technological innovation in design and construction firms.

Keywords: Innovation, leadership, technology, entrepreneurship

Introduction

The US construction industry, an important sector of the economy, faces critical challenges. For example, productivity growth in construction is far below the national average. In fact, the decline in construction productivity has been among the most serious in the US economy; only the mining industry has done worse in the last decade (Cremeans, 1981; Allen, 1995).

Some hypotheses explaining the possible causes of the construction productivity decline have been proposed. The Business Roundtable (1982b) found that the US construction industry is far less progressive than many other major industries in developing and adopting new technology. The National Research Council (1986) also concluded that the slow adoption of new technology and inadequate inventive activities have undoubtedly been major factors, though possibly not the only factors, in the productivity problems of the construction industry.

Moreover, the slow rate of technological advancement in the US construction industry has caused concerns regarding international competition. For example, the Office of Technology Assessment of the US Congress has investigated the strengths and weaknesses of US design and construction technology in terms of international competition (United States, Congress, Office of Technology Assessment, 1986). They found European and Japanese technological superiority in many sectors of the design and construction industry.

At this point, it seems clear that the current rate of technological progress in the US construction industry is not satisfactory when we consider the industry's need to improve productivity and increase competitiveness. The US construction industry needs to increase its rate of technological innovation.

Many industrial professionals and scholars have addressed this issue of why construction lacks technological advancement and how to increase its rate of innovation. The Business Roundtable (1982b) reported that the cause was not the lack of capability in the US to develop new construction technology, but the absence of a coordinated effort to link market needs and inventive capacity.

The Business Roundtable (1982a) tried to entice inventive activities in construction by highlighting strong demand-side forces in markets; they suggested that three areas of construction, piping, electrical work and installation of mechanical equipment, have the highest potential for gains from technological research. On the other hand, supply-side factors in developing construction technology have been identified, for example, by Moavenzadeh (1985). He advocated a high-technology revolution to restore the troubled US construction industry, arguing that several promising technologies such as computers, robotics and advanced materials are standing ready.

Many concerned researchers have also identified institutionalized R&D as possibly a major source of technological innovation and asserted the urgency of an increased level of investment in construction R&D (National Research Council, 1986; Sidwell *et al.*, 1988). Meanwhile, in an attempt to identify major forces and factors of innovation, some have tried to understand differences in the innovation process in the US construction industry conceptually (Tatum, 1987; Nam and Tatum, 1989). Many empirical studies, based on observing examples of innovation in construction projects and in firms, provide some insights regarding the nature of innovation processes in construction (Stewart and Tatum, 1988; Tatum and Funke, 1988; Tatum *et al.*, 1989; Nam *et al.*, 1991).

Whether conceptual or empirical, the main focus of the research mentioned above has been on the institutional or organizational aspects of construction innovation. However, will the rate of innovation increase if the fragmentation of the industry is decreased in some way? Or should government policy encourage the formation of large construction firms that can afford large R&D programmes? There has been a gap in the current discussions regarding construction innovation. What has been most neglected in the current discussion of technological innovation in the construction industry is the role of individuals who exert great influence in the process of technological innovation. Obviously, highly enthusiastic and committed individuals who are willing to make special efforts and take risks play an important role in technological innovation.

A rich stock of theories regarding the role and nature of this type of individual in the innovation process has evolved during the last two decades. However, these are mainly from the studies of successful innovations in the manufacturing industry. The applicability of these theories to construction is doubtful, since many aspects of construction differ from manufacturing. For example, institutionally, the levels of product diversification, industry fragmentation, concern regarding legal liability and government regulation are different, organizationally, the levels of specialization are distinct and culturally, the level of technological conservatism is dissimilar.

What types of individuals are indispensable in the successful process of construction innovation – in particular at the top of the hierarchy in a construction firm? Is there any commonality regarding the characteristics and managerial behaviours of top managers who drive construction innovation? Are the roles of these individuals significantly different from those of top managers found in successful processes of manufacturing innovation? To answer these questions, the authors will focus on the relationship between the type of leadership and the success of technological innovation in construction.

The authors' arguments are based on the result of interviews with more than 90 construction professionals who were involved in ten innovative projects (see Table 1); these US construction projects occurred during the period 1985–1989. The ten innovative projects consist of three building and seven heavy construction projects distributed across seven states. The writers should point out that they did not investigate the residential sector. The sizes of the selected projects are extremely diverse: they range from a $350 million project to a $1.6 million one. All the selected projects were recognized for their innovativeness by more than two trade publications during the period 1985–1990.

