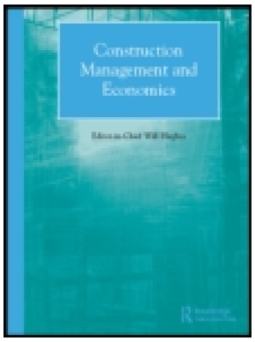

Construction Management & Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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Construction Management and Economics (2002) **20**, 621–631

Spon Press
Taylor & Francis Group

The construction industry as a loosely coupled system: implications for productivity and innovation

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Received 7 March 2002; accepted 13 June 2002

Previous research suggests that the construction industry is characterized by (1) particular complexity factors owing to industry specific uncertainties and interdependences, and (2) inefficiency of operations. The aim of this study was to analyse the operations and behaviour of firms as a means of dealing with complexity. The observations made indicate that the industry as a whole is featured as a loosely coupled system. Taking this as a starting point, the couplings among activities, resources and actors were analysed in different dimensions. The pattern of couplings builds on two interdependent layers: tight couplings in individual projects and loose couplings based on collective adaptations in the permanent network. It is concluded that the pattern of couplings seems to favour short term productivity while hampering innovation and learning.

Keywords: Construction, loosely coupled system, productivity, innovation

Introduction

> The physical substance of a house is a pile of materials assembled from widely scattered sources. They undergo different kinds and degrees of processing in large numbers of places, require many types of handling over periods that vary greatly in length, and use the services of a multitude of people organized into many different sorts of business entity.

These characteristics of the construction industry were expressed almost 50 years ago in a well known study of the distribution of house building materials (Cox and Goodman, 1956). One of the conclusions of the study is that the number of possible permutations and combinations of specific places and entities is enormous, even for one product. The complexity of the construction operations and the subsequent problem solving capability needed are perceived as formidable. However, this problem is in fact solved over and over again as new houses go up in their millions. Similar opinions concerning the complexity of the industry have been expressed more recently. For example, Shammas-Thoma *et al.* (1998) discussed 'all those remarkable processes that enable the construction process to function at all'. Winch (1987) argued that construction projects are amongst the most complex of all undertakings. Gidado (1996) further emphasized this view by stating that there is a continuous increase in the complexity of construction projects.

These underlying conditions shape the industry's way of functioning and its performance. Now and then firms in the construction industry are blamed for inefficiency of operations (Cox and Thompson, 1997). Specifically, it has been argued that a short term perspective promotes suboptimization (Gann, 1996) and hampers innovation and technical development (Dubois and Gadde, 2000). A number of authors have argued that construction has failed to adopt techniques that have improved performance in other industries, such as just-in-time (Low and Mok, 1999), total quality management (Shammas-Thoma *et al.*, 1998), partnering with suppliers (Cox, 1996), supply chain management (Vrijhoef and Koskela, 2000) and 'industrialization' of manufacturing processes (Gann, 1996). It seems to be a common view among most authors that the construction industry would be better off to change its behaviour in accordance with the norms of other industries.

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ISSN 0144-6193 print/ISSN 1466-433X online
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190210163543

However, assume that Winch (1987) and Gidado (1996) are right in the statements about the particularities of construction complexity. If so, it might well be that management techniques that improve performance in other industries are not readily transferable to this context. If construction follows a different logic then it might even be a mistake to try to adopt management techniques applied in other contexts.

Aim and scope

The aim of this study was to analyse the operations and the behaviour of firms in the construction industry. The perspective chosen holds that the behaviour of firms can be seen as their attempts to cope with the complexity of construction projects. In this respect we suggest that the industry is to be regarded as a 'loosely coupled system' (Weick, 1976).

The construction industry as a loosely coupled system

Complexity in construction

Gidado (1996) argued that complexity in construction originates from a number of sources: resources employed, the environment in which construction takes place, the level of scientific knowledge required, and the number and interaction of different parts of the workflow. He distinguished between two main categories of complexity. One is related to 'uncertainty' and deals with 'the components that are inherent in the operation of individual tasks and originate from the resources employed or the environment'. The second type of complexity stems from 'interdependence' among tasks, and represents those sources of complexity that 'originate from bringing different parts together to form a work flow' (Gidado, 1996).

The uncertainty in the undertaking of individual activities has four causes: (1) management is unfamiliar with local resources and the local environment; (2) lack of complete specification for the activities at the construction site; (3) lack of uniformity of materials, work, and teams with regard to place and time (every project is unique); and (4) unpredictability of the environment. Obviously these characteristics make it difficult to apply a centralized approach to decision-making. Prevailing conditions call for decentralization of authority.

