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The Construction Industry as a Loosely Coupled System - Implications for productivity and innovativity

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Abstract

Previous research suggests that the construction industry is characterised by (1) particular complexity factors owing to industry specific uncertainties and interdependencies, and (2) inefficiency in operations. The aim of this paper is to analyse the operations and behaviour of firms as a means to deal with complexity. Our observations indicate that the industry as a whole appears to be featured as a loosely coupled system. Taking this as a starting point the couplings among activities, resources and actors are analysed in different dimensions. The pattern of couplings builds on three interdependent layers; tight couplings in individual projects, loose couplings in the permanent network and collective adaptations in 'the community of practice'. The paper concludes that the pattern of couplings seems to favour short-term productivity while hampering innovation and learning.

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INTRODUCTION

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

These characteristics of the construction industry were expressed almost fifty years ago in a well-known study of distribution of house-building materials (Cox and Goodman 1956:36). 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' (p. 43). The complexity of the construction operations and the subsequent problem solving capability needed is perceived 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, Shamas-Thoma et al (1998) discuss 'all those remarkable processes which enable the construction process to function at all'. Winch (1987) argues that 'construction projects are amongst the most complex of all undertakings' (p. 970). Gidado (1996) further emphasises this view by stating that there is 'a continuous increase in the complexity of construction projects' (p. 231).

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 in operations (e.g. Cox and Thompson 1997). Particularly it has been argued that a short-term perspective promotes sub-optimisation (Gann 1996) and hampers innovation and technical development (Dubois and Gadde 2000). A number of authors argue that construction has failed in adopting 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), the supply chain principle and 'industrialization' of manufacturing processes (Gann 1996). It seems to be a common view among these authors that the construction industry would be better off, if its behaviour changed in accordance with the norms of other industries.

But assume that Winch and Gidado are right in the statements about the particularities of construction complexity. If so, it might well be that management principles that improve performance in other industries are not easily transferable to this context. If construction follows another logic then it might even be a mistake trying to adopt these management principles.

AIM AND SCOPE OF THE PAPER

The aim of the paper is to analyse the operations and the behaviour of firms in the construction industry. We do this by understanding the behaviour of firms as attempts to cope with the complexity of construction projects. In this respect we suggest the industry to be regarded as a 'loosely coupled system' (Weick 1976).

The paper is structured in the following way. First we explore the characteristics of the complexity in construction. After that we discuss how the actual operations in the industry can be interpreted as responses to its inherent complexity. Then we describe the main features of loosely coupled systems and present an analysis of the pattern of tight and loose couplings in construction. The conclusion of the analysis is that the pattern of couplings seems to be appropriate for dealing with the productivity in individual construction projects. In the discussion we also bring up some consequences for learning and innovation related to the present structure and suggest some alternative patterns of couplings.

The empirical background of the paper is a study of a house-building project and its connections to other projects reported in Dubois and Gadde (2000). Therefore, our observations and conclusions regarding the logic of the operations in the construction industry mainly relate to house-building.

THE CONSTRUCTION INDUSTRY AS A LOOSELY COUPLED SYSTEM

Complexity in construction

Gidado (1996) argues that complexity in construction originates from a number of sources; the resources that are employed, the environment in which construction takes place, the level of scientific knowledge required, and the number and interaction of different parts in the workflow. He makes a distinction 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' (ibid: 215).

The uncertainty in the undertaking of individual activities has four causes:
- Management is unfamiliar with local resources and local environment
- Lack of complete specification for the activities at the construction site
- Lack of uniformity of materials, work, and teams with regard to place and time – "every project is unique".
- Unpredictability of environment

These characteristics obviously make it difficult to apply a centralised approach to decision-making. Prevailing conditions call for decentralisation of authority.

The second determinant of complexity is associated with the interdependencies among the operations in construction. Gidado (1996:216) points to three factors:
- The number of technologies and the interdependence among them.
- The rigidity of sequence between the various main operations
- 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'. The second is 'the practice of subcontracting portions of a project to special trade contractors by primary contractors'. Both factors cause interdependence, which call for co-ordination. The nature of these interdependencies seems to favour local co-ordination rather than centralised.