Four sections structure this paper. First, in order to build a basis for comparison with out research findings, we will briefly summarize the background from manufacturing regarding the role of individuals in the innovation process. In the following sections, we will report our findings using many real world examples and identify some unique aspects of leadership essential for construction innovation. In the last section we draw some important implications from this analysis regarding the task of top management in the process of construction innovation.

Role of key individuals in the innovation process: background review

Types and roles of key individuals

Many researchers have stressed the importance of key individuals in the innovation process. Quinn (1985) claimed that the following type of individual is a crucial factor in the success of innovative small companies: 'inventor/entrepreneurs' who are need or achievement oriented, experts and fanatics. They underestimate the obstacles and length of time to success, enjoy flexibility and quickness and foresee tangible personal rewards if they are successful.

In fact, the significance of the entrepreneur role was well recognized by Schumpeter (1942) a long time ago: 'the function of entrepreneurs is to reform or revolutionize the pattern of production' (p. 132). Frequently, the term 'champion' is used to designate individuals who lead the innovation process. This critical role that 'champions' of technological change play within indus-

Table 1 Characteristics of the innovative projects studied

Case number and type	Size (million)	Innovative aspects	Significance
1. Soft-ground tunnel	\$200 (1986)	Twenty-four (8 foot diameter and 1476 foot long each) concrete drifts for the wall of a 63 foot diameter tunnel	World's largest diameter soft-earth tunnel (The Outstanding Civil Engineering Achievement for 1990 by ASCE)
2. Concrete pier	\$61 (1987)	Structural design that eliminated batter piles and extensive use of precast concrete	The longest one-piece concrete cylinder piles ever built (224 foot, 54 in diameter)
3. Office building	\$51 (1987)	Ductile concrete core with a structural steel frame in seismic zone four	The first use of ductile concrete core in seismic zone four
4. Cable-stayed bridge	\$200 (1985)	Single-plane stays with tendons encased in a steel pipe	The longest (1200 foot) main span cable-stayed bridge in the world in 1987
5. High-rise steel-frame building	\$350 (1987)	The first use of chevron braces in a high seismic zone	The tallest building in seismic zone four
6. Restoration of earth-fill dams	\$5.1 (1988)	Roller compacted concrete plating on the slope of the spillway sections of two earth-fill dams	First use of RCC plating on the declining surface of a dam
7. Highway concrete overlay	\$1.6 (1986)	The development of a fast-cure concrete mix without any significant deviation from existing concrete materials or paving equipment. The construction costs was close to that for an asphalt counterpart.	Because this new mix reached a compressive strength of 1300 psi within 12h, the project allowed traffic back onto the road in only 24 h
8. Outfall pipeline	\$10.2 (1985)	Installation of two, 5 foot diameter, 10 000 foot steel pipelines at 600 foot depth under sea	Record depth pipelines
9. High-rise concrete building	\$177 (1987)	Four 10 foot diameter steel tubes filled with 19 000 psi concrete to create the main columns	World-record high-strength concrete
10. Arch bridge	\$19 (1987)	Pre-stressed steel-tie system installed under the deck in an arch bridge	A 520 foot centre arch span was tied by cables; this system allowed its steel members to be lighter

trial organizations has been recognized only during the last two decades (Maidique, 1980).

Arthur D. Little, Inc. (1985, p. 36) identified three types of champions who work together: 'the technical champion' who carries an idea from the initial concept through to development into a viable product or process, 'the business champion' who provides a business framework for a technical idea and 'the executive champion' who sponsors the idea at the highest level, using his/her power to protect it, move it along and seize the opportunity to exploit it.

While it is not yet known whether entrepreneurs or champions are born, developed or the results of serendipity and circumstance (Tornatzky *et al.*, 1983), it is certain that the function of the champion must be linked with the entrepreneurial function, which includes risk taking, the provision of capital, the development from idea or prototype to operational status and the coupling of the market-place with the inventor's concept (Susskind and Zybkow, 1978).

Evolution of entrepreneurial roles as the firm evolves

Most firms follow a typical sequence of development in three stages from small to integrated to diversified (Chandler, 1962). According to Maidique (1980), as a firm grows, the role of the entrepreneur changes and many different types of champions emerge. In a small entrepreneurial firm, the technological entrepreneur fulfils all the functions of the three types of champion. In an integrated firm, continued growth requires changes in the entrepreneur's role and middle managers – business champions – begin to serve as integrators between technical champions and top managers. When a firm diversifies and enters fields with which the entrepreneur is not intimately familiar, the process changes; now a new kind of champion – an executive champion – emerges, bridging the gap between the entrepreneur, the business champion and the technical champion (Maidique, 1980).