The second determinant of complexity is associated with operational interdependence in construction. Gidado (1996) pointed to three factors: (1) the number of technologies and the interdependence among them; (2) the rigidity of sequence between the various main operations; and (3) the overlap of stages or elements of construction. These conditions emanate from two characteristics of the industry identified by Eccles (1981). The first is 'the organization of the production work force into a variety of trades' and the second is 'the practice of subcontracting portions of a project to special trade contractors by primary contractors'. Both factors cause interdependence, which calls for coordination. The nature of these interdependences seems to favour local rather than centralized coordination.

The point of departure of this paper is that complexity emanating from uncertainty and interdependence sets the conditions for the behaviour of the firms in the construction industry. Below, we discuss some central features of the operations in construction.

Central features of construction

It has been argued that construction is inherently a site-specific project-based activity (Cox and Thompson, 1997). This view is shared by Shirazi *et al.* (1996), who concluded that construction is mainly about coordination of specialized and differentiated tasks at the site level. The emphasis on site-specific activities provides us with two central features of construction. The first is the focus on individual projects, in terms of decentralized decision-making and financial control. The prevailing organizational arrangements when it comes to responsibility and authority put the emphasis on the efficiency of individual projects, which makes sense as a response to the roots of complexity identified above. The strong reliance on localized decision-making is explained by the fact that management is unfamiliar with local resources and local environment. The second feature is the need for local adjustment at the construction site. These adjustments are necessary because of the three remaining uncertainty factors: lack of complete specification, lack of uniformity and an unpredictable environment. When these conditions prevail it is difficult (and even unsuitable) to develop components and systems tailored to the situation at specific sites. Therefore it is quite unusual for building materials manufacturers to develop products adapted to particular contractors or specific construction sites. The industry still relies on what Stinchcombe (1959) identified as standardized parts, whereas the use of standardized activities tends to be the norm in many other industries. The prevailing uncertainty makes the use of standardised parts an appropriate strategy, which is further reinforced by the benefits gained from increasing economies of scale in the manufacturing of building materials.

The complexity with respect to interdependences also seems to favour standardization, and thus local adjustments. Owing to the number and interdependences among technologies, customized solutions from one supplier would impact on other components and systems. The rigidity of sequences and the overlap of stages in turn make coordination difficult. It is most likely, therefore, that these conditions are better taken care of through decentralization and local adjustments than through centralized activities and customized solutions.

There are some other features of the behaviour of construction firms that need to be stressed. The strong emphasis on individual projects favours a narrow perspective, both in time and scope. Efficiency is supposed to be promoted by competitive tendering. Cox and Thompson (1997) found the perception of the actors to be that competitive tendering assures that subcontracting is carried out at the lowest possible cost. The strong reliance on competitive tendering explains the use of standardized parts. Adapted or customized solutions would be difficult to use while maintaining the current tendering procedures. Competitive tendering also sets the conditions for the relationship among the parties. Gann (1996) found that the relationships are often typified by market-based, short term interactions between independent businesses. In addition, Thompson *et al.* (1998) identified market-based interaction as the norm for the behaviour, and concluded that firms 'traditionally paid very little attention to the relational elements of business transactions'. The final characteristic of behaviour in the industry we bring up is the multiple roles of firms. The activity scope of a firm tends to be broad, including design, production and distribution in various combinations, which may also vary between different projects. The division of labour among the actors varies greatly from project to project and the role of the individual firm can be very different (Dubois and Gadde, 2000).

Loose couplings

Our second starting point is to regard the construction industry as a loosely coupled system (Weick, 1976). In this section we describe some important aspects of loose couplings. According to Orton and Weick (1990), any location in an organization contains interdependent elements that vary in the number and the strength of their interdependences. For example, every single industrial activity is to some extent interdependent with a number of other activities: they are coupled in various ways. Some of these couplings are 'tight' while others are 'loose'. Glassman (1973) discussed the degree of coupling between two units (events/elements/systems, etc.) on the basis of the activity of the variables that the two units share. If two units have few variables in common, or if the variables in both are weak compared with other variables influencing the two units, then they are relatively independent of each other and thus loosely coupled (Aldrich, 1980). Weick's (1976) characterization of loose couplings is that 'coupled events are responsive but that each event also perceives its own identity and some evidence of its physical or logical separateness'. The attachment among the events may be circumscribed, infrequent, weak in its mutual effects, unimportant, and/or slow to respond. Loose couplings may occur in a number of dimensions: among individuals, among subunits, among organizations, between hierarchical levels, between organizations and environments, among ideas, between activities, and between intentions and actions.

