Routledge
Taylor & Francis Group

Construction Management and Economics

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

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To cite this article: Jan Bröchner (1990) Impacts of information technology on the structure of construction, Construction Management and Economics, 8:2, 205-218, DOI: 10.1080/01446199000000017

To link to this article: https://doi.org/10.1080/01446199000000017

Construction Management and Economics, 1990, **8**, 205–218

Impacts of information technology on the structure of construction

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Changes in the structure of the construction industry can be attributed in part to information costs being reduced over time. Co-ordination, inspection and the translation of client needs are facilitated, affecting employee incentives within firms, transactions between firms and the role of intermediaries.

These aspects of information technology influence the optimal configuration of construction processes within each firm in the industry. Patterns of integration are seen as dependent on the interaction of aspects of information technology with attributes of each construction process. Geographic expansion, diversification or subcontracting, integration with materials supply and into real estate are considered.

An emerging industry pattern with three types of firms: specializing, co-ordinating and local is indicated, while in the long run, a development towards individuals in project networks is foreseen.

Keywords: Information, industry structure, integration, construction management

Introduction

Although the total annual volume of Swedish building and civil engineering has changed little, with a reduction by only 15% since the early 1970s, there is clear evidence of a structural shift in the industry. Medium-sized contractors with between 50 and 500 employees have declined more than others, as shown in Table 1. To some extent, the effect is to be explained by a change away from new housing work. This shift can be studied in Table 2, where the figures for large firms refer to contractors with 500 or more employees.

Growth in the market for repair, maintenance and refurbishment has coincided with a greater proportion of total supply coming from very small firms. Experimenting with the data and holding demand constant for various types of work, a strongly improved position appears for the large contractors, whereas employment in the 50–99 employees category falls steeply. These trends are distorted or hidden by the changes in market demand.

Thus we need at least one other explanation of structural change in addition to the effect induced by the development of demand. Since we lack important shifts in production technology during the period, we have to look elsewhere for clues. A survey of 29 Swedish medium-sized building firms with an average of 125 employees has been made by Broms and Hanson (1987), who have catalogued and ranked what the firms indicate as internal and external threats to their survival. Respondents assigned the highest rank to 'excessive central administrative staff', followed by 'faulty project management'. After these two dominant threats, new employment conditions for operatives and technical incompetence were

0144–6193/90 $03.00+.12

perceived as threatening. Interestingly enough, there was little mention of changing demand for various types of construction work as an external threat.

Discontinuities in the size distribution of building firms can be seen in many countries. The structure of the US homebuilding industry shows a gap between large and small firms. Beginning with a discussion of managerial span of control, Eichler (1982) identifies two styles of management, either a high degree of centralized control of all operations or an indirect style with top management co-ordinating regional managers while not being concerned with the surveillance of production detail. The first style is found among the smaller merchant builders. An interpretation of the responses to the Swedish survey is that they contain what we should expect for firms finding themselves almost in no–man's land between two styles of control.

Table 1. Structure of Swedish contracting 1970–85

	Year			
Size of firm	1970	1975	1980	1985
No. of firms				
2–49 employees	5 148	5 465	5 051	3 938
50–99 employees	206	152	122	90
100–499 employees	125	89	71	48
500+ employees	31	20	16	16
No. of employees				
2–49 employees	43 681	41 099	39 857	26 916
50–99 employees	14 211	10 307	7 610	6 157
100–499 employees	23 628	15 909	14 160	9 071
500+ employees	88 802	62 744	68 821	56 852

Source: Statistics Sweden.

Table 2. Output shares (%) for medium and large firms

	Year			
	1971		1987	
Type of work	Medium	Large	Medium	Large
Total	100	100	100	100
New housing	51	39	31	22
Housing repair and maintenance	3	2	10	8
New other building	35	35	40	45
Other building repair and maintenance	4	1	7	5
Civil engineering	14	26	11	18

Source: Statistics Sweden.

If there is more than one optimal structure for the internal control of building firms, it is conceivable that the range of firm sizes for each type of managerial control is sensitive to changes in the underlying technology of information and lower costs of information. Let us therefore assume that different aspects of information technology have different effects on the integration of firms within the construction sector.