Organizational size, structure and innovativeness

The OECD (1982) found that larger firms are more able to afford the investment for innovation and more able to tolerate the risk of adoption, whereas smaller firms are more likely to value technology and to use simpler decision-making processes. Therefore, organizational size may be related to the effectiveness of the innovation process. Nevertheless, it has often been reported that, relative to their market share, larger firms do not seem to develop a greater proportion of innovations than smaller firms (Utterback, 1974). Many researchers report that small firms are better in producing innovation (OECD, 1982).

In terms of economic behaviour, a small firm is characterized by its inability to exercise market power and particularly to influence the prices of goods (Galbraith, 1973). As far as organizational behaviour is concerned, the small firm is characterized by a pre-bureaucratic phase of development in which the personality of the entrepreneur is paramount. In this context of organizational size, Utterback (1974) reported that 'in mature industries, such as textiles, machine tools, and construction, innovation is more likely to come from smaller, new firms than from older, larger firms, as well as from firms in other industries' (p. 659).

Quinn (1985) found that the most notable and common constraints in less innovative companies, often large companies, include top management isolation, intolerance of fanatics, short time horizons, excessive rationalism, excessive bureaucracy and inappropriate incentives. To be innovative, Quinn (1985) pointed out that, at times, there is no need for detailed planning, cumbersome procedures and excessive rationalism; rather, the most important patterns in the large innovative companies are a supportive atmosphere for innovation, orientation to the market, small and flat organization, use of multiple approaches, skunkworks and interactive learning.

In addition, he described three strategies for large firms regarding the climate for innovation: an opportunity orientation rather than cost cutting, structuring for innovation (e.g. a small team led by a champion, breaking down the bureaucratic barriers to innovation, etc.) and complex portfolio planning to balance the needs of existing product lines against the needs of potential new lines.

Organizational rigidity is always mentioned as a barrier to innovation in larger firms. Putnam (1985) stated that bureaucratic rigidity and barriers should be eliminated for high-quality, trouble-free production. Whereas Quinn (1985) held a vertical (or hierarchical) viewpoint in analysing organizational barriers to innovation in large firms, Putnam (1985), taking a horizontal viewpoint, found structural barriers that prevent the team spirit from crossing departmental lines. Thus, Putnam (1985) argued that it is no longer enough to design first and perform manufacturing engineering and quality control later, saying that traditional concepts of departmental and functional organization are obsolete. He suggested an integrated manufacturing concept, which brings manufacturing engineering, quality engineering and test engineering in on the design process from an abstract idea to a finished item. He named this simultaneous collaboration of specialized functions 'work cells' or 'group technology' (Putnam, 1985, p. 140).

According to the above background research, it seems that characteristics of organizational structure such as complexity, rigidity, formalization and centralization inhibit innovation. This background also indicates that the role of leadership changes as the firm evolves.

Construction is a project-based activity; a construction project involves multiple organizations. We next analyse the distinctive types of the organizations we found in ten successful construction innovations.

Leading organizations in innovative construction projects

Owners, designers, contractors and other members of the project teams participated in the ten innovative projects we studied. However, these organizations' participation in the projects does not necessarily imply that all of them were characteristically innovative. Some owners were unable to understand or were disinterested in the technology incorporated in their projects, some designers opposed the innovative ideas suggested by the contractors and some contractors continuously complained about the non-conventional designs given to them.

However, while some organizations opposed the new ideas or passively participated in the projects, some firms committed themselves to the innovations. The authors identify them as progressive organizations; usually, the innovative projects were accomplished through the combined efforts of a couple of such progressive organizations. We classified these firms into three types based on roles played by key individuals in the organizations: driving force, technical collaborator and innovation supporter.

Key individuals in the 'driving force' type of organization carried ideas from conception through to development into a viable process or product. They persuaded other organizations to participate in the project and led the innovation process. The 'driving-force' organizations in the ten innovative projects included five design firms involved in cases 1, 4, 5, 9 and 10, four general contractors in cases 2, 3, 7 and 8 and one owner organization in case 6 (for the types of project see Table 2 and for a classification see Table 3).

For example, a bridge engineer involved in case 10 successfully persuaded the owner and the citizens groups to approve the use of their previously developed cable technology for the construction of a landmark bridge. A structural engineer in case 9 not only developed the new idea of using large-size steel tubes with high-strength concrete, but also led other organizations – a ready-mix concrete supplier and a supplier of admixtures – to develop high-strength concrete.