Weick (1976) analysed the potential effects of loose couplings, which may be functional and/or dysfunctional. In this section we direct our attention primarily to the ways in which loose couplings contribute to handling complexity in operations. First, a loosely coupled system may be a good system for localized adaptation where any one element can adjust to and modify a local unique contingency without affecting the whole system. Hence, localized adaptations may be swift, relatively economical and substantial. Second, loose couplings serve as buffering mechanisms against unfavourable conditions in the environment, so the organization as a whole will not have to respond to each little change in the environment. As Weick put it: 'loose couplings allow some parts of an organization to persist'. Third, loose couplings provide a sensitive sensing mechanism. This is a consequence of localized adaptation, decentralization and low extent of coordination. It is argued that loosely coupled systems preserve many independent sensing elements and therefore know their environments better than is true for more tightly coupled systems, which have fewer externally constrained, independent elements. Fourth, loosely coupled systems preserve the identity, uniqueness, and separateness of elements and may therefore generate variety. The system can potentially retain a greater number of mutations and novel solutions than would be the case with a tightly coupled system. The greater freedom in a loosely coupled system would imply that the actors deal with problems in a multitude of ways, thus favouring variety and innovation. Finally, in a loosely coupled system there is more room available for self-determination by the actors. According to Weick, it is likely that a sense of efficacy might be greater in a loosely coupled system with autonomous units than it would be in a tightly coupled system where discretion is limited.

Table 1 summarizes this discussion of the central aspects regarding complexity in construction, the central features of the industry conduct, and some important characteristics of loosely coupled systems. A loosely coupled system may cope with certain aspects of the complexity originating from uncertainty and interdependence, since its functions are characterized by limited central authority and low costs of coordination. The loose coupling, in turn, sets the conditions for the behaviour of the firms in the industry, which is an important issue for analysis. However, in suggesting that the construction industry features the functions of loosely coupled systems we must follow Orton and Weick (1990), arguing that the recognition of an organization 'being' a loosely coupled system is the beginning of the analysis, not the end. Researchers should not simplify the concept but invoke it: 'what elements are loosely coupled, what domains are they coupled on, and what are the characteristics of the couplings and decouplings?' (Orton and Weick, 1990).

Based on observation of the construction industry as 'behaving' like a loosely coupled system, it is thus fruitful to scrutinize the tight and loose couplings prevalent in it. According to Weick (1976), it is the pattern of couplings (tight and loose) that together produces the observed outcomes of a system. In the next section an attempt is made to further explore the pattern of couplings and shed more light on the interrelated complexity factors and functions of loose couplings.

The pattern of couplings in the construction network

For an analysis of tight and loose couplings we may begin with Figure 1, where a construction project is illustrated in its network context. The project may be considered as a specific temporary network within a more 'permanent' network. In Figure 1 firms A, B and C are all involved in operations at a construction site. Their input in the project comprises resources of various kinds (A1, B1 and C1). The firms are also involved in other projects in which they have to coordinate their activities and resources with (partly) different sets of other firms. For example, in Figure 1 firm C needs to consider four different dimensions of co-ordination: (a) within the individual project (C1 with A1 and B1); (b) among firms involved in supply chains (i.e. with D and E); (c) among different construction projects (C1 with C2); and (d) inter-firm coordination beyond the scope of the individual project (i.e. with A and B).

Coordination within construction projects

Owing to (1) the importance of time, (2) the need to perform and coordinate the activities sequentially, and (3) the specialization of actors, there are tight couplings between activities undertaken on site. According to Gidado (1996), this is one important factor that makes construction complex: '. . . in a rigid sequence of work flow, time or duration change in any specialist's work may affect the duration of others or even the overall production process duration. This sort of knock-on effect may also affect production cost.' Furthermore, the activities are not only sequentially interdependent but also organized in parallel sequences, i.e. stages or elements of the construction process are overlapping. According to Gidado this adds to the complexity: 'The overlapping of major elements of production is used by practitioners simply to compress or shorten the production time. In practice, this process is dictated by a number of resource-dependent factors. Even by considering these factors, overlapping may change the interdependence of activities (or trades in particular) within individual elements and also create a new structure of interdependences between the roles of the overlapping elements. These changes may increase the effects of