Aspects of information technology

For the purpose of studying integration, a simple description of the main aspects of information technology, new as well as old, including telecommunications is needed. Three basic aspects are improvements of (i) co-ordination, (ii) inspection, and (iii) translation, taken in a wide sense of the word. These improvements lead to more efficient (iv) employee incentives, reduced (v) transaction costs and a tendency to (vi) eliminate firms acting as intermediaries in the industry.

(*i*) *Co-ordination*

During the last 150 years, a very slow process of virtual reduction of distances has taken place, considerably increasing our ability to co-ordinate activities through space and time (Beniger, 1986). Examples of recent advances with a potential for better co-ordination include bar coding of materials and equipment, which typifies a high degree of formalization, and cellular telephones as well as telefax, both of which stand for a flexible man–machine interface. This development raises the efficiency of a localized industry such as construction with its dispersed and temporary site arrangements. Moreover, the introduction of widespread computer support in a construction firm can be shown to have consequences for the managerial hierarchy when new lines of vertical communication are opened in the firm (Rounds and Warning, 1987). Then there is the relation between firms in the industry: it can be considered a historical fact that sudden improvements in co-ordination possibilities upset market structures, as in the case of the telegraph in the nineteenth century (DuBoff, 1983).

(*ii*) *Inspection*

When a process consists of multiple stages, the output from one stage can serve as an input to a following stage only after a control of quality, however simple the control activity may turn out to be. It is obvious that high costs of inspection force a buyer to rely more on trust in symbols such as the name of the producer, the name of the product or an official certificate. These symbols are carriers of a reputation for the required level of quality.

In two ways, improvement of information technology will substitute inspection for reliance on reputations. First, the ability to subject a production process to continuous monitoring is increased: the role of sensors in robotics is a case in point. Secondly, there is no inspection without comparison, and the ability grows to organize, store and retrieve information which can be used for comparative purposes – in prefabrication, on the building site.

(*iii*) *Translation*

Vast increases in computing, storage and retrieval powers improve the methods of translating functional needs of the client into choices of construction technology and, ultimately, into plans for production activities. Computer-aided design and the emerging use of expert systems are examples of better translation facilities.

(*iv*) *Incentives for employees*

Greater ease of co-ordination and inspection contributes to the development of employee incentives, based on monitored contributions to the total performance of the firm. Because the human effort spent on supervising employees and distributing incentives is very much a function of the information technology that is available to the firm, the tasks of middle management will tend to be restructured and reduced (Centre for Strategic Studies in Construction, 1988). In fact, a highly simplified and formalized model can be used to optimize the number of management levels in the firm as well as the number of employees on each level (Williamson, 1970). The model includes an explicit control loss between levels. When improved information technology reduces control loss, the span of control of each manager is broadened, measured by the number of employees reporting directly. The outcome is a flatter hierarchy of management in the firm.

(*v*) *Transactions*

Better inspection facilities added to better translation facilities make it easier to enter and enforce contracts with other firms. In short, the costs of transaction decline. The relation between production and transaction costs can be seen to generate the industry structure in an extended micro-economic analysis. Although we might predict the general effect of information technology on transaction costs, the cost associated with transaction depends on many factors, as acknowledged by Williamson (1985, pp. 390–1): technology (economies of scale or scope); the nature of rivalry, including progressiveness; customer attributes, including competences to evaluate product; incentive and control efficacy; market vagaries and uncertainties.

(*vi*) *Elimination of intermediaries*

The existence of intermediaries between producers in an industry and the end users can be explained by the level of co-ordination, inspection and translation that is achieved with the information technology at hand. The structural balance shifts with developments in information technology: DuBoff (1983) charts the disappearance of middlemen from the food industry in the wake of the telegraph. Some intermediaries deal only in information, the architectural firm being one example.

Integration of construction firms

Before studying the information effects on the structure of production, both the integrating effects and the disintegrating ones, the complexity of ownership of production resources and economies of scale or scope in production should be noted.

