Noncontractual Methods of Integration on Construction Projects

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Abstract: Several progressive engineering and construction firms are now working to overcome the well-recognized problems of disintegration. One critical problem is the adverse consequences for technological advancement. Familiar and new forms of contracts, such as design-build and partnerships, are one way to increase integration. Organizational and information integration offer other alternatives to improve coordination and efficiency. Based on investigations of several recent construction innovations, this paper describes four noncontractual means of integration on construction projects: (1) Owner's leadership; (2) the long-term relationship; (3) employing integration champions; and (4) the professionalism of project participants. Providing real-world examples of construction innovations, the paper describes how each method helps overcome disintegration. The conclusions and practical applications highlight the need for new forms of integration, the feasibility of using noncontractual means, and the significant benefits of these means. The applications include actions by government agencies, owners, contractors, and educational institutions to increase the frequency and benefits of noncontractual integration.

Introduction

To increase the rate of innovation in manufacturing, many researchers suggest that it is no longer enough to design first and do manufacturing engineering and quality control later (Quinn 1985; Putnam 1985). Traditional concepts of departmental and functional organization are now not appropriate in manufacturing. Simultaneous collaboration of specialized functions—the integrated manufacturing concept—is a way to bring manufacturing engineering, quality engineering, and test engineering to the design process from start to finish (Quinn 1985; Putnam 1985).

Whereas product and process designs are becoming integrated in manufacturing, in construction, product design is often completely separated from production process management. Separating the two functions has significant effects on the use and development of construction technology. The low degree of integration between design and production functions in the fragmented construction industry appears to be a major factor limiting the size and rate of innovation ("Integrating Construction" 1982; O'Connor and Tucker 1986; Tatum 1987).

Thus, integration of design and construction appears to provide a major opportunity for advancing technology on construction projects. For current practices, for example, design and construction integration appears easiest to achieve on design-build projects. However, in most public construction projects where the negotiated design-build contract cannot be used, there may be other arrangements conducive to integration.

This paper reports part of the findings from a study of construction in-

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novation sponsored by the National Science Foundation, Lehigh University, Bethlehem, Pennsylvania (Nam and Tatum 1989). The focus of this research was how innovations come about in the U.S. construction industry. More than 90 industry professionals involved in recent innovative construction projects were interviewed. They were selected based on the presence of a qualitatively different constructed product, technological significance, and publication of the project in more than one source.

One major finding of this research was that a high degree of interaction between the design and production functions was closely linked to successful construction innovation. The investigation found that some contractual arrangements and clauses appeared to stimulate collaboration among the parties involved.

A more important finding, however, is that although contractual improvements can effectively achieve project integration, some noncontractual means appear to offer even greater potential for integration. These means include: (1) Owner's leadership; (2) the long-term relationship between organizations; (3) employing integration champions; and (4) the professionalism of project participants.

In this paper, the writers differentiate disintegration from fragmentation. The term fragmentation represents too many small firms and too much specialization in the U.S. construction industry. In contrast, with a vertical view of production, the writers use disintegration to depict the results of incongruent goals and consequent divergent behaviors of various organizations participating in a construction project.

Historical and Cultural Reasons for Lack of Integration

The structure of the construction industry has risen largely in response to the demands placed upon the industry. Specialization is necessitated by many product characteristics, such as complexity, continuously changing technology, and custom-built nature, and by the great variety of product types (Cassimatis 1969; Rossow and Moavenzadeh 1974). Also, the history of construction-related regulations suggests that constructed products are highly related to public safety and health, comprise a major part of the human environment, and are subject to immense social responsibility (Knowles and Pitt 1972; Garnham 1983; Harper 1985).

Recently, the disastrous collapse of structures, automobile accidents due to highway design, and serious accidents at nuclear power plants are causing increased emphasis on social responsibility in producing constructed products. The growing attention to environmental protection also increases awareness of social responsibility.

The consequences of an emphasis on social responsibility are ultraconservatism, the proliferation of government regulations, and the need for checks and balances (or distribution of responsibility) among various team members. The need for specialized knowledge and checks and balances has led to the separation of design and construction functions (Nam and Tatum 1988).