Table 1 Complexity factors, central features of construction and the effects of loose couplings

Complexity in construction			
Interdependence	**Uncertainty**	**Central features of construction**	**Effects of loose coupling**
Number of technologies and interdependences	Lack of complete activity specification	Focus on single projects	Localized adaptation
		Local adjustment	Buffering mechanism
Rigidity of sequence between the various main operations	Unfamiliarity with local resources and local environment	Utilization of standardized parts	Sensing mechanism
		Competitive tendering	Generation of variation
Overlap of stages or elements of construction	Lack of uniformity of materials, work and teams with regard to time and place.	Market-based exchange	Self-determination
		Multiple roles	
	Unpredictability of environment		

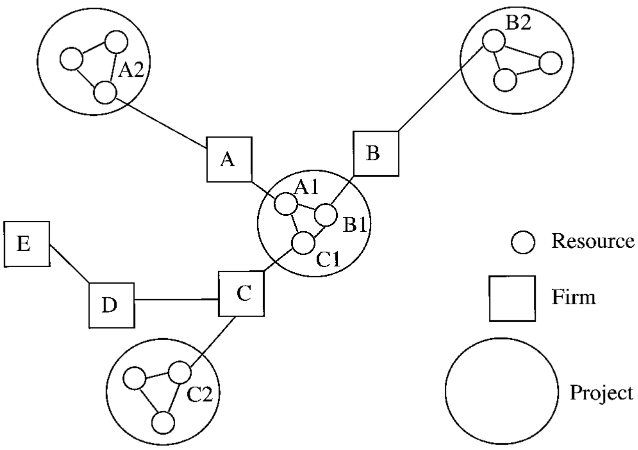

Figure 1 A construction project in its context (modified from Dubois and Gadde, 2000)

inherent complexity and uncertainty factors on project complexity.'

Another effect of the strong interdependence among the activities undertaken in every construction process is that the consequences of changes are difficult to assess and overview. In the 'Tavistock studies' it was found that: '. . .each time a design decision was taken it set in train a chain of consequences which could and did cause the initial decision to be changed, a clear example of how decisions and actions depend on one another' (Crichton, 1966, p. 17). These characteristics thus require tight couplings between the activities undertaken in individual projects.

Coordination within supply chains

Most of the 'input' resources used in buildings are standardized. Furthermore, the chain of activities, including transportation and storage, from the production of building materials to the site seem to be based on standardized rules. Typically, large orders are sent directly from the factory to the construction site, while smaller orders are delivered from the distributors' warehouses. Factory deliveries normally imply rather long lead times from order to delivery, whereas the distributor may be able to deliver on shorter notice. Hence, distributors provide 'slack' resources, and this is important when the exact volumes and timing are difficult to foresee, a difficulty that results from the very strong interdependence among activities carried out on site and that may result in delays.

Hence, the couplings in the supply chains in construction are both tight and loose. They are loose in terms of the coupling between the production of building materials and what is done on site; see e.g. Vrijhoef and Koskela (2000) and Akintoye *et al.* (2000). The loose couplings result from the rather long lead times and the 'slack' provided by distributors. The couplings are tight in the relation between the activities undertaken on site and the activities carried out in the supply chains. If the material has not arrived to the site when needed the whole production plan may be jeopardized.

Coordination within firms

Every firm involved in on-site activities has to coordinate its activities and resources among the different construction projects in which it is involved. The strong interdependences among activities performed at each and every site and the effects of any interdependence in terms of time extensions and delays implies that every firm needs some slack resources. If not, then the 'knock-on' effects from delays in one project would carry over to other projects. The (firm) internal coordination of activities undertaken and resources employed at different sites may thus even be subject to competition if the slack is not sufficient (Crichton, 1966). This is of particular importance to firms specializing in activities undertaken late in the process.

In addition, the firms may be specialized in terms of resources, but their roles may vary among projects and thus also their roles vis-à-vis other firms involved (Dubois and Gadde, 2000). Gidado (1996) referred to the learning curve concept, stating that the varying nature of interdependences or interfaces of roles of teams in construction may bring about the occurrence of any one or a number of inherent complexity and uncertainty factors: 'It is human nature to learn from experience and improve in future similar processes; therefore, when roles are repeated over and over by the same team, it is quite possible that the effect of . . . standard time or cost may decrease'.