First, there is the distinction between vertical and horizontal integration. Vertical integration means the common ownership of multiple sequential stages of production and distribution which use what is widely regarded as a reasonably unified product or process technology (Gold, 1986). In the context of building activities we have in particular backward vertical integration into materials supply and forward into real estate management. Product expansion or diversification is sometimes a case of vertical integration, while sometimes the integrated activities belong to parallel stages of production, making diversification a special form of horizontal integration. Geographic expansion is a typical form of horizontal integration. Examples of publicly stated reasons for integration of various kinds are given by Ball (1988).

However, many types of intermediate and incomplete integration are met with in the construction industry. The interpretation of a general contractor with his trade subcontractors as constituting a single quasifirm is due to Eccles (1981a), the quasifirm seen as an analogue of the inside contracting system of manufacturing firms. The difference between the construction sector and other industries is only one of degree. Several alternatives to vertical integration are listed by Gold (1986): joint ownership of one or more component stages; long-term contracts with suppliers; joint production planning between suppliers and buyers to minimize the inventories of both while ensuring the continuity of production flows (just-in-time, *kanban*); joint planning by suppliers and their industrial customers for mutually supporting adjustments in their production technologies. All of these can be parallelled within the field of construction.

In the construction sector, economies of scale in the narrow sense of the word are almost entirely ruled out by definition because of the uniqueness of the products. Nevertheless, it appears that returns to purely physical scale also in productive sectors outside construction are much less inportant than generally assumed (Gold, 1981). Instead, specialization and information economies of scale can be shown to be of paramount importance, theoretically, as by Wilson (1975). The phenomenon that the costs of providing the services of a sharable input in two or more product lines are less than the total costs of providing these services for each product line separately is usually referred to as economies of scope (Panzar and Willig, 1981), and precisely these economies are relevant to construction activities. The 'sharable input' of this definition is to a great extent to be identified with management information handling.

Finally, there is a dynamic side of integration. The existence and type of economies of scale in information will change over time. We are looking at an industry in transition, marked by both integration and disintegration in the long term. However, there is also a rationale for short-term integration as a means of information acquisition and reputation building. This is especially so when main contractors take over specialist trade contractors to gain knowledge of production methods, costs and business relationships as well as to give a downward impetus to oligopolistic pricing practices in the trade. A third dynamic phenomenon is the dependence of mergers and acquisitions on the phase of the business cycle; the factors that determine the time pattern of diversification over the cycle are still a source of disagreement (Smyth, 1985 and Ball, 1988).

Geographic expansion

Although geographic expansion appears as an evident outcome of information technology that facilitates co-ordination and successively widens the span of control, there are barriers

within each country and when expanding across national borders. The creation of global firms in the construction sector is retarded by legal, cultural and other factors (Casson, 1987) which complicate the design of employee incentives and client relations. Also, financial patterns are often reversed when working abroad; instead of the contractor being able to draw upon clients, suppliers and subcontractors to an extent that makes him a constant debtor at home, he finds it necessary to provide finance for the foreign client (Smyth, 1985).

At the present state of information technology, globalization will often be confined to incomplete integration with certain functions of the firm such as research and development centralized and the results of these activities being the subject of interfirm transactions. Reputations of contractors may, however, play a greater role with the spread of multinational client organizations, so that a business relationship can be preserved and transferred in space and time.

Diversification

The efficient bundling of activities into a single firm is here assumed to be influenced by the information aspects of the construction methods concerned. In other words, the idea is that technology embodied in these methods determines organizational structure only by means of technology-specific information requirements and the information technology available.

A classification of technologies in construction should then permit the identification of candidates for integration, given a certain stage of development of information technology. Moss (1981) suggests that goods and services are to be characterized by the degree to which they are storable, portable and cognizable. Using these three categories, which give us the possibility to analyse the potential for supporting the market exchange (as opposed to integration) of any commodity, three corresponding strategies in terms of durability, compactness and standardization are formulated. All of these strategies for commodities will weaken the integrative links between production stages. The third strategy, standardization, is very closely related to information technology, in particular the aspects of co-ordination and inspection.