Central features of construction

It has been argued that construction is ‘inherently a site-specific project based activity’ (Cox and Thompson 1997:128). This view is shared by Shirazi et al (1996) who conclude that construction is mainly about co-ordination of specialised and differentiated tasks at the site level. The emphasis on site-specific activities provides us with two central features of house building. The first is the *focus on individual projects*, in terms of decentralised decision-making and financial control. The prevailing organisational arrangements when it comes to responsibility and authority put the emphasis on the efficiency of single projects, which makes sense as response to the roots of complexity identified above. The strong reliance on localised 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 owing to the three remaining uncertainty factors; lack of complete specification, lack of uniformity and unpredictable environment. When these conditions rule the game it is difficult (and even unsuitable) to develop components and systems tailored to the situation at specific sites. Therefore it is quite unusual that building materials manufacturers develop products that are adapted to particular contractors or specific construction sites. The industry still relies on what Stinchcombe (1959) identified as ‘standardised parts’ while the use of ‘standardised activities’ tended 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 that are gained from increasing economies of scale in manufacturing of building materials.

Also the complexity with respect to interdependencies seems to favour standardisation and thus local adjustments. Owing to ‘the number and interdependencies among technologies’ customised solutions from one supplier would impact on other components and systems. The ‘rigidity of sequences’ and the ‘overlap of stages’ in turn makes co-ordination difficult. It is most likely therefore that these conditions are better taken care of through decentralisation and local adjustments than through centralised activities and customised solutions.

There are some other features of the behaviour of construction firms that must be observed. 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 lowest possible cost. The strong reliance on competitive tendering explains the use of standardised parts. Adaptations and customisation would rule out the possibility of using tendering procedures. Competitive tendering also sets the conditions for the relationship among the parties. Gann (1996) found that that the relationships ‘are often typified by market-based, short-term interactions between independent business’ (p. 445). Thompson et al (1998) also identified *market-based interaction* as the norm of the behaviour and concluded that firms ‘traditionally paid very little attention to the relational elements of business transactions’ (p. 36). The final characteristic of the behaviour in the industry 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 vary greatly from project to project and the role of the individual firm can be very different (Dubois and Gadde 2000:211).

Loose couplings

According to Orton and Weick (1990) any location in an organisation contains interdependent elements that vary in the number and the strength of their interdependencies. 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) discusses the degree of coupling between two ’units’ (events/elements/systems, etc.) on the basis of ’the activity of the variables which the two units share’. If two units have few variables in common, or if variables in both are weak compared to other variables influencing the two units, then they are relatively independent of each other and thus loosely coupled (Aldrich, 1980). Weick´s characteristic 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’ (Weick 1976:3). 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 sub-units, among organisations, between hierarchical levels, between organisations and environments, among ideas, between activities, and between intentions and actions.

Weick (1976) analyses the potential effects of loose couplings, which may be functional and/or dysfunctional. In this section we primarily direct the attention to the ways in which loose couplings contribute to handling complexity in operations.

• *Localised adaptation*
A loosely coupled system may be a good system for localised adaptation where ‘any one element can adjust to and modify a local unique contingency without affecting the whole system’. Hence, localised adaptations may thus be ‘swift, relatively economical and substantial’.

• *Buffering*
Loose couplings serve as a buffering mechanism against unfavourable conditions in the environment. Owing to that the organisation as a whole will not have to respond to each little change that occurs in the environment. As Weick puts it: loose couplings allow some parts of an organisation to persist.

• *Sensing mechanism*
Loose couplings provide a ‘sensitive sensing mechanism’. This is a consequence of localised adaptation, decentralisation and low extent of co-ordination. 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.

• *Variation generation*
Loosely coupled systems preserve the identity, uniqueness, and separateness of elements. Therefore, the system potentially can 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.

• *Self-determination*
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.

In Table 1 the complexity factors and the functions of loose couplings are summarised.