Coordination among firms beyond the individual construction project

In construction, one and the same team very seldom (and then rather by coincidence than by conscious planning) works together in more than one project, and even if some of them meet in another project their roles vis-à-vis one another may have been altered. Hence, the couplings between activities undertaken at one site and activities undertaken at other sites are loose. Even less tight are the couplings between activities undertaken by different firms beyond the scope of an individual construction project.

Gann (1996) argued that difficulties in creating couplings outside individual construction projects have fostered the development of prefabricated standard components, i.e. the types of component that are produced without prior knowledge of some specific project. This relation probably goes both ways, i.e. the existence of standard components has made it unnecessary to develop customized solutions through the creation of couplings external to construction projects. Regardless of the direction of the relation, on-site, and thus localized, adaptations are very characteristic of the construction production system.

The mix of loose and tight couplings

The pattern of couplings in construction is characterized by tight couplings in individual projects and loose couplings in the permanent network. The loose couplings among firms make it problematic to apply the coordination mechanisms for handling complexity that are used in other business contexts. Typically, in most other industries uncertainty and interdependence are managed through tight couplings among firms. Relational exchanges and inter-firm adaptations are common means of handling these issues. By contrast, the construction industry is characterized by few inter-firm adaptations beyond the scope of individual projects, and firms tend to rely on short term market based exchange. These conditions also imply that the individuals in the project teams are recombined in each project, which further complicates coordination.

Considering the small number of firm-specific adaptations it is quite surprising that it is possible to create the tight couplings in the projects. The explanation is that the construction industry is characterized by certain ‘collective adaptations’ (Dubois and Gadde, 2000). For example, the standardized components and systems used have been developed through continuous collective efforts among material producers, contractors and the governmental authorities who prescribe norms and other conditions. Collective adaptations are formed in what can be identified as ‘a community of practice’ (Brown and Duguid, 1998). These authors argued that a great deal of knowledge is both preserved and held collectively. Collective knowledge is generated when people work together in tightly knit groups known as ‘communities of practice’. The claim is that this type of common practice promotes collective knowledge, shared sense-making and distributed understanding. A community of practice develops a shared understanding of what is done and how it is done. In this way a strong community of practice reduces uncertainty and serves as an informal coordination mechanism in loosely coupled systems. For example, Meyer (1975) argued that the school system in the USA works because everyone else knows roughly what is going on. The community of practice forms a common culture, which functions as a template for how firms perceive the environment. It also serves as a pattern for action and guides the behaviour of firms. Powell (1991) discussed the benefits of this type of shared expectations: ‘Shared expectations arise that provide psychological security, reduce the cost of information processing, and facilitates the coordination of different activities. Moreover, established conceptions of the way things are done can be very beneficial; members of an organization can use these stable expectations to predict the behaviour of others.’

The construction industry relies on a strong community of practice. Important aspects of this common practice are revealed in a study by Kadefors (1995). Governmental regulations have a significant impact on the design and construction of houses. Building codes, norms, and principles for housing subsidies impose requirements favouring certain standards. The regulatory system concerning the work environment and workers’ health and safety contributes to reinforcing the community of practice. The industry itself is also a source of formal standardization. The firms involved have established numerous forms of common contract formulas, which set standards in terms of operations, components, documentation, and work principles. Moreover, the tendering procedure requires that suppliers’ offerings are standardized. Without standardization, contractors would not be able to evaluate the different offerings. The generic roles of the participants in the processes of design, planning and construction are also standardized. Individual firms take on different roles in different projects. Therefore, the generic roles of designers, general contractors and subcontractors (plumbers, carpenters, etc.) must be similar in different projects. These roles are closely related to standardization of skills and knowledge, which follows from the existence of an informal control system. This is acknowledged in standard contracts, according to which the quality of the contractor’s work should conform to ‘current standards of workmanship’ (Kadefors, 1995). The need for formulations of this type stems from the difficulties in exactly specifying every detail of each task in the contract. Reliance on the standard of workmanship helps reduce the type of uncertainty described by Gidado (1996) as ‘lack of complete specification’. These conditions are important reasons for the strong reliance on decentralization of authority and the requirements for localized adaptations.