Standardization as a concept overlaps with quality control, which is the focus of the analysis of vertical integration carried out by Casson (1987), who concentrates on the characteristics of the production activity itself rather than the resulting commodities. Casson introduces a dichotomy with either transformation or sorting in order to discuss decentralization of quality control. Concreting is a good example of a transformation activity. Activities dominated by sorting should be sensitive to improvements in the ability to inspect and to co-ordinate.

The most ambitious attempt up to now in classification of construction technologies has been presented by Tatum (1988), although innovation rather than the effects of information technology is his theme. Aspects of information technology appear twice in his classification: first, when information is considered as an element among construction–applied resources, secondly when uncertainty is treated as one of the attributes of each construction method. With information as a resource element, the translation aspect of information technology is obviously pertinent, whereas methods-related uncertainty of quality, timing or cost in the second case may arise through insufficient tools for coordination and inspection.

Summing up, we find that uncertainty concerning intermediate products, their availability and quality, is conducive to integration. If information technology develops so that co-ordination and inspection are alleviated, tendencies towards integration between firms

standing for separate stages of production will be weaker. The reduction of uncertainty through application of better information technologies does not proceed at an even pace, however; our ability to predict external influences such as the weather is not improved at the same rate as our short-term predictions of the whereabouts of materials and equipment. At the same time, lowered transaction costs will, as a general observation, increase the dependence on market relationships.

Subcontracting

In many ways, the traditional pattern of subcontracting in construction is surprising: a system where technologies are imperfectly separable (and increasingly so, according to Lansley, 1987) while quality control is difficult seems a prime candidate for integration into a single firm. It is therefore important to see how intimately related to information several of the factors are which Hillebrandt (1984) offers as explanations to subcontracting practices. Common to a number of these factors is the need for efficient capacity use of specialized operatives as well as of management and physical resources. If our ability to co-ordinate resource use increases considerably, we find that subcontracting loses much of its reason of existence. Specialized assets will be used more efficiently, also within the integrated firm. There seems to be no clear direction of structural change when information technology improves: co-ordinatory power weakens both some of the arguments for integration and for subcontracting. A closer look at transaction costs is consequently called for.

Applying a transaction costs approach to empirical data on US subcontracting practices, Eccles (1981b) has been able to explain the lack of integration between contractors in so far as greater project complexity and size leads to a greater dependence on subcontractors, while a more extensive market also carries with it a larger proportion of subcontractors. Since he disproves the hypothesis that seasonal variability, which can be foreseen, is a determining factor, it appears that pure market uncertainty is the factor that encourages subcontractor use. We obtain the characteristic neither-market-nor-hierarchy incomplete integration, the quasifirm of Eccles (1981a) or as described by Gunnarson and Levitt (1982).

A number of observations on the division of information technology-sensitive tasks on the building site are presented by Casson (1987) against the background of his quality control analysis. Thus, the contractor has the advantage of inspectional economies for subcontractors' operations when several subcontractors are monitored jointly on the site. Activities which are seldom let out to subcontractors are found to be those that influence safety (erection of load-bearing structures, handling of cranes and hoists) or punctuality. In both these cases, information technology would appear to promote subcontracting, provided that, e.g. robotics are able to raise safety levels and that the ability to co-ordinate improves punctuality. Unfortunately, the Swedish pattern of distribution of work for subcontractors does not agree with this picture. Instead, subcontracting appears as a link in a process which successively reduces price uncertainty for the general contractor, and must be seen in the context of Swedish fixed-price general contracting as opposed to quantity contracts.

Integration backward to materials supply

At first sight it seems odd that so few examples of backward vertical integration from construction to materials supply can be identified. Eccles (1981a) presents the case against backward integration when demand and prices are uncertain, but the firm is relatively sure of

obtaining the necessary resource inputs. Looking at the early twentieth century, Chandler (1977) found that in construction and other labour intensive, low-energy-consuming industries where administrative co-ordination did not result in sharp reductions of unit costs, or provide services, and so create barriers to entry, vertical integration did not provide a profitable alternative to horizontal combination.

What backward integration there is, does nevertheless conform to predictions based on the portability strategy formulated by Moss (1981): high transportation costs associated with certain physical resources used on the site encourage integration. It also helps to explain why integration into business activities with a geographically wider market for the products than the construction activities of the firm is unusual.