Complexity owing to uncertainty	**Complexity owing to interdependence**	**Functions of loose couplings**
Lack of complete specification of activities Unfamiliarity with local resources and local environment Lack of uniformity of materials, work and teams with regard to time and place Unpredictability of environment	The number of technologies and the interdependence between them The rigidity of sequence between the various main operations The overlap of stages or elements of construction	Localised adaptation Self-determination Sensing mechanism Variation generation Buffering

Table 1. Complexity factors and functions of loose couplings

A loosely coupled system may cope with certain aspects of the complexity owing to uncertainty and interdependence since its functions are characterised by limited central authority and low costs of co-ordination. In suggesting that construction is featured by the functions of loosely coupled systems, however, we must follow Orton and Weick (1990) arguing that the recognition of an organisation '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? What are the characteristics of the couplings and decouplings?' (ibid: 219).

Based on the observation of the construction industry as 'behaving' like a loosely coupled system it thus seems fruitful to scrutinise the tight and loose couplings prevalent in it. According to Weick (1976) it is the pattern of couplings (tight and loose) that produces the observed outcomes of a system. The coming section is an attempt to further reveal the pattern of couplings and shed some more light on the interrelated complexity factors and functions of loose couplings.

Tight and loose couplings in the construction network

The analysis of tight and loose couplings departs from Figure 1 where a construction project is illustrated in its network context.

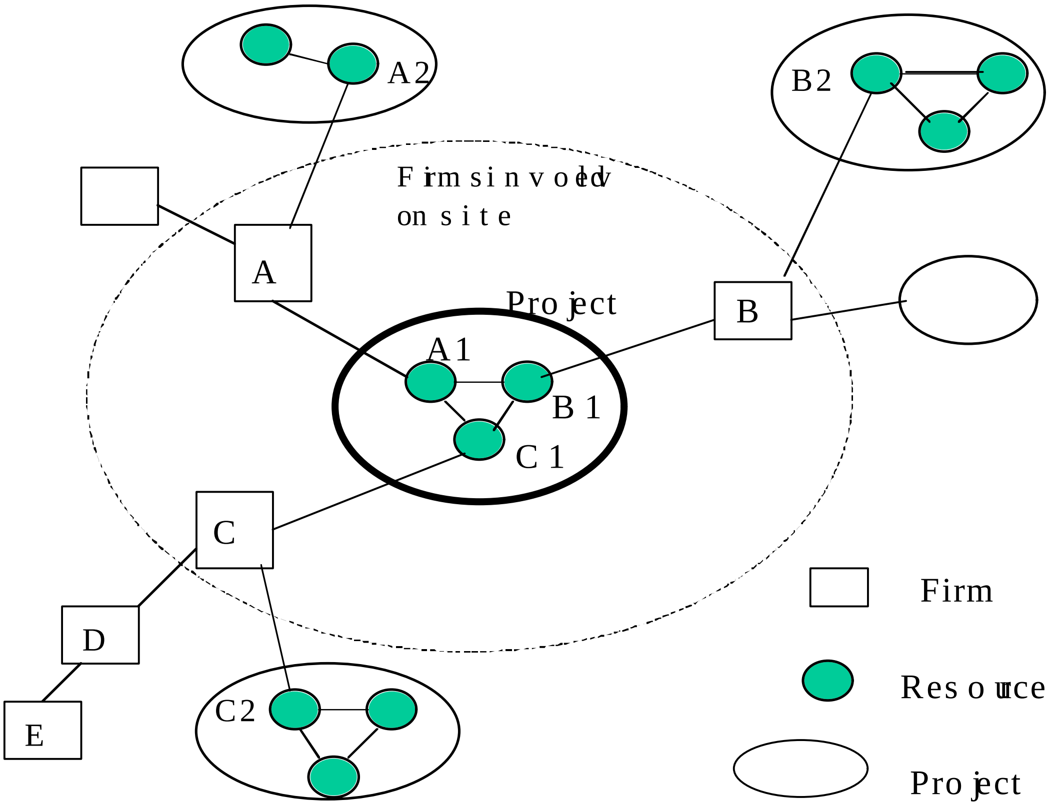

Figure 1. The construction project in its network context (Source: Dubois and Gadde 2000).