Discussion

The aim of this study was to understand the logic of the operations in the construction industry, and it has revealed that the behaviour of the firms differs considerably from what is common in other industries, particularly in terms of the absence of inter-firm adaptations. The industry operates similarly to what have been identified as loosely coupled systems (Weick, 1976). The pattern of tight and loose couplings can be interpreted as a means of coping with the prevailing complexity in construction operations. The tight couplings in individual projects combined with the loose couplings in the permanent network embedded in the community of practice make it possible to come to grips with uncertainty and interdependence. In particular, it appears that the loose couplings in the permanent network provide the slack necessary to handle the tight couplings in projects. Our discussion of the features of industry operations revealed six central aspects. The focus on individual projects, the use of standardized components, local adjustments, and the multiple roles played by firms allow both for handling complexity in individual projects and securing economies of scale in manufacturing. Our overall conclusion is thus that the behaviour of the industry seems to be an appropriate response to the inherent complexity of construction projects.

However, the central features identified also include competitive tendering and market-based exchange among firms. It is not clear whether loose couplings in these respects are necessary to attain the benefits of slack and flexibility. Therefore, a further exploration of the relationship between complexity and the nature of business conditions and exchange is the first topic of the discussion. Our findings indicate that the prevailing pattern of couplings seems favourable for the short term productivity of individual projects, whereas the long term effects are less obvious. The second issue for discussion is therefore the consequences implied by these couplings for innovation and learning in the permanent network. Finally, we introduce some potential features emanating from alternative patterns of couplings.

Complexity and the nature of exchange

Crichton (1966) found construction to be characterized by technical interdependence and organizational independence. The organizational arrangements in the industry are based on the assumption that dependence on individual counterparts should be avoided, because dependence might impose problems in various respects. This view used to be current in other industries as well, but it has gradually been abandoned through recognition of the advantages that can be gained from close relationships. Obtaining these benefits entails counterpart specific adjustments that, in turn, necessitates dependence on specific partners (Gadde and Håkansson, 2001). Therefore, it is most probable that development of close relationships in the permanent network would improve performance in construction as well.

Shammas-Toma *et al.* (1998) argued that the tendering system and the short term perspective are to blame for many shortcomings in construction, for example the problems of adopting concurrent engineering practices and the difficulties in integrating design and building activities. These problems emanate mainly from the sequence of operations in the open tender form of the building process. Because of this procedure, design affects construction planning while construction planning cannot affect design. Shammas-Toma *et al.* (1998) illustrated the consequences for contractors who have to build according to specified dimensions, shapes, strength requirements, etc., regardless of the problems that the design specification may pose during construction. Similar criticism was expressed by Vrijhoef *et al.* (2001), who argued that the actors involved in the design project organization have no common and clear understanding of what should be designed. Thus, in this respect relational exchange could contribute to improved coordination and reduce complexity stemming from interdependence. The other dimension of complexity is concerned with uncertainty. Competitive tendering and market-based exchange reduce the uncertainty associated with the evaluation of offerings and switching costs. On the other hand, interaction in close relationships can be used as means for reducing other types of uncertainty, for example need uncertainty and transaction uncertainty (Ford *et al.*, 1998).

The implication of this discussion is that changes in the pattern of couplings may affect both performance and complexity. It seems likely that other patterns could improve the performance in construction without increasing the complexity. As argued above, four of the central features of the industry's behaviour seem to be relevant means for managing complexity. However, when it comes to competitive tendering and market-based exchange the situation is different. The analysis leads us to question whether these conditions are necessary for gaining the benefits from local adjustment, standardized components, focus on individual projects, and the multiple roles of the firms. Tighter couplings among firms might be beneficial to the overall performance in construction. There also seems to be increasing interest among firms in developing closer relationships. For example, Cox and Thompson (1997) stated that the search for more collaborative contractual relations has become a contemporary theme in the construction industry. However, the authors (and others) found that these efforts have not yet been very successful. Our conclusion is that a change in this direction must be difficult to undertake, because it is not in accordance with the norms of the community of practice. We agree with Kornelius and Warmelink (1998), who argued that coordination through bilateral relationships is problematic in construction.

The organizational independence identified by Crichton (1966) is not only a characteristic of inter-firm relationships. The decentralization of authority to the individual project leads to loose couplings even between different entities within firms. We have argued that these conditions provide opportunities for localized adaptations and support self-determination. On the other hand, large contractors have an obvious interest in taking advantage of potential economies of scale in purchasing. Decentralization of authority might constrain these efforts, because in loosely coupled systems a centrally located authority has limited possibilities to intervene in local operations. According to Weick (1976), the same mechanisms that work as buffers by isolating trouble spots, and thus preventing the trouble from spreading, also make it difficult to repair the defective element. These conditions may, however, be representative of other project based activities as well. For instance, von Krogh (1998) observed similar tendencies in R&D projects. O'Dell and Grayson (1998) argued that decentralised decision making in temporary organisations makes project leaders focus on maximizing their own accomplishments and rewards. Therefore, they might act in ways that contradict the goals of the organization as a whole. The authors conclude that too much emphasis on the individual project's self-determination results in situations where the left hand does not know what the right hand is doing.