Searching for possible changes induced by information technology, there are reasons for a closer look at transformation processes and their duration. When Chandler (1977) discusses changes in the construction industry in the nineteenth and early twentieth centuries, he notes that there was little need to build a complex organization to co-ordinate the flow of goods from one process to another. Although construction is still a labour-intensive industry, with 'little opportunity to speed up the processes of production by a more intense application of energy', the effect of improved information technology will improve co-ordination to an extent where the total duration of work on site will be the sum of the serial transformation processes which make up the critical path of site activities.

A peculiar relation between contractors and suppliers is that suppliers provide finance for building operations as trade credit, just as subcontactors support main contractors financially. Financial services are almost nothing but the handling of information (Synnott, 1987). Since finance and the structure of firms offering finance is dependent on current information technology, there is the possibility that the financial provision will be relocated in the future system of production stages. Financially strong firms may both co-ordinate construction and offer finance to clients (or just co-ordinate finance) – not only abroad, but also on the domestic markets, due to superior information on the creditworthiness of customers. Such a line of business is then a byproduct of the main services offered and the contacts and insight created by those services. An alternative is that the co-ordinator co-ordinates finance from various sources, in a manner that resembles co-ordination of construction.

Integration forward to real estate

Forward vertical integration by construction firms into the property market has been dealt with primarily by Grebler (1973), Eichler (1982) and Smyth (1985). Many and often mutually dependent reasons for this form of vertical integration have been adduced. Some of these reasons will cease to exert integrating force with improvements in information technology, others will keep or strengthen their force, as we shall see.

The need to even out capacity use, especially the importance of an even employment of people, is one of the main factors of integration. With property holdings, the construction workers can be set to maintenance and renewal work when construction demand is at an ebb. This is very close to the argument for the acquisition of virgin land for countercyclical development activities. Obviously, this argument for integration has to do with variations and uncertainty corresponding to the issue of subcontracting. If uncertainty is reduced, then foresight will reduce the need for alternative activities in slack periods. Also, with lowered transaction costs, the use of external workers will be more attractive.

Asymmetries in the taxation of corporate income from highly variable construction returns may prompt investments in the property market. This integrative effect would reinforce other reactions to variability in activities. Investment allowances and other deductions may also create synergies between construction activities and property holdings. Capital gains taxes in times of inflation is another factor causing asymmetries, more so in the construction sector than elsewhere, since buildings are very durable goods. Because improved information technology means a growing ability to handle and calculate tax effects of a complex of activities, the behaviour of firms will mirror tax regulations more closely than before.

There may also be financial reasons. Financial actors may perceive too high a risk associated with pure construction operations and conversely underrate the risk in property markets. If the high stock market rating of property assets in comparison with contractors' traditional assets is considered, there is an incentive for construction firms, when going public, to integrate forward into property (Smyth, 1985). This argument may be weakened not only by higher perceived risks in property investment but also and independently by better information, since this line of reasoning assumes that financial markets possess very limited information on risks associated with various activities, something which is bound to change with the transparency of operations that more efficient information systems promise.

A major reason is the acquisition of information on end-user preferences. Formal and informal contacts with end users generate both general insight into future construction needs and into specific demand in a given locality and time period. This is beneficial for both the construction and the property acquisition part of the corporate whole. However, improved general access to databases for user demand, as pointed out by Hasegawa (1988), will erode part of this position of privilege.

Not entirely unrelated to end-user information is the ability to acquire knowledge on the long-term behaviour and costs-in-use of the construction technologies employed. Latent defects show up with time. Today, the client or the buyer of an existing structure faces prohibitive costs based on the documentation and interpretation of documents describing the long-term characteristics of a building. If specialist knowledge on durability is more generally accessible, this factor declines in importance for integration.

Finally, there is the issue of reputation. Being both a builder and a property manager reinforces the impression of professionalism in execution. This certainly assumes that search and quality inspection costs are so high for clients that reputations are of great value to producers, which may not be true in the long run, when product qualities in themselves take on added importance.