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 a construction project. Their input in the project consists of resources of various kinds (A1, B1 and C1). The firms are also involved in other projects in which they have to co-ordinate 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:

- co-ordination within the single project (C1 with A1 and B1)
- co-ordination among firms involved in supply chains (i.e. with D and E)
- co-ordination among different construction projects (C1 with C2)
- inter-firm co-ordination beyond the scope of the single project (i.e. with A and B).

Co-ordination within construction projects

Owing to (1) the importance of time, (2) the need to perform and co-ordinate the activities sequentially, and (3) the specialisation of actors, there are tight couplings between activities undertaken at 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" (ibid: 218). Furthermore, the activities are not only sequentially interdependent but also organised in parallel sequences, i.e. stages or elements of construction 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 interdependencies between the roles of the overlapping elements. These changes may increase the effects of inherent complexity and uncertainty factors on project complexity. (Gidado 1996: 218)

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 so called 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 1966:17). These characteristics, thus, lead to tight couplings between the activities undertaken in single projects.

Co-ordination within supply chains

The main part of the 'input' resources used in buildings is standardised. Furthermore, the chain of activities, including transportation and storage, from the production of building materials to the site seem to be based on standardised rules. Typically, large quantities are sent directly from the factory to the construction site while smaller quantities are delivered from the distributors' warehouses. Factory deliveries normally means rather long lead times from order to delivery while the distributor is able to deliver on shorter notice. Hence, distributors provide 'slack' resources, which is important when the exact volume demand and timing is difficult to foresee. The latter as a result from the very strong interdependency among activities carried out on-site which 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 at site. This is dealt with by 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 jeopardised.

Co-ordination within firms

Every firm involved in on-site activities have to co-ordinate its activities and resources among the different construction projects in which it is involved. The strong interdependencies among activities performed at each and every site and the effects of this interdependence in terms of time extensions and delays implies that every firm need some extent of slack resources. If not, the 'knock-on' effects from delays at one project would carry through to other projects. The (firm) internal co-ordination of activities undertaken and resources employed at different sites may thus even be subject to competition if the slack is not sufficient (Crichton 1966, Dubois and Gadde 2000). This would be of particular importance for firms specialising in activities undertaken late in the process.

In addition, the firms may be specialised 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) refers to the learning curve concept stating that the varying nature of interdependencies 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. (Gidado 1996:217)

Co-ordination among firms beyond the individual construction project

In construction one and the same team is only seldom (and then rather by coincidence than by conscious planning) working together in more than one project. And, even if they are to work together 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 an individual construction project.

Gann (1996) argues that difficulties in creating couplings outside individual construction projects have fostered the development of prefabricated standard components i.e. the type of components that are produced without prior knowledge of the design or type of building. And, this relation probably goes both ways, i.e. the existence of standard components have made it unnecessary to develop customised solutions through the creation of couplings external to construction projects. Regardless of the direction of the relation it is a fact that on-site, and thus localised, adaptations are very much characterising the construction production system.

Couplings among co-ordination dimensions

Obviously, tight couplings prevail in the first co-ordination dimension, i.e. among activities carried out within individual construction projects. Furthermore, the couplings between this dimension and the other co-ordination dimensions seem to be tight. Thus, to cope with the tight couplings identified the others need to provide 'slack'.

The interdependence among activities undertaken within construction projects can be characterised as reciprocal. The loose couplings identified in the supply chains and among different construction projects are mainly characterised by sequential interdependence and function as buffers to deal with the tight couplings within individual projects. The fourth co-ordination dimension - inter-firm relationships beyond the scope of individual construction projects - seems almost non-existing. This characteristic has been discussed by Kornelius and Warmelink (1998) suggesting that co-ordination in construction is more complex compared to other industries owing to its inherent network characteristics that cannot be dealt with by bilateral relationships.