There are barriers that prevent integration, such as owners' resistance due to perceived extra costs; traditional roles of construction people, which make them unaccustomed to working in the design office; reluctance of architects and engineers to accept input from construction personnel, and lack of qualified personnel, training programs, and incentives; and unawareness of potential benefits ("Integrating Construction" 1982).

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In much of the U.S. construction industry, the established contractual system also dictates the separation of design and production functions. There are ways to overcome this, however, even in public works construction. A recent pier project illustrates integration to produce innovation (Nam 1992). The pier's original design used 36-in. (90-cm) diameter piles in an extremely complex configuration, including many batter piles. A general contractor, who formed a strategic alliance with a marine dredging firm that had a large capacity crane, won the job and submitted a redesign as a value engineering proposal, which called for 54-in. (140-cm) diameter piles. This redesign with heavier piles simplified the pile configuration, because no batter piles were needed.

The designer engaged by the contractor to redesign the pier commented on the original design (Valery M. Buslov, personal interview, February 24, 1989)

> The original design, which specified a forest of piles in various angles, looks like a nightmare for the contractor. But it was not the original designer's fault; it was because of the competitive bidding system that has a built-in fault. If I had been asked to do it using a conventional pile, I would have done the same design.
>
> Professionally, the original designer did what was expected under the circumstances, wherein the piles needed to be small enough to attract as many contractors as possible. They used 36 in. (90 cm): this one was the limit of normal contractors' capabilities.

It is evident that the state of construction process technology affects the design process in various ways. However, under the public bidding process, the designer cannot foresee who the contractor will be. Consequently, he is not aware of the process technology available to the contractor. This lack of information forces the designer to create designs feasible for construction by many firms. The obvious consequence of this practice is that the designer is reluctant to innovate, fearing that contractors will either refrain from bidding or will submit high bid prices.

Consequence of Disintegration on Project Environment

A designer is usually selected by the owner based on his or her professional reputation. The actual construction of a building is performed by the general contractor, who is usually selected through price competition. Once the contract is awarded on a fixed-price basis, the contractor may have incentives to decrease production cost by using innovative methods or equipment, but there is little inducement for him to improve quality.

The two entities are living in different worlds: the designer's world of reputation and the contractor's world of price competition and cost reduction. This divergence of goals typically leads to a lack of cooperation or even an adversarial relationship between designer and producer. Although new ideas in design can often be introduced with new materials or methods of construction, continued coordination between these two occupations in the whole process is difficult. This helps make a potentially dynamic industry technologically rigid (Nam and Tatum 1988).

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Technological Consequence of Disintegration

To provide maximum benefit for the owners from contractors' price competition, the designer usually considers the prevailing construction practices in the design and avoids setting specific methods that may benefit particular contractors. The obvious consequence of this is that the designer is reluctant to introduce new construction materials and methods. Thus, prevailing construction process technology is one of the forces that often restricts innovation by the designer.

Construction innovation is, almost by definition, achieved through a collaborative effort, and it is difficult to disentangle the roles played by particular individuals or organizations involved in the project. The project environment collectively created by those people or organizations could be a setting for innovation; the project environment exerts an enabling, as well as a limiting, effect on the creativity of the people or organizations that work in it. For example, some kinds of individual initiative would not be possible except within a favorable environment. Creative ideas should supplement one another. A design firm's innovative design often requires nonconventional process technology from a contractor.

Often, new design ideas can be introduced only with, or from, new materials or methods of production. Construction process technology is one force that motivates or restricts the designer. But under many forms of contract, the contractor does not have incentives to cooperate with the designer during the design or the production stages.

Current Efforts Toward Integration in Construction

In an effort to correct the consequences of disintegration in the U.S. construction industry, how to integrate design and construction functions has been discussed considerably.