In the shorter time perspective, the client will still have to turn to a reputation in order to reduce search costs (Shapiro, 1983). Reputations are useful and efficient during an interval only of the development of information technology, just like standardization of products is needed for some time to survive a certain stage of development of information technology. In a full-information world, goods quality is immediately found by inspection, but this is far too costly or impossible in the short run.

Information intermediaries

An information intermediary is an agent who first collects information in the stores and then sells it to the customer who would otherwise have to do his own searching (Hänchen and von

Ungern-Sternberg, 1985). Moss (1981) stresses the storage function of the intermediaries: they are able to provide information services at a later date. Firms that serve as information intermediaries are common in construction, in most cases as design consultants, but there are also management contractors who are pure co-ordinators and information intermediaries in that capacity. Certain if not most financial institutions should be viewed as a third type of information intermediary in construction.

Using the concept of trilateral governance, Reve and Levitt (1984) have explored the relation between client, consultant and contractor explicitly as a form of incomplete integration, basing the analysis on a transaction cost approach. However, a more generalized view of information middlemen seems to be called for, not just the triangular relationship, but also other polygons should be admitted.

It is typical of the construction industry that there is a large number of intermediaries who mainly serve as consultants to translate clients' needs into a design for construction. Of course, the main reason is that most clients appear on the market very seldom, if not only once. This is in contrast to other industries, where buyers find it easier to specify their needs and check that their needs are met by the products offered to them. Incomplete integration through franchises may approach an intermediary role for the franchisor, provided that he does not perform any other work than pure information production.

An information intermediary can be thought of as an investor in information. As any investor, the intermediary will be deeply affected by a general reduction in the unit cost of the object of investment, namely information. However, these intermediaries cannot be entirely replaced because of their arbitration role, although it is difficult to imagine what place there is left for arbitration in a full-information world. They act both as trustees and judges to the client, and they cannot be entirely replaced by an expert system as they deal in informal assessments; their manner of guiding is to tell informally what record suppliers and contractors have. Since a major function of the intermediaries in construction is to assess reputations and deal in informal knowledge, they themselves are even more dependent on their own reputations and the manner of establishing and preserving their standing (Reve and Levitt, 1984). The alternative to individual testing of reputations is the standardization achieved by government authorities and professional bodies: Schulenburg (1986) discusses advance evaluation of professional quality.

Besides the storage and arbitration functions, there are also the economies of bulk transactions and information economies of scale (Moss, 1981), which may preserve the role of independent intermediaries in construction, at least in a transitory phase. The returns to increased scale may occur stepwise, and we can perhaps identify a scale platform where integration with computing and finance consultancies is a profitable strategy.

With many predecessors, Nam and Tatum (1988) deplore the separation of product design from production management in construction as opposed to manufacturing. However, the merging of design and production management occurs in design-and-build as well as in turnkey deliveries, and the development of information technology promises the electronic integration described by Benjamin and Scott Morton (1988): integration of formerly distinct transaction processes, integration of multiple forms of data representation and knowledge, and integration of groups through communication. It is especially the integration of multiple forms of data that is important, based on an improved, shared data access and on the other hand, improved interconnection. Absorbing the design stage may also contribute to higher barriers to competition within the industry.

The process of integrating design and production is not what is generally considered as

vertical integration, but rather a case of elimination of an information intermediary as a corporate entity. A closer parallel to the situation when two production processes are integrated vertically is when two intermediaries merge vertically. Declining demand during the 1970s has in certain cases had the effect that process engineering has been combined with construction engineering.

An emerging differentiation

Since adjustment to new information technology is a slow and gradual process, as it works through changes in fundamental attitudes, incentives and culture in the firm, the structure of the construction industry of today is more likely to reflect optimal firms in the setting of the 1960s or the 1970s rather than the technological possibilities of the late 1980s.

As part of the activity of each firm in erecting barriers to competition, firms in a fragmented industry such as construction with its unique products in dispersed and isolated markets may choose to pursue a strategy of increased product complexity (Porter, 1980). Competitive tendering based on detailed drawings and specifications develops such a fierce degree of efficiency with better facilities of information translation that contractors will feel a strong urge to transform the extremely competitive auction into a buyer–seller relation with more complexity.