The pattern of couplings and the community of practice

The tight couplings in individual projects are embedded in other couplings in the permanent network. Most couplings among firms are loose which should make it problematic to develop the co-ordination mechanisms required for handling the complexity in construction projects. In most other industries uncertainty and interdependence are typically managed through tight couplings among firms. Relational exchange and inter-firm adaptations are common means of handling these issues. In contrast, the construction industry is characterised by loose couplings among firms. Our analysis shows that there are few inter-firm adaptations beyond the scope of individual projects and that the firms 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 co-ordination. Altogether these characteristics should make it difficult to form the tight couplings in the projects, which makes it interesting to discuss why this is possible.

As previously discussed inter-firm adaptations in construction are limited in comparison with other industries. However, the construction industry is characterised by substantial 'collective adaptations' (Dubois and Gadde 2000). The standardised components and systems that are used have been developed through continuous collective efforts among material producers, contractors and governmental authorities, who prescribe norms and other conditions. These collective adaptations are formed in what can be identified as 'a community of practice' (Brown and Duguid 1998). These authors discuss the preconditions for learning and argue that 'a great deal of knowledge is both preserved and held collectively' (p. 91). Collective knowledge is generated when people work together in 'tightly knit groups known as communities of practice'. The authors claim 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 it does and how to do it. In this way a strong community of practice reduces uncertainty and serves as an informal co-ordination mechanism in loosely coupled systems. For example, Meyer (1975) argues that the school system in the US 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 pattern for action and guides the behaviour of firms. Powell (1991) discusses the benefits of this type of shared expectations:

> Shared expectations arise that provide psychological security, reduce the cost of information processing, and facilitates the co-ordination of different activities. Moreover established conceptions of 'the way things are done' can be very beneficial; members of an organisation field can use these stable expectations to predict the behaviour of others. (ibid: 194)

The construction industry relies on a strong community of practice. Important aspects of this common practice are revealed in a study by Kadefors (1995). First, governmental regulations have a significant impact on the design and construction of houses. Building codes, norms, and principles for housing subsidies to a large extent impose requirements favouring certain standards. The regulation system concerning working environment and workers' protection contributes to re-enforcing the community of practice. Second, the industry itself is a source of formal standardisation. The firms involved have established numerous forms of common contract formulas, which set standards in terms of operations, components, documentation, and work principles. Third, the tendering procedure requires that suppliers' offerings are standardised. Without standardisation contractors would not be able to evaluate the different offerings. Fourth, the generic roles of the participants in the processes of design, planning and construction are standardised. 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 the fifth aspect concerning standardisation of skills and knowledge, which follows from the existence of an informal control system. This is acknowledged in the standard contracts according to which the quality of the contractor's work should conform to 'current standards of workmanship' (ibid. p. 403). 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 explained by Gidado (1996) as 'lack of complete specification'. These conditions are important reasons for the strong reliance on decentralisation of authority and the requirements for localised adaptations. As argued by Stinchcombe (1959) 'operative decisions are very important at the work level' (p. 182).