Means for Integration

Many means for integration have been proposed and extensively used. For example, the construction management approach (Barrie and Paulson 1984), the negotiated contract method, the design-build approach, and constructibility improvement programs (Tatum et al. 1985; O'Connor and Tucker 1986; Tatum 1987) focus on cooperation between the designer and the contractor in integrating a project, as does manufacturing. Using emerging computer technology, many researchers aim to streamline information processing among various organizations participating in a construction project (Wilson 1987; Teicholz 1989; Howard et al. 1989; Sanvido and Medeiros 1990).

At least three means of integration exist in the U.S. construction industry. They are different in terms of goal congruency, organizational boundary, and information processing environment:

1. Organizational integration of design and production functions physically in one organizational boundary under common leadership (i.e., a vertical integration).
2. Contractual integration between different organizations for a relatively short time (e.g., during a project). This is to achieve a high level of goal congruency within the project team (i.e., project integration).
3. Information integration within an organization or across organizations to increase coordination and efficiency (e.g., integrated computer technology).

Organizational Integration

On many construction projects in the United States, the participants are independent of one another and are brought together only to be disbanded once the project is completed. The outcome is the dispersion of the management function for a project among many independent participants. This may result in less efficient coordination, organization, and operation of projects than might be possible if these participants were more closely tied together in a vertically integrated firm.

There is, however, an increasing tendency toward some vertical integration, such as architect-engineer design firms and design-build firms, especially in the larger corporations specializing in industrial construction (Cassimatis 1969; Rossow and Moavenzadeh 1974; "Design-Construct" 1988).

Major advantages of the design-build approach are close cooperation between design and production from start to finish and the possibility of using the fast-track construction method. Also, from the design-build firm's point of view, learning can be accumulated more rapidly. Arguments against such vertically integrated firms include the owner's limited flexibility in putting together a design-production team.

Contractual Integration

One early advocate of contractual integration was the Business Roundtable. Based on the degree of involvement of construction expertise in engineering, they identified three categories of integration, minimum, average, and thorough ("Integrating Construction" 1982).

The construction management approach is an outcome of various efforts to improve the construction delivery system. Although it has several variations, the essence of the concept is the introduction of a new participant, a construction manager, who has construction know-how and serves as the owner's agent from the initial planning stages through the end of the project.

The construction management approach is a promising development and certainly represents a viable alternative to traditional project-delivery systems. However, there is no evidence yet that this approach has a clearly positive impact on project integration. It is also doubtful that it will ever totally replace the traditional contractual systems.

Information Integration

The literature shows an emerging interest in integration design and construction operations using advanced computer technology. The discussion centers around increasing efficiency by developing a common data base that is accessed, used, and updated by multiple users.

Though information processing technology is increasingly used in many engineering and construction firms, it appears to be too immature to strongly influence project integration. Proof is needed to support the claim that implementing advanced information processing technology is a major factor increasing project integration. Obviously, information integration alone is insufficient to overcome disintegration. It should be augmented by other means.

Requirements for and Benefits of Integration

Paulson (1976) first identified a close relationship between expenditures and the impact of decisions (termed cost influence) during the design, construction, and operation of a facility. Since then, others suggested an early construction involvement in the design process, since early decisions have

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the greatest influence on total project cost ("Integrating Construction" 1982; Tatum et al. 1985; Tatum 1987). These benefits can extend to operation and maintenance.

Integration is frequently carried out through a constructibility program—the planned involvement of construction in the design process. As an important means to decrease the capital cost of new facilities, the Business Roundtable ("Integrating Construction" 1982) suggested improving constructibility by integrating resources and technology into design.

The Business Roundtable reported cost and schedule reduction as the benefits of integration. Integration could, they argued, improve the design and construction relationship, optimize design details and sequence to meet construction's needs, incorporate the latest appropriate construction technology into the design, develop work-simplifying methods, and minimize labor-intensive designs.

O'Connor and Tucker (1986) studied constructibility improvement for a major refinery project. They identified several improvements: construction-sensitive designs, effective communication of engineering information, optimal constructor-originated techniques, effective construction management standards, vendor or subcontractor service improvements, and constructor input to design.