In four cases, not only the designers, but also the general contractors were driving forces for the construction innovations. For example, a marine general contractor in case 2 drove the redesign of the project and a concrete paving contractor in case 7 developed a new concrete mix and successfully sold it to the owner, a state department of transportation. In case 6, the owner, the US Army Corps of Engineers, led the search for roller-compacted concrete technology and effectively implemented it on their project.

The second type of progressive organization is identified as a 'technical collaborator'. Upon receiving the initiative from the driving force, members of these organizations provided technical expertise for the project. In case 2, the structural engineer, who was hired by the general contractor mentioned above, provided marine construction expertise to perfect the contractor's idea of simplifying the pier design. Equipped with the R&D capacity, the owner in case 7, a state department of transportation, helped the concrete paving contractor in their efforts to develop fast-cure concrete. These technical collaborators neither initiated the ideas nor led the innovation process. Nevertheless, without their technical consultation advice or even encouragement, the projects would not have been innovative.

The third indispensable type of progressive organization is recognized here as an 'innovation supporter'. With enough understanding of the background technology involved, they sponsored the new ideas at the highest level and protected them. These innovation supporters were generally the owners of the projects. For example, rather than merely responding to the innovation by setting an extraordinarily high level of quality for their products, the owners of the high-rise buildings in cases 5 and 9 actually invited the innovation. In spite of the complex bureaucratic procedural barriers to redesigning the pier, the Navy, the owner in case 2, aggressively sponsored the idea of redesign suggested by the contractor. The Navy even influenced the original designer to cooperate with one of their competitors in the process of 'invalidating' their original work.

After identifying progressive organizations that led the innovations above, we will now examine the characteristics of innovation supporters, which are mostly owner organizations. We will then analyse the type of leadership exercised in organizations that fit the driving force and technical collaborator types.

Owner's leadership in innovative construction projects

Owner's involvement and commitment

Whereas in manufacturing the buyer's role takes the generally passive form of market demands, in the construction industry the role of the buyer (i.e. owner) is generally more active. Rather than being just buyers of finished products, owners, particularly in the building and heavy sectors of the construction industry, are often major participants in the projects. They establish the mechanism by which the involved parties communicate and collaborate, make decisions on important technical matters throughout the project execution and sometimes share a high proportion of the risk. Thus, the owner may play an indispensable role in the execution of a construction project.

For better results in construction innovation, a high level of owner involvement in the project appears critical. As shown in Table 2, evidence from the ten construction innovations indicates that this statement is true in most of our cases. Only one owner (in case 4) – though they were heavily involved in the project – showed a low commitment to innovation. Two other owners (in cases 3 and 10) were low in both involvement and commitment. On the other hand, seven owners exhibited extremely high levels of both involvement in their projects and commitment to innovation.

A high-rise building project (case 9) is a good example of a construction innovation largely attributable to both the owner's high level of involvement in the project and the commitment to innovation. The owner was willing to invest heavily in the opening stages of the project. To determine the areas of success and the areas needing improvement, the owner undertook a detailed survey of the tenants in their prior projects. Their long-term strategy anticipated design improvements from continued cooperation with a single structural designer. This long-term relationship over five high-rise building projects had developed into a bond of trust and understanding between the two parties. Defining the roles of owner and structural designer did not require formal statements; each of them knew what was expected of each other. The owner encouraged the structural engineer to investigate several different design options. Innovation was not only an acceptable alternative, it was expected by the top management of the owner organization. When

Table 2 Owner's level of involvement in the projects and their commitment to innovation

Case number and type	Evidence of owner's high level of involvement in the project and commitment to the innovation (owner in this project)	Cases of low-level involvement and commitment
1. Tunnel	Established a review board for technical oversight and disclosed all geotechnical data Invested resources in test-tunnelling programme Specified unprecedented risk-sharing provisions Provided a unique dispute resolution clause	
2. Pier	Allowed redesigning the pier Influenced the original designer to cooperate with the redesigner	
3. Building		Owner's concern was on hotel building; paid less attention to the office building It was a design-build project
4. Bridge		The owner's physical involvement was high, but in terms of input, timely decision making or risk sharing, the owner's commitment was minimal
5. Building	Set specific demands for the high quality of the product Established a sizeable internal construction management group and played a leadership role Departing from the conventional contractual practices, directly hired many consultants including a structural engineer	
6. Dam	Designed the project Took the risk of applying RCC to a new area with an untested construction method Furnished the mix design to the contractor	
7. Paving	Led the contractors by pledging to give them demonstration projects and market for new product Designed the project	
8. Pipeline	Specified very demanding project requirements Allowed the designer to specify the 5 foot diameter steel pipe, tolerating many complaints from domestic manufacturers Allowed the contractor to implement new ideas, even against the advice of its designers	
9. Building	Invested heavily in the opening stages Encouraged the designer to investigate several different design options Sponsored designer's extensive R & D	
10. Bridge		Was only responsive to the new ideas initiated by the designer
Total	Seven owners	Three owners