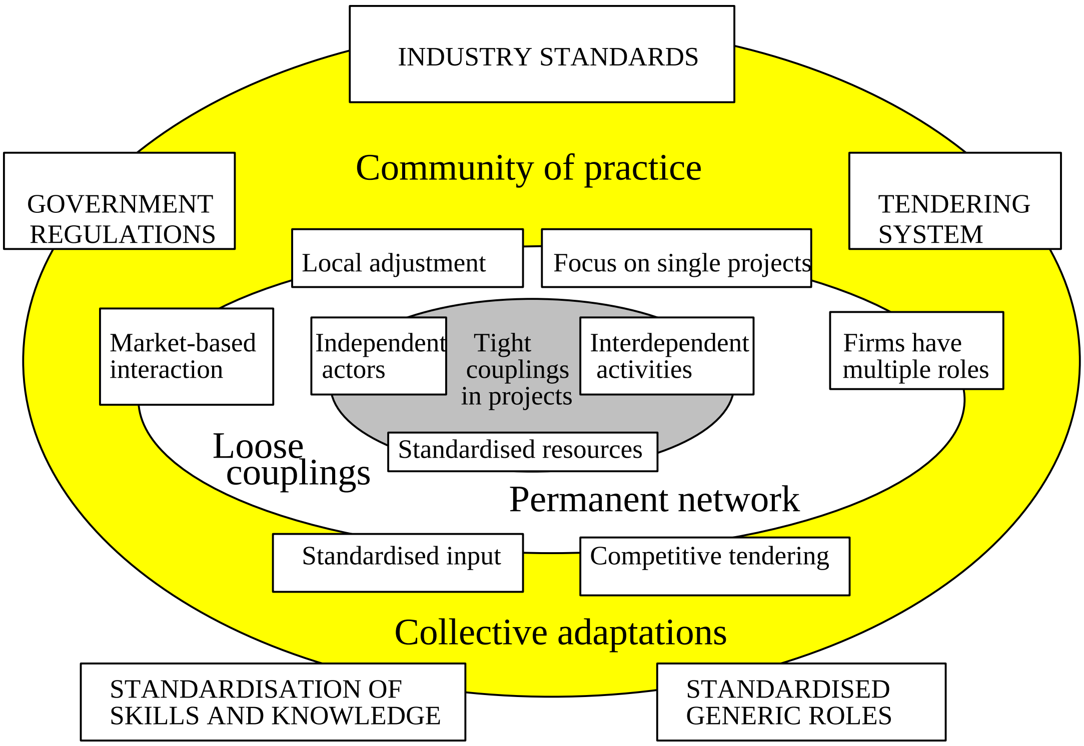

Figure 2: The pattern of couplings in the construction industry

Figure 2 summaries the discussion of the pattern of couplings in the construction industry. The individual project is characterised by tight couplings owing to the conditions in the temporary network. The project task is to handle the activity interdependence arising when standardised resources are adapted to local conditions by actors that strive for independence beyond the scope of individual projects. The tight couplings in the temporary network are embedded in loose couplings in the permanent network of firms. Our analysis identified six different aspects of the behaviour of firms that can be classified in terms of loose couplings. A strong community of practice completes the pattern of couplings. The collective adaptations provide means to cope with the tight couplings that are required in each construction project, while the loose couplings provide the slack needed to maintain flexibility.

DISCUSSION

The aim of this paper is to understand the logic of the operations in the construction industry. The analysis reveals 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 similar to what has 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 the construction operations. The tight couplings in individual projects combined with the loose couplings in the permanent network makes it possible to come to grips with the two roots of complexity – i.e. uncertainty and interdependence.

In particular, it appears that the loose couplings in the permanent network together shape the slack that is necessary in order to handle the tight couplings in projects. The focus on individual projects, the use of standardised components, the local adjustments, and the multiple roles played by firms allow both for handling complexity in individual projects and securing economies of scale in manufacturing. The 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 pattern of loose couplings in the industry behaviour also involves competitive tendering and market-based exchange among firms. It is not quite clear whether loose couplings in these respects are necessary to attain the observed benefits in terms of slack and flexibility. Therefore, a further exploration of the relationship between complexity and the nature of exchange is the first topic of the discussion. The prevailing pattern of couplings seems favourable for short-term productivity of single projects, while the long-term effects are less obvious. The second issue for discussion, hence, is which consequences these couplings imply for innovation and learning in the permanent network. Finally, we bring up some potential features emanating from alternative patterns of couplings.