Handling the complexity is made simpler by information technology. However, at least in the initial stages, heavy investment in software development and training is needed to achieve a new and more efficient internal structure of labour division within the firm. The optimal economies of scale in information can be reached by horizontal and vertical integration, not least comprising information intermediaries. A conscious strategy of this type implies that information technology comes to the forefront, most conspicuously if, with precedent in information-heavy services such as banking, a chief information officer (CIO) is included in the top management core (Synnott, 1987) instead of being relegated to a position of a lower rank manager of a data processing department.

Regardless of the strategy being a well-formulated, conscious outcome of management or just an imputed phenomenon, it appears that there are three paths which are generated by the aspects of information technology already presented.

First, there will be a path leading to specialized contractors, working on an increasingly global market for their technological knowhow, investing in research and development and sustained by a global network of good telecommunications. They will tend to integrate backwards into specialized materials and equipment supply.

Secondly and concurrently, there will be more management contractors with no operatives employed, co-ordinating the specialist subcontractors. It is conceivable that these co-ordinators integrate into project finance, design, marketing and property management. They correspond to information intermediaries in our scheme. They will perhaps absorb today's consultants, if these do not merge with consultants in computing and finance due to information economies of scope.

Thirdly, there will remain a market for locally entrenched construction firms which possess the informal knowledge and the personal contacts needed for markets for resources and products. They too will rely on specialist contractors in many cases but they will have a core of operatives of their own, perhaps with broader skills in refurbishment as a non-specialized base, bordering on the do-it-yourself alternative for small clients.

So far, the pattern has been presented without an analysis of the possibilities for incomplete integration. Franchising and semi-dependent subsidiaries are two examples of incomplete integration with specific relations to individual aspects of information technology. When global co-ordination and translation into technology turns easier, product inspection by customers is still costly, and employee incentives remain difficult to improve, franchising arrangements should be attractive. The specialist firms in particular may attain an efficient level of centralized research and development by such arrangements. But if global co-ordination is more difficult whereas efficient incentives for employees can be designed, the semi-dependent subsidiary, the one that sells perhaps half its services to other firms in the market, may be a superior choice of organization.

Individuals in project networks

A continued development of information technology will eventually unsettle the balance between three types of firms just outlined. In particular, all three types will be subject to dissolving forces when costs of transactions are reduced to a still lower level. A network based on a multitude of contracts between individuals will be an increasingly attractive alternative in the absence of employee incentives sufficient to sustain integrated firms. Members of the network, which can be based on a single project, are all information intermediaries, except for the operatives engaged in physical handling and *in situ* transformation processes.

There is scope for further division of labour among intermediaries, provided that there are better telecommunications. Reductions in telecommunication costs will not be enjoyed simply as cost reductions without any further effects, but the ensuing division of labour may paradoxically lead to an actual increase in transaction costs while production costs dwindle (Matthews, 1986).

It may not be immediately apparent why the efficient information intermediary should be the individual. Office automation and further consequences of the translation and co-ordination aspects of information technology have already removed many of the reasons for a vertical division of labour in design firms; traditional secretaries and draughtsmen are made obsolete. Moreover, the content of expertise will change with the development of expert systems and other forms of artificial intelligence, improving the access to technical knowledge used in construction.

Although the provision of industry-wide databases represents a new stage in the application of information technology, the process of locating a fellow intermediary in a database and proceeding to a contractual relationship still implies a value given to trust in a reputation. The building and maintenance of reputations needs face-to-face contacts and other informal ways of communication. In this light, the marked increase in the volume of business travel can be interpreted as a consequence of improved telecommunications, owing to the substitution effect. Even a sharp decline in the proportion of face-to-face communications compared to electronic media is compatible with more travel when there is a rapid expansion of telecommunications.

The project network corresponds to a financial network. Decentralized finance is however nothing new to construction projects with their reliance on client advances and trade credits. Taking into account greater speed expected in site operations, a number of time-consuming transformation and assembly operations will remain and preserve the need for financial bridging of the duration of projects.