Loose couplings and innovation

Thus far we have dealt with the effects of the pattern of couplings in terms of efficiency and productivity. Below, we focus on some of the consequences for innovation and dynamics. According to Teece (1998) the opportunities for learning are closely related to previous activities and experiences: if many aspects of a firm's learning environment change simultaneously the ability to form cognitive structures favouring learning becomes severely restricted. This is a problem because learning is a process of trial, feedback and evaluation. Gann (1996) argued that this process is seldom successful in construction, and concluded that 'each house is treated as a pilot model for a design that never had any runs'. It seems to be the case that the pattern of couplings does not foster economies of scale in design, planning, and construction, although they are beneficial for economies in manufacturing of building materials.

On the other hand, these industry conditions should be favourable for the development of new ideas. The pattern of couplings makes each construction site an experimental workshop. In complex networks experimentation is an important breeding ground for innovation (Gadde and Håkansson, 2001). One typical outcome of loose couplings is the ability to generate variation (Weick, 1976). Localized adaptations imply that any one element can adjust to local contingencies. This means that loosely coupled systems potentially can generate a larger number of mutations and novel solutions than would be the case with a tightly coupled system, because the actors deal with problems in a multitude of ways. However, Weick argued that, although a local set of elements can adapt to local idiosyncrasies without involving the whole system, this same loose coupling could also forestall the spread of advantageous mutations that exist somewhere in the system. Hence, the loosely coupled system may contain novel solutions to new problems, but the very structure that allows these mutations to flourish may prevent their diffusion. These conditions prevail in construction and may be explained by the pattern of couplings. Below we discuss explanations related to the project, the individual firm and the relationships among the actors.

First, the project organization does not promote learning. One reason is the temporary nature of the project, offering no guarantee of further contacts among team members. The consequences were discussed by Crichton (1966, p. 22): '. . . there is no input of commonly shared experience of other building processes. Each member of the building team brings little more than his own accumulated experiences (and prejudices) to bear on current problems. Learning, in the sense of adaptations brought about by experience, is therefore a slow and uncertain process that takes place at an individual level rather than at industry level.'

However, time limitations also make individual learning problematic. For example, von Krogh (1998) observed that time constraints made it difficult for individuals to get the most learning benefit out of R&D projects. He also argued that too little effort is devoted to transmitting knowledge and experience from one project to another. Projects are problematic in this respect because they do not have an organizational memory (Björkegren, 1998). They lack the natural transfer mechanisms of permanent organizations where structures and routines can contribute to knowledge absorption. Therefore learning needs to be transferred via the level of the firm.

The second explanation of the problems with innovation in construction relates to the organizational arrangements within the firm. In this respect loose couplings not only make it difficult to intervene in localized decision-making, they also prohibit learning and innovation because in strongly decentralized structures the left hand not only does not know what the right hand is doing but also it may not even know that there is a right hand (O'Dell and Grayson, 1998). Therefore, in an organization based mainly on decentralization and project activities 'lies unknown a vast treasure house of knowledge, know-how and best practice' (O'Dell and Grayson, 1998). These conditions are prevalent in construction as well. The activities at construction sites generate a lot of ideas from creative problem-solving tasks. However, the pattern of couplings in the industry is an obstacle to their diffusion.

Third, the loose couplings in the permanent network serve as a barrier to innovation. Long-term relationships and adaptations beyond individual construction projects are necessary to foster learning and innovation. For example, Loasby (1976) argued that learning cannot take place through anonymous contracting but requires continuous interaction through which an individual or a company commits to the group and thus becomes one within the group. The existing market based short term exchanges cause problems in this respect. The outcome of this procedure is that the constellation of firms involved in the temporary network does not have joint plans beyond the project (Thompson *et al.*, 1998). Therefore, neither the individual nor the company becomes 'one within the group'. They become 'one within *a* group' the constitution of which changes from one project to the next. The problems associated with these organizational arrangements are analysed by several authors. Kreiner (1995) pointed out the danger of the short term based project focus, arguing that the fact that projects occupy only a bracket in time, and thus have neither history nor future, allows evolutionary processes little scope for improving performance'. Cox and Thompson (1997) argued that because the constellation of actors is continually changing it is difficult to make use of experience gained in previous projects. They concluded that this creates particular cost inefficiencies for the client as a new learning curve is climbed each time.