the structural engineer suggested a composite column design that required world-record concrete strength, the owner was willing to look at this creative design.

Thus, as Table 2 shows, it is not coincidental that most owners (i.e. seven) in the ten innovative projects displayed high levels of both involvement and commitment. Then, a question arises regarding what made these owners exhibit such high levels of involvement and commitment. The answer may lie in their technical competence.

Owners' technical competence

Constructed products are generally costly and they have serious consequences of failure. These characteristics may be responsible for the owner's technical conservatism. Sometimes, however, conservatism stems from a limited knowledge of the technology in question; thus, the ability to understand the technology usually alleviates the conservative attitude and sometimes even leads to an unusually progressive stance.

Indeed, the seven owners who displayed high levels of involvement and commitment also maintained a high level of technical competence. This took diverse forms.

1. Maintain sizeable construction management groups internally (cases 5, 8 and 9).
2. Retain a capacity for internal R&D and design the project themselves (cases 6 and 7).
3. Devise some means to supplement their technical competence (e.g. by establishing a technical review board in case 1 and hiring many consultants in the majority of cases).
4. Maintain a rich history of innovation (in case 7): the owner is proud of the organization for being one of the most progressive and envied transportation departments in the nation and in the world.
5. Possess not only technical expertise but also professionalism (in case 2): 'The Navy has more than enough understanding of the pier technology and engineering process involved in the innovation to realize the advantage of our idea of total redesign – despite the complex bureaucratic process the Navy has to overcome' (R.C. Koch, personal communication).
6. Maintain long-term relationships with the same designers or contractors and allow them to perform R&D sometimes at the owners' expense (in cases 5, 7 and 9).

From the experience of the seven successful innovation cases, the authors believe that the owner's technical competence has a close link with their active participation in the project execution or at least to a better understanding of the technical matters for timely approval of innovative ideas.

Leaders and champions in the driving-force and technical-collaborator organizations

In one sense, all innovations depend on individuals. In many cases in this study, it seemed likely that the absence of one specific person would have prevented or delayed success. These individuals were described by other professionals involved in the innovation as 'champions.'

From the data in Table 3, it appears that in the successful process of construction innovation it is necessary for single individuals to fulfil diverse functions – possessing, at least, power and technical competence. In eight cases out of ten (the two excluded are cases 1 and 6), managers with the authority for approval of key ideas in the construction innovation had a high level of technical competence. In other words, the managers involved in construction innovations were the engineers who brought up the basic concepts for the key ideas. They devoted substantial time not only to discussion of technical matters, but also to detailed design.

For example, the executive vice-president and founding partner of a structural engineering firm led the structural innovation in case 5. It seemed to be one of the unwritten policies of the firm that top managers got personally involved in the actual design. The executive vice-president did not just manage his subordinate engineers to find solutions, he also initiated and developed the solutions.

A manager with extensive experience in marine construction was hired from a marine-speciality firm to be a vice-president of a marine general contractor. This manager took responsibility for preparation of the estimate for a naval pier project (case 2). In order to obtain technical advice regarding his idea of using larger piles, he soon contacted a structural engineer, with whom the marine general contractor had a long-term business relationship. The project engineer in the structural engineering firm contrasted the contractor from others with whom he had worked. He observed:

> I think the top management of this firm is not only aggressive in the sense that they always pursue something new, but they have enough experience to understand the technical problems and to come up with some good ideas. Some contractors come to us with an idea that does not have anything behind it except their wish to simplify things (V.M. Buslov, personal communication).