Complexity and the nature of exchange

Crichton (1966) found construction to be characterised by technical interdependence and organisational independence. The organisational 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 possible to gain from close relationships. Obtaining these benefits entail counterpart specific adjustments that, in turn, necessitates dependence on specific partners (Gadde and Håkansson 2001). Therefore, it is most likely that development of close relationships in the permanent network would improve performance in construction as well. Shammas-Toma et al (1998) argue that the tendering system and the short-term perspective are to blame for many short-comings in construction, for example the problems of adopting concurrent engineering practices and the difficulties in integrating design and building activities. These problems mainly emanate from the sequence of operations in the open tender form of the building process. Owing to this procedure 'design affects construction planning while construction planning can not affect design'. Shammas-Toma et al (1998) illustrate the consequences for contractors which have 'to build according to specified dimensions, shapes, strength requirements etc., regardless of the problems that the design specification may pose during construction' (p. 183). Thus, in this respect relational exchange could contribute to improved co-ordination 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 in figure 2 may affect both performance and complexity. It seems likely that other patterns could improve the performance in construction without increasing the complexity. Four of the characteristics of the industry behaviour seem to be relevant means for managing complexity. However, when it comes to competitive tendering and market-based exchange we are faced with another situation. The analysis leads us to question whether these conditions are necessary for gaining the benefits from local adjustment, standardised components, focus on single projects, and the multiple roles of the firms. Tighter couplings among firms might be beneficial to the overall performance in construction. It seems also to be an increasing interest among firms in developing closer relationships. For example, Cox and Thompson (1997) state that 'the search for more collaborative contractual relations has become a contemporary theme in the construction industry' (p. 129). However, the authors (as well as others) found that these efforts have not been very successful so far. Our conclusion is that a change in this direction must be difficult to undertake because it is not in accordance with the cultural norms of the community of practice. We agree with Kornelis and Warmelink (1998) who argue that co-ordination through bilateral relationships is problematic in construction. Therefore, (successful) collaborative relationships may not be possible to develop unless the community of practice is changed.

The organisational independence identified by Crichton (1966) is a characteristic not only of inter-firm relationships. The decentralisation of authority to the single project leads to loose couplings also between different entities within firms. We have argued that these conditions provide opportunities for localised adaptations and supports self-determination. On the other hand, large contractors have an obvious interest in taking advantage of potential economies of scale in purchasing. Decentralisation 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 prevent the trouble from spreading, also make it difficult 'to repair the defective element'. These conditions may however be representative for other project based activities as well. One example is that von Krogh (1998) observed similar tendencies in R & D projects. O'Dell and Grayson (1998) argue that decentralised decision-making in temporary organisations makes project leaders focus on maximising their own accomplishments and rewards. Therefore, they might act in ways that contradict the goals of the organisation as a whole. The authors conclude that too much emphasis on the individual project's self determination leads to situations where 'the left hand doesn't know what the right hand does'.

Loose couplings and innovation

This far we have dealt with the effects of the pattern of couplings in terms of efficiency and productivity. Hereon 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 changes simultaneously the ability to form cognitive structures favouring learning become severely restricted. This is a problem because learning is 'a process of trial, feedback and evaluation'. Gann (1996) argues that this process is seldom accomplished in construction and concludes 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 do not foster economies of scale in design, planning, and construction while 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). Localised adaptations imply that any one element can adjust to local contingencies. This means that loosely coupled systems potentially can retain a greater 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 argues that while 'a local set of elements can adapt to local idiosyncrasies without involving the whole system, then this same loose coupling could also forestall the spread of advantageous mutations that exist somewhere in the system'. Hence, while the loosely coupled system may contain novel solutions for new problems, the very structure that allows these mutations to flourish may prevent their diffusion. These conditions prevail in construction and can be explained by the pattern of couplings. Below we discuss explanations related to the project, the individual firm, the relationships among the actors and the community of practice.

First, the project organisation is not promoting learning. One reason is the temporary nature of the project offering no guarantee of further contacts among team-members. The consequences are discussed by Crichton (1966:22):

> … 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, which 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 argues 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 organisational memory' (Björkegren 1998:110). They lack the natural transfer mechanisms of permanent organisations where structures and routines can contribute to knowledge absorption. Therefore learning needs to be transferred via the level of the firm.

The second explanation for the problems with innovation in construction relates to the organisational arrangements within the firm. In this respect loose couplings not only make it difficult to intervene in localised decision-making. They also prohibit learning and innovation because in strongly decentralised structures 'the left hand not only does not know what the right hand is doing, but it also may not even know that there is a right hand' (O'Dell and Grayson, 1998:157). Therefore, in organisations mainly based on decentralisation and project activities 'lies unknown a vast treasure house of knowledge, know-how and best practice' (ibid:154). 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 a hinder for their diffusion.