Tighter couplings among firms in the permanent network could thus enhance the opportunities for innovation. We have argued above that such conditions might also improve the possibilities of reducing uncertainty, through the continuous interaction in close relationships. Furthermore, if couplings become tighter it is most likely that the parties will find new ways to adapt to each other, as has been important for innovation in other industries. For example, some of the adjustments now undertaken at the construction site might be conducted more efficiently up-stream of the supply chain through utilization of more specialized resources in terms of machinery and manpower (e.g. Vrijhoef and Koskela, 2000).

The fourth barrier to innovation is found in the strong community of practice. We identified the community of practice as a means of enhancing productivity and efficiency, because it allowed for tight project couplings in spite of the loose couplings in the permanent network. The community of practice stabilizes conditions that promote short term productivity. However, the same conditions hamper innovation because they tend to make firms similar and independent. This is a problem where learning is concerned, because heterogeneity and interdependence are greater spurs to collaborative action than homogeneity and discipline (Powell, 1998). In construction the resources of different suppliers are quite homogeneous and a contractor could not expect to learn more from one of them than from another. These conditions differ from the situation in many other industries (Powell, 1998). Furthermore, government regulations and industry standards make the system difficult to change, and this in turn hampers innovation. According to Kadefors (1995), the existence of joint industry standards simplifies work considerably. However, these standards also imply that only certain well tested constructions are included, and therefore the technical solutions and work procedures actually are reduced. The tendering system favouring standard offerings thus functions as a barrier to innovation and the creation of new solutions.

Alternative patterns of couplings

We argue here that the construction industry has the features of a loosely coupled system. The particular pattern of couplings favours productivity in projects, while innovation suffers. These characteristics have made the industry as a whole lag behind other industries in terms of traditional performance measures. Depending on what theoretical foundations have been built on, this observation has led researchers and consultants to prescribe either more competition or more cooperation to increase the performance of the industry as a whole.

The strong project focus makes coordination in other dimensions difficult or even pointless. Each project is considered to have a life of its own – without either history or future. Furthermore, it is only loosely coupled to the overall network structure, thus having few connections with other projects. Therefore, performance criteria relate to what takes place within the boundary of the individual project. This focus makes it problematic for a contractor to coordinate efforts in different projects. Furthermore, it complicates interfirm cooperation. The boundary around individual projects calls for standardized interfaces among firms, favouring short term productivity and hindering learning. Strongly focusing on one single dimension of performance means neglecting others.

In construction, the most obvious experiment would be to put less emphasis on the project boundary. Such a change would allow for increasing coordination in other dimensions. Successful experiments of this kind can be observed in other industries. For example, 'just-in-time' delivery is the outcome of close coordination of supply chains, and 'customization' is the outcome of close collaboration in inter-firm development teams. Such network structures emphasize other performance criteria, and are based on other combinations of tight and loose couplings. Vrijhoef and Koskela (2000) suggested a number of ways in which an increasing supply chain orientation might contribute to improved performance. Among other things, they advocated changes in the interface between site activities and the supply chain and transfer of activities from the site to the supply chain.

What these alternative efforts have in common is first that they are based on inter-firm cooperation and counterpart-specific adjustments leading to interactive effects. Second, connections between relationships make it possible to build on previous interactive effects which, in turn, foster learning in the structure as a whole. The main characteristic of these successful attempts is the interdependence among organizations and projects, in contrast to the independence typical of projects and firms in construction.

However, when we suggest more attention to inter-firm cooperation, we must also emphasize that the dialectic nature of couplings stressed by Weick (1976) should not be forgotten. Couplings are interrelated, and thus any change of a coupling impacts on the others. The pattern of couplings in the construction industry favouring project efficiency is clearly an obstacle to innovation and learning. We have pointed out some possible modifications of the present pattern of couplings. However, following Weick (1976), changing some of the couplings necessarily means that other couplings will change as well. It is the pattern of couplings that shapes (and is affected by) the behaviour of the actors. Different patterns have different consequences for complexity. Each pattern reduces some uncertainties and increases others, in the same way that it solves some interdependences and creates new ones.

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