Criticism of Past and Current Attempts to Achieve Integration

Suggested solutions, such as using negotiated contracts, professional construction management methods, and constructibility improvement programs, are an effort to integrate design and production by promoting the exchange of information. However, there is no quantitative evidence to convince the owner to take these suggestions and relinquish the possible benefits of a competitive system. Whether the possible advantages of promoting cooperation between designer and contractor, especially in a negotiated contract approach, outweigh the advantages of competitive bidding remains open.

Also, most suggestions call for some type of contractual modification. They require certain contractual arrangements that encourage the reconciliation of designer's and contractor's conflicting objectives as well as some contractual clauses that foster the exchange of information among parties involved in the projects. It appears that major efforts in the U.S. construction industry toward integration have focused on contractual issues.

Research on Link between Integration and Innovation

When the writers started the innovation research, they tried to examine the effect of project integration through contractual arrangement upon construction innovation. Their hypothesis stated that innovative construction projects have certain types of contractual arrangements that encourage the reconciliation of the project participants' conflicting objectives as well as some contractual clauses that foster the exchange of information among the parties involved.

To prove the latter statement, the writers tried to identify contractual arrangements and clauses associated with innovative projects. They expected higher use of negotiated design-build contracts, design-build competition approaches, professional construction management methods, or constructibility improvement programs for the innovative projects.

As shown in Table 1, a majority of the innovations investigated in this

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TABLE 1. Environment of 10 Innovative Projects

Case number (type) (1)	Contractual arrangement (2)	Special clauses extensively used (3)	Input of process technology during design (4)	Project environment (claims) (5)
#1 Public	traditional	dispute review board risk sharing test bore	constructibility study by tunnel review board	cooperative (not adversarial) (claims resolved by dispute review board)
#2 Public	traditional (later, similar to design-build)	value engineering	—	harmonious: contractor even directed what designer hesitated to do
#3 Private	design-build	—	—	harmonious: contractor hired designer
#4 Public	traditional	—	—	adversarial between owner and contractor (claims resolved within project)
#5 Private	negotiated with contractor	—	preconstruction service by contractor	harmonious
#6 Public	traditional	experiment	constructibility study inside owner's organization	cooperative (not adversial)
#7 Public	traditional	—	contractor developed new mix that owner later specified in contract	harmonious
#8 Public	traditional	—	—	adversarial between contractor and designer
#9 Public	negotiated with contractor	research and development for designer mock-up	preconstruction service by contractor	harmonious
#10 Public	traditional	—	—	cooperative (not adversarial)

study seemed to benefit from a cooperative project environment: Out of ten, there were only two innovative projects that suffered adversarial relationships between participants. The authors did find evidence of integration through various contractual means, such as negotiated design-build contracts or constructibility improvement programs (i.e. cases 1, 2, 3, 5, and 9).

Among the ten innovations investigated in this study, however, two cases of integration (cases 6 and 7) appeared to result, in part, from noncontractual means. Our study also included seven public projects on which traditional contractual arrangements were required. In those projects, special clauses were often used. Nevertheless, those contractual provisions for project in-

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tegration would not have functioned well had they not been augmented by other noncontractual means (cases 2, 3, 5, 6, 7, and 9).

NONCONTRACTUAL MEANS FOR PRACTICAL INTEGRATION

The noncontractual means the authors found common across the integrated projects were:

- Owners' involvement and leadership.
- Establishment of long-term business relationships between organizations.
- Employing an integration champion.
- Professionalism of participants.

These means are not at all systematic, nor is there any guarantee that they will always promote innovation on a project. Considering the low probability for a radical change in the contractual system of U.S. public construction projects, however, these means are worth trying. Thus, the writers call the integration achieved in a project through these noncontractual means a practical integration. The following briefly describes these means.