In an outfall pipeline project (case 8), the project participants agreed that most of the credit for the innovative construction method should go to the project manager of the general contractor. He organized pieces of available technology, brainstormed the details with fellow employees and convinced the owner regarding the benefits of the innovation despite the objections of the designer. He illustrated the importance of an active information seeker or a 'gatekeeper': it was his daily habit to seek and preserve technological information. He subscribed to more than a dozen speciality magazines and spent much time reading these to identify

Table 3 Champions in the driving-force organizations: their position and their technical competency

Driving force	Project number	Position of the champion in the firm	Technical competence
Designers	1	Partner	Initiated the idea of turning vertical-concrete piles 90°. (He backed up the development of that idea persistently but later retired)
	4	Founding partner Chairman of the board Technical director	Has over 37 years experience in the design of pre-stressed concrete structures Supervised the design and construction of over 80% of the pre-cast concrete segmental bridges in France Designed 18 of the last 21 bridges built to cross the Seine River in Paris, France
	5	Founding partner Executive vice-president	PhD in structural engineering With pencil in hand, he initiated and developed the design
	9	Founding partner Chairman of the board	In the past 35 years, has personally been responsible for the structural design of many of the significant structures in the US including the New York World Trade Center In 1965, was the only structural engineer elected in the first election of the National Academy of Engineering
	10	One of the founders Honorary chairman of the board	Had tried to put cables in everything that he could possibly put them in. Indeed, he has been the driving force of the firm's many innovations associated with cable technology Is one of the most respected engineers in the US and is called the father of pre-cast concrete in the US
Contractors	2	Vice-president	Such extensive experience in marine construction as to be scouted to be a vice-president of the company
	3	Executive vice-president	Performed the role of executive champion as well as the role of key engineer Orchestrated the team effort of various organizations Was personally involved in the conceptual design phase
	7	President	Was neither an experienced professional in concrete technology at the beginning of the innovation process, nor an engineer by formal education. However, gradually he became a technical expert who led the innovation process Put his hands in the concrete mixes throughout the experiments
	8	Project manager	Was persistently collecting fragmented, obscure and seemingly trivial scraps of information, which is not usually regarded as a suitable job for a person at the project manager level
Owner	6	High authorities of the Corps of Engineers in Washington, DC	Were apparently well aware of the technology of RCC and of a RCC-paving machine The high authorities dictated the innovation in this case

potential benefits of new technology. This innovation represents a good example of success through the persistent collection of fragmented, obscure and seemingly trivial scraps of information – which is not usually regarded the job of a project manager.

The project manager of the structural designer for a soft-ground tunnel project (case 1) hinted at an important factor that forced him to develop the new tunnel design: 'It was his idea that we should consider turning vertical-concrete piles 90 degrees. He was one of our firm's partners at that time and backed up the development of that idea persistently' (L.J. Holloway, personal communication).

In a bridge project (case 10), the top management of the structural engineer decided to use a tie system during the schematic design phase. It is not clear who initiated the idea of using cable as a tension tie and who approved this idea. As a result, the processes of idea generation and decision making were hazy. However, the project engineer of this firm speculated that it was the honorary chairman himself who initiated the idea at the start of the design process, because usually he was actively involved in major technical decisions.

There is no doubt that the major driving force of the innovation in a high-rise building project (case 9) was the chairman of the structural engineer. It was evident that he had authority for important decision making and a very high level of technical competence. He was one of the founders of the firm. In the previous 35 years, he had been personally responsible for the design of many significant structures in the US, including the New York World Trade Center. In 1965, he was the only structural engineer elected in the first election of the National Academy of Engineering. Again, in this case, it was the chairman of the board who initiated the innovation.

The authors believe that an exceptionally high level of technical competence enabled the top persons to overcome the uncertainty of construction innovation. The authority of their positions also enabled them to overcome the resistance to innovation. Had they not possessed these two – technical competence and authority – together, the authors suspect that the innovations would not have been possible. Our findings illustrate important characteristics that make a person a leader in an innovative firm.

Qualifications of champions in construction

Regarding the role of 'champions', however, the authors feel that it is necessary to make some careful qualifications. Most top managers in construction say that their innovations usually develop from experience on past projects. This statement highlights just how important incremental innovation is in this conservative industry. The underlying requirement is the technical proficiency of people, accumulated from past project experience.

Managers in design or construction firms surely recognize the importance of quality people for innovation. Nevertheless, many do not seem to recognize other important factors that supplement and develop the quality of people. To some degree, the authors believe it is a myth that construction innovation comes primarily from the brightest construction professionals who have strong educational backgrounds or the most extensive experience. Except for the fact that they generally had experience on several earlier projects that employed similar technologies, there was little evidence that these persons are superior in educational backgrounds or experience. Two other factors appeared critical in making them innovative.