Thirdly, the loose couplings in the permanent network serve as a barrier to innovation. Long-term relationships and adaptations beyond individual construction projects are necessary requisites to foster learning and innovation. For example, Loasby (1976) argues that learning cannot take place through anonymous contracting but requires continuous interaction through which individuals and companies increasingly 'commits to the group and thus becomes one within the group'. The existing market-based short-term exchange causes 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 is completely changed from one project to another. The problems associated with these organisational arrangements are analysed by several authors. Kreiner (1995) points to the danger with 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' (p. 345). Cox and Thompson (1997) explicitly discuss the implications for learning owing to the fact that the constellation of actors all the time is changing. These conditions make it difficult to make use of experience gained in previous projects. The authors argue that this 'creates particular cost inefficiencies for the client as a new learning curve is climbed each time' (p. 128).

Tighter couplings among firms in the permanent network could thus improve the opportunities for innovation. We have argued above that such conditions might even improve the opportunities to reduce 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 which 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 the supply chain through utilisation of more specialised resources in terms of machinery and manpower. In turn this might result in a change from the strong reliance on standardised input to more customised solutions tailor-made for specific buildings (Gadde et al 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 stabilises conditions, which promote short-term productivity. However, the same conditions hamper innovation because they tend to make firms similar and independent. This is a problem when learning is concerned because 'heterogeneity and interdependence are greater spurs to collaborative action than homogeneity and discipline' (Powell 1998: 231). 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 also differ from the situation in many other industries. For instance, the textile industry is similar to construction in being a craft industry. However, Powell (1987) found the German textile industry to be characterised by a wide range of institutional arrangements linking small and medium-sized firms in ways that 'further the well-being of the industry as a whole'. In contrast to construction firms these companies are highly specialised and the more distinctive each firm is 'the more it depends on the success of other firms'. These conditions form – and are formed – by the community of practice. In the German textile industry the organisational arrangements are important means of assuring collaboration for innovation. These arrangements in turn 'strengthen the social structure in which textile firms are embedded and encourage co-operative relations that attenuate the destructive competition' (Powell 1987:70).

Furthermore, government regulations and industry standards make the system difficult to change which 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' (p. 402). The tendering system favouring standard offerings thus functions as a fence against innovation and creation of new solutions.

Alternative patterns of couplings

We argue in this paper that the construction industry has the features of a loosely coupled system. The particular pattern of couplings favours productivity in projects while overall innovativity 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 applied this observation has led researchers and consultants to prescribe either 'more competition' or 'more co-operation' to increase performance of the industry as a whole.

The strong project focus makes co-ordination in other dimensions difficult, or even pointless. Each project is supposed to have its own life – without either history or future. Furthermore it is only loosely coupled to the overall network structure, thus having few connections to other projects. Therefore, performance criteria relate to what takes place within the boundary of the single project. This focus makes it problematic for a contractor to co-ordinate its efforts in different projects. Furthermore it complicates inter-firm co-operation. The boundary around individual projects call for standardised interfaces among firms favouring short-term productivity and hindering learning. Focusing one single dimension of performance means that others are neglected. Torvatn (1996) discusses potential disadvantages following from emphasising one particular system boundary while others are not considered. As a solution to this problem experimentation with different performance boundaries is recommended.

In construction the most obvious experiment would be to put less emphasis on the project boundary. Such a change would allow for increasing co-ordination in other dimensions, where successful experiments can be observed in other industries. For example, ‘just-in-time delivery’ is the outcome of close co-ordination of supply chains and ‘customisation’ is the outcome of close collaboration in inter-firm development teams. Such network structures emphasise other performance criteria and are based on other combinations of tight and loose couplings.

What these alternative efforts have in common are firstly that they are based on inter-firm co-operation and counterpart-specific adjustments leading to interactive effects. Secondly, 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 organisations and projects contrasting the independence typical for projects and firms in construction.

However, when suggesting more attention to inter-firm co-operation, 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 for innovation and learning. We have pointed to some possible modifications of the present pattern of couplings. However, following Weick (1976), changing some of the couplings necessarily means that other couplings are changed as well. It is the pattern of couplings that shape (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 as it solves some interdependencies and creates new ones.

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