Owner's Leadership

In a Naval pier project (case 2), a contractual integration was achieved with the contractor hired a consulting firm to redesign the project. The integration between the redesigner and the original designer, who reviewed the redesign, was not based on contractual arrangement. Nevertheless, cooperation between the redesigner and the original designer started from the very beginning of the redesign. The original designer released design data to the redesigner. This included not only the fixed prominent design criteria but the derivative design criteria such as berthing and moving forces. The project manager of the contractor evaluated the relationship between these two designers (Walter Reichert, personal interview, February 23, 1989) "It is usually a big problem in the value engineering process. Usually original designers get upset when someone changes their work; there is usually an adversarial-type relationship. But in our project, they worked together surprisingly well."

The review process could have been tense, considering the original designer was reviewing a redesign of its own work. Instead, there was cooperation and teamwork throughout. The vice president of the original design firm explained why they cooperated with a competitor in the local market (Joseph Bonasia, personal interview, February 22, 1989)

> We could give them a hard time if we wanted to . . . In fact, however, some of the high ranking people in the Navy, an Admiral, frequently called us and informed us that they would appreciate if we cooperate with the redesigner to save the Navy's money by coming up with an innovative design . . . It's a small business. So satisfaction of a client is the number one business strategy.

This case is a notable example of how the owner's leadership, not only in the initial stage as suggested by many constructibility studies but during project execution, could influence project integration. Having future projects as a powerful tool, owners in this study, whether they were private firms or government agencies, often took a key role in encouraging construction professionals to maintain long-term perspectives and business strategies. These appeared to create a harmonious project environment. With only short-term interests, people might have behaved opportunistically.

Therefore, it is not a coincidence that a majority of innovative projects in our study exhibit a high level of owner involvement. A common feature of the owner's involvement is his role as a link among various organizations involved in the project.

Long-Term Business Relationship

Maintaining long-term business relationships between different organizations, often without any clear legal binding, appears vital in fostering an integrated environment and, thus, a successful innovation process. For example, a high-rise concrete building project (case 3) used the design-build approach. The project team developed a ductile moment-resisting concrete frame for the building core, which was the first such structural system ever implemented in a high seismic region. The contractor hired a structural engineer with whom the contractor had maintained a long-term business relationship. Only because the structural engineer was familiar with the process technology the contractor developed for concrete construction—an efficient block-out forming method—could the structural engineer conceive the idea of putting holes in the concrete shear wall. Subsequently, constructibility was fully examined by integrating design and construction expertise. The integration between these two firms that enabled the innovation was based on a contractual arrangement and a long-term business relationship.

Learning is not just a phenomenon at an individual cognitive or organizational level but in a network of organizations. One advantage of long-term relationships between independent organizations seems to be the development of relatively informal bonds that facilitate interorganizational learning. Without the interorganizational learning already accumulated, the innovation in this case would not have been possible.

Similar examples of interorganizational learning were also found in cases 5, 7, and 9. Therefore, in some of the innovative projects in this study, the success of an individual organization appears not to be primarily contingent on its own action but on the collective ability of a large group of independent organizations to jointly create a valuable result.

The development of an effective team, a cooperative working frame, does not seem to be possible if every participant acts opportunistically. Instead, trust was strongly emphasized; this seemed to lead to a contract based more on trustful relations than on price competition. These organizational networks seemed to foster the development of a higher degree of cooperation, flexibility, and effectiveness.

The building code authorities could also be involved with interorganizational learning. More than simply regulating, the authorities can participate in innovation. For example, prior to another high-rise building project (case 9) that involved developing high-strength concrete, the building code officials maintained a long-term relationship with the structural designer. The city kept track of previous high-strength concrete developments by the designer. As a result, the officials could actively participate in the mock-up project, and even significantly contribute to the development of a quality

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control procedure for the consistent production and placement of 19,000-psi (131,000-kPa) concrete.

The public owner of a highway paving project (case 7), in which a fast-cure concrete was developed, supplied their knowledge and technicians in the development phase and provided a series of experimental projects. In developing the new material for this project, the success of the contractor depended, to a considerable extent, on the traditional cooperative environment between a local concrete paving industry association and the owner. Therefore, the innovation in this case was not the outcome of a single event but of many strands from the past.