Champions with slack resources

One prerequisite for innovation is slack resources – either in the form of time or funds. The question should not be whether slack should exist, but rather how much slack should be permitted. Excessive slack resources can rapidly increase costs and deteriorate a firm's competitive position. On the other hand, a lack of slack resources may also ruin a firm's competitive position because costly out-of-date technology cannot compete with improved methods and materials. It is a strategic decision of management to provide a certain amount of slack resources to their employees.

In construction, however, management attitudes to innovation are often ambivalent. An organizational culture of 'innovation' may be manifested through the official company brochures which often contain such slogans as 'our bread-and-butter engineering is innovation' or 'we pool the most innovative design professionals in the country' and so on. Nevertheless, the subculture manifested by the construction professionals' daily practice is that, because of the uncertainty it brings, innovation may be viewed as a threat. The construction industry is conservative. Certain pressures and forces make for stability; the accepted norm is 'do what the clients want to do' or 'cling to a proven way'. Slack resources are rarely permitted. While considering themselves favourably inclined towards innovation, management actually tends to take steps to thwart innovation.

The cases in this study illustrate success stories in which managers in progressive firms decided to provide slack resources for innovation. Strategies in these firms emphasized product development rather than cost cutting. Of course, all innovations require professionals with time and money, but in many successful cases of construction innovation, the availability of these resources stands out as especially important.

To person phenomenon in construction innovation

Because the resistance mentioned above, active or passive, explicit or hidden, must be overcome, successful innovation often owes much to dedicated top managers who commit themselves personally to pushing a project through. In our study, this additional key factor for successful innovations was indicated by the champions who held positions of authority as well as power beyond authority.

The authors found many examples of champions who held a position of authority or of sufficient power in most organizations identified as 'driving forces' earlier in this paper. Table 3 lists the individuals in the 'driving-force' organizations to whom people involved in the ten projects gave the most credit for the major ideas and the subsequent success of the innovations.

This characteristic of the champion in a position of authority or with power essential for the success of construction innovation parallels the concept of the executive champion in manufacturing. Nevertheless, one distinctive difference is that the role of the executive champion in construction cannot be separated from that of the technical champion and business champion or even from that of the integration champion who orchestrates the efforts of various champions in various organizations involved in the project.

This may occur because the role of power in the process of construction innovation increases proportionally with the newness and the scale of the project. Consequently, in the conservative construction industry, decision making tends to be centralized for projects involving extreme newness and large size. For these projects, a single person at the top may act as a technical champion, executive champion, business champion and integration champion. As Table 3 illustrates, in an overwhelming number of cases of innovation in this study, the technical and business functions were performed by a senior manager.

Many examples in our study attest to this interesting 'top person' phenomenon in the process of construction innovation. The chairman of the board and director of technology in a structural engineering firm (case 9) retained a high degree of control over activities regarding technological developments; he personally approved each detailed drawing. The executive vice-president of another structural engineering firm (case 5) remained closely involved with design. He was the initiator of the major ideas implemented in the innovation. He was also the contact person with the owner and the building code officials.

Leaders with technical competence

Why is it that top managers with the authority for approval of key ideas in construction innovation should have a high level of technical competence? The authors suspect that this necessity stems from the high risk of failure in the constructed product. For example, it is evident that one of the success factors of the innovation in case 8, an outfall pipeline project, was the risk-taking attitude of the project manager for the general contractor. Protesting the risky construction method he proposed, the project designer for the original concept even walked out of the project.

The authors do not consider the property of risk taking in construction solely in terms of an individual personality. In medical practices, for example, doctors do not believe in a so-called risk-taking attitude or a 'do it first, then fix it' mentality. Usually, it is not their personality, but, for the most part, the inherent nature of their jobs that makes medical doctors or construction professionals conservative. Imagine the extent of monetary loss if a 5 foot diameter, 10 000 foot long pipeline, 600 feet under the sea collapsed. The risks involved in exercising new technology in construction cannot be compared with those in manufacturing. This example of successful innovation indicates that a high level of technical confidence can overcome the high intrinsic uncertainty of construction innovation. The authority of the project manager's position also enables them to overcome the resistance to innovation. Had they not possessed these two characteristics – technical competence and authority – together, the innovation in this project would not have been possible.

Conclusions and practical implications

Owner's leadership

In manufacturing, the role of buyers in the innovation process is generally passive: they provide 'market demand' or 'potential needs' to which innovators actively respond. In construction, however, it is well known that the owner is not a mere buyer of the end product: the owner is one of the key players before and during project execution. Thus, the Business Roundtable (1981, 1982b) claimed that technological progress in construction requires the owner's involvement and leadership.