This particular case indicates that integration of goals between public and private sectors cannot be obtained overnight. They need to establish a long-term working relationship or to have already established a history of co-operative relationships. It seems to take a significant amount of time for a government agency to establish a high level of confidence in contractors' technical competence and professionalism. It also takes time for the private sector to influence a government agency to make decisions based on a long-term perspective, which often translates into an effective innovation-oriented procurement policy.

Integration Champion

Three types of champions are critical to the success of an innovation process (*From Vision* 1985): (1) The technical champion who carries an idea from initial conception, through development, and into a viable product or process; (2) the business champion who provides a business framework for a technical idea; and (3) the executive champion who sponsors an idea at the highest level, using his or her power to protect it, to move it along, and to seize the opportunity to exploit it.

The characterizations of the three types of champions were derived from observations of the manufacturing industry. Construction differs from manufacturing in at least one distinctive aspect: Construction projects present significant coordination and integration problems. In the construction industry, there is an extreme specialization of functions. Because of this, innovation requires organized and deliberate efforts to achieve coordination among the various professions. Therefore, it is not wise to simply adopt the champion theories of manufacturing for construction, nor is it prudent to presume that the current system and culture of construction that causes difficulties in integration or coordination, whatever they are, is at fault.

In most cases in this study, many champions were identified. It is difficult, however, to adequately categorize the roles played by some key individuals in terms of the three types of champions. For example, the chairman of the structural design firm for case 9 initiated and developed his firm's contacts with the city building code officials, and he led the development efforts of a ready-mix concrete supplier. Both of these activities took place outside of the organizational boundary of his firm. A material consultant to the structural designer acted as liaison between the designer and the ready-mix concrete supplier to improve the flow of communication. A consultant to the contractor, a civil engineering professor, directed the mock-up tests while orchestrating the efforts of various parties, which included contractors, designers, material suppliers, testing agencies, city officials, and others, toward reaching an overarching goal.

These individuals were obviously more than technical champions. Their activities surpassed the three types of champions identified in the process

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of innovation within manufacturing. The writers argue that the underpinning characteristic of the roles played by the chairman of the structural designer, the material consultant to the structural designer, and the consultant to the contractor was integration or coordination of the efforts from various organizations, each having their own technical, business, and executive champions.

Many individuals in our case studies devoted themselves to the role of integration champion. The innovation in a highway paving project (case 7) would not have been possible without a decade of integration efforts by the local concrete paving association during the 1970s. The executive director of this association tried to promote a cooperative working relationship between the local concrete-paving contractors and the state and county engineers. He did that in several ways; one of the successes was the annual concrete paving workshop that he initiated. One top manager of the owner organization commented (John Lane, personal interview, April 2, 1989)

> This workshop grew from 100 registered professionals in the mid-1970s to 650 in 1988. This included 250 from the local concrete-paving industry and 400 state and county supervisors and engineers, equipment manufacturers, cement producers, chemical suppliers, and others.
>
> The workshop promoted a feeling of goodwill among participants. It was in this cooperative environment the executive director of the association had promoted between the owner and concrete paving contractors that enabled the team effort necessary for the innovation of fast-cure concrete.

Without these energetic individuals, whom we will call integration champions, a majority of innovations in this study would not have been possible. The integration champion facilitates interorganizational cooperation and learning. The concept of integration champion may be incorporated into a contractual arrangement. The dispute review board (case 1) and construction management contracts provide examples.

If, despite a growing tendency toward teamwork, individuals still stand out in cases of innovation in construction, it seems less because of technological creativity or the generation of new ideas than because of their ability to combine the technical creativities of various organizations. As constructed products become more complex, demanding sophisticated new technology and more specialists, individual integration champions who orchestrate the collaboration will be more important to innovation.

Professionalism

One of the most subtle factors contributing to practical integration seemed to be the professionalism of the people involved in the innovative projects. The term professionalism includes many attributes. One is a specialized knowledge and skill, based on training or education of exceptional duration, which enables a professional to offer a specialized service (*Competition* 1985).

Thus, genuine professionalism promotes mutual respect and trust on which people cooperate. The project manager of a public owner of a cable-stayed bridge project (case 4) said, "It is hard for anyone not to admire the structural designer in this project. He seems to have all the solutions for the problems we face in the field." In the absence of any contractual obligation,

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respect and trust between professionals appears to be a strong motivation for cooperation.

A more distinctive characteristic of professionalism is commitment to a calling; that is, the treatment of occupational requirements as an enduring set of normative and behavioral expectations (Moore 1970). This commitment requires a high degree of integrity on the part of the practitioner in exercising his judgment on behalf of his client (Competition 1985). This attribute is one that a professional engineer examination cannot probe. Though the original designer of the Naval pier project (case 2) was somewhat influenced by the owner's leadership, they were more than receptive in the redesign process. The redesigner recalled the nature of the review process: "I have to give credit to the original designer. It had to be very difficult for them to have somebody invalidate their design by a method that was better and quicker . . . In this project, however, they were more than receptive; they took a professional attitude towards this redesign and review process" (Valery M. Buslov, personal interview, February 24, 1989).

From the time the original designer confirmed the technical feasibility of the proposal, they made every effort to support the value engineering. The contractor analyzed the reason why there was such a high level of continued cooperation between the two competing designers throughout the project: "The professionalism of individuals involved in this project was critical to the success . . . I consider professionalism not just being a P.E.; it is more than that. One aspect of professionalism is an ability to cooperate to perfect the whole project" (Robert C. Koch, personal interview, February 23, 1989).

Conclusions and Practical Applications

This empirical research indicated that a high degree of integration between design and production functions had a close link to a cooperative project environment and, thus, to the success of innovations on many construction projects. This investigation found that some contractual arrangements and clauses appeared to stimulate collaboration among the parties involved.

A more important finding, however, which more or less deviated from traditional means for integration, is that as effective as the contractual improvements in achieving more integration are, some noncontractual means for project integration do seem important for achieving innovation. Evidence from this study demonstrates that, despite unfavorable infrastructure, which should also be improved, practical integration on a construction project is still possible.

Early in this paper, the writers identified three major means for project integration in construction: organizational, contractual, and information. The writers would like to add a fourth means, noncontractual integration, as an important vehicle for achieving project integration and thus increasing the chance for innovation. The writers suggest that, while these four means of project integration supplement each other on construction projects, each means should be more carefully studied, developed, and refined.

The implication of these results, especially the finding of the essential role of noncontractual means for project integration, is that owners, designers, and contractors should each seek to identify situations that provide the opportunity for noncontractual integration. The typical contractual arrangement of U.S. public construction, separate design and construction, lowest bid, and fixed price, could be a hindrance to innovation (as in cases

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1, 2, 4, 6, 7, 8, and 10). Many cases in this research, however, demonstrated that progressive construction professionals induced innovation despite such barriers. There are many ways to innovate. Some designers and contractors exploited the opportunity, which appears to be a profound problem for others.

The methods of noncontractual integration do not represent major changes in firms or project operations, but the cases indicate that these means can contribute to significant innovation on construction projects. These means indicate the need for actions by managers to foster conditions supporting innovation. Creating them requires developing this experience in the firm, selecting personnel who will support integration, and considering these means in setting up project teams. Because noncontractual means of integration require these persistent actions, they will be hard for competitors to duplicate.

Another implication is that, in the process of innovation in public construction, a history of cooperation and a tradition of harmonious working relationships are major factors for success. Government agencies that do public construction can gain substantial benefits from genuine cooperation with construction industry professionals, although this is not achieved overnight.

In the majority of innovative projects in this study, there was one aspect that could not be readily reproduced in noninnovative projects: the professionals "got along" very well. The question is then how to increase professionalism in construction and nurture integration champions. Educational institutions may share the largest part of the responsibility for this long-term task. If the future of the U.S. construction industry depends on the extent of its technological innovation, professionalism and the study of integration champions, as much as technology itself, should be treated seriously. This implication may result in developing many ways of educating construction students in the importance of professionalism and leadership for integration.

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