These empirical cases support this key role of owners. In most cases, the owner's risk sharing, commitment to innovation and leadership in project planning and execution seemed to be critical for the success of the innovation process.

Furthermore, the results of this research suggest that there might be a close relationship between the owner's technical competence and their active participation in the project or at least a better understanding of technical matters for timely approval of innovative ideas. In addition, the owner's important role as the leader of the project appeared to influence the project environment by encouraging more integration among project participants.

Leaders and champions in design and construction firms

Concerning the process of innovation, ever since Schumpeter (1942) recognized the significance of the role of the entrepreneur in reforming or revolutionizing the pattern of production, many researchers have stressed the importance of the role of key individuals. Quinn (1985) claimed that the existence of 'inventor/entrepreneurs' is a crucial factor in the success of innovative small companies. Langrish *et al.* (1972) and the OECD (1982) reported that in most small manufacturing companies, an outstanding person in a position of authority usually makes a special technical contribution to the innovation. Recently, the term 'champion' has been employed to refer to the individuals who lead the innovation process (Maidique, 1980).

Compared with these previous theories, one distinctive aspect of the findings from this study of ten construction innovations is that in construction such a top manager phenomenon was frequently found even in firms of substantial size. In many progressive design and construction firms in this study, which were generally medium sized or larger, technical ideas came from the top person. In other words, the top managers involved in the innovative projects were not only the managers of subordinate engineers, but themselves the genuine engineers who brought up the basic concepts of the construction innovation. This is different from the manufacturing industry where the ideas for innovation often start at the bottom of the hierarchy in medium- or large-sized organizations (OECD, 1982).

Technologically competent leaders

One of the important implications from a comparison of the findings with the theories in manufacturing is that top managers, from whom the engineers involved in construction innovations seek final authority regarding the use of the key ideas, need to be technically competent. Top managers who want to increase the rate of construction innovation need first to increase their efforts to maintain the technical competence required to initiate the basic concepts or key ideas for construction innovation. They need to devote time to continued learning about technical matters.

Managers of many construction firms recognize the importance of construction innovation in the reputation of the firm; thus, their brochures contain terms such as 'innovative' and 'innovation.' Despite this clear recognition of the role of innovation for the success of the business, many managers, in particular high level managers, appear to have a limited view concerning their roles in the innovation process. They no longer see themselves as engineers who actively make technical decisions; they claim that their roles as managers prevent them from being personally involved in engineering. The belief in the supremacy of management (including marketing, customer contact and management of R&D) over engineering appears common in design and construction.

The authors do not deny the vital need for management to allocate resources effectively for the successful process of construction innovation. It is the managers' role to oversee the gatekeeping process and have various kinds of intrafirm technology blended effectively, updated continuously and used to spawn other hybrid technology internally. However, exclusively focusing on these duties may lead to ignoring the peculiar demands of construction innovation. Failure may only mean losing profits in manufacturing, but in construction, failure often means going out of business. The risk of failure is higher in construction; a trial-and-error approach is not acceptable. Consequently, a high level of manager's understanding of all technologies employed in innovation is required. While their good management practice is a supplementary condition, their technical competence is a necessary requirement for the successful process of construction innovation.

Providing champions with resources and power

The authors also agree that advocating the volition and persistence of the champion has some merit. However, construction professionals should not be misled by the careless adoption of the champion stories from the manufacturing industry without recognition of the differences in construction. Rather, practically speaking, construction researchers should provide construction professionals with an increased understanding of the qualifications for construction champions. This should not be based on the discussion of individual personality, but the understanding of the level of power, technical competency and resources an individual may have.

Findings from investigations of manufacturing point out that a conducive attitude and commitment of top management towards innovation is critical for success. In addition, it seems that for the engineering and construction industry a higher level of technical expertise and technical commitment of the top management is an essential precondition for the success of construction innovation. Top executives in innovative firms appear to assume responsibility actively for technological decision making and have sufficient technical expertise to do so.

The authors suggest characterizing construction champions as well-prepared individuals who not only have extensive experience but also adequate resources and power. Giving power to employees and creating slack resources is not an easy decision in the highly competitive construction market; it requires prudent management based on a long-term strategy. To give technical discretion to employees appears to loosen control of a business and may undermine the reputation of the firm. This is why construction firms are reluctant to provide power and slack resources to employees. However, the ten successful innovations in this study suggest that managers should do this if they want to make their firms innovative.

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