What there is of recent statistical evidence from Sweden points to a tendency of atomization in the construction sector. Between 2000 and 3000 legal entities as new firms are set up each year within the construction sector, but just about one in ten of these firms have three or more employees (in 1986, 13%; Statistics Sweden, 1988). In the initial discussion of the figures of Table 1, we found a growing gap between employment and the volume of construction investment, a discrepancy which to a large extent can be explained by the growth of market share for single-person firms.

Conclusions

We have looked at the effects of various aspects of information technology via patterns of integration in the construction industry. It is likely that there will in a transitory phase be a tripartite structure in industry, based on specializing, co-ordinating and local firms, while ultimately, information technology may lead to a pattern with individuals in networks. It remains to be seen what the issue of reputations implies at that stage, as well as the standardization of information. Strategies for individual firms should acknowledge that the development of existing skills within the organization is to be seen in relation to the underlying structural effects of aspects of current information technology.

References

Ball, M. (1988) *Rebuilding construction: economic change and the British construction industry.* Routledge, London.

Beniger, J.R. (1986) *The Control Revolution: technological and economic origins of the Information Society.* Harvard University Press, Cambridge, Mass.

Benjamin, R.I. and Scott Morton, M.S. (1988) Information technology, integration, and organizational change, *Interfaces*, **18**, 3, 86–98.

Broms, B. and Hanson, R. (1987) *Stora lokalföretag eller lokala storföretag?* Byggentreprenörerna, Stockholm.

Casson, M. (1987) *The firm and the market: studies on multinational enterprise and the scope of the firm.* Basil Blackwell, Oxford.

Centre for Strategic Studies in Construction (1988) *Building Britain 2001.* Reading.

Chandler, A.D., Jr. (1977) *The visible hand: the managerial revolution in American Business.* Harvard University Press, Cambridge, Mass.

DuBoff, R.B. (1983) The telegraph and the structure of markets in the United States, 1845–1890, *Research in Economic History*, **8**, 253–77.

Eccles, R. (1981a) The quasifirm in the construction industry, *Journal of Economic Behavior and Organization*, **2**, 335–59.

Eccles, R. (1981b) Bureaucratic versus craft administration: the relationship of market structure to the construction firm, *Administrative Science Quarterly*, **26**, 449–69.

Eichler, N. (1982) *The merchant builders.* The MIT Press, Cambridge, Mass.

Gold, B. (1981) Changing perspectives on size, scale, and returns: an interpretive survey, *Journal of Economic Literature*, **19**, 5–33.

Gold, B. (1986) Technological change and vertical integration, *Managerial and Decision Economics*, **7**, 3, 169–76.

Grebler, L. (1973) *Large scale housing and real estate firms: analysis of a new business enterprise.* Praeger, New York.

Gunnarson, S. and Levitt, R. (1982) Is a building construction project a hierarchy or a market? In *Proceedings Internet 7th World Congress on Project Management, Copenhagen, 12–17 September 1982*, J.O. Riis *et al.* (eds). Copenhagen, Danish Project Management Society, pp. 521–9.

Hänchen, T. and von Ungern-Sternberg, T. (1985) Information costs, intermediation and equilibrium price, *Economica*, **52**, 407–19.

Hasegawa, F. and the Shimizu Group FS (1988) *Built by Japan: competitive strategies of the Japanese construction industry*. John Wiley, New York.

Hillebrandt, P.M. (1984) *Analysis of the British construction industry*. Macmillan, London.

Lansley, P.R. (1987) Corporate strategy and survival in the UK construction industry, *Construction Management and Economics*, **5**, 141–55.

Matthews, R.C.O. (1986) The economics of institutions and the sources of growth, *Economic Journal*, **96**, 903–18.

Moss, S. (1981) *An economic theory of business strategy: an essay in dynamics without equilibrium*. Martin Robertson, Oxford.

Nam, C.H. and Tatum, C.B. (1988) Major characteristics of constructed projects and resulting limitations of construction technology, *Construction Management and Economics*, **6**, 133–48.

Panzar, J.C. and Willig, R.D. (1981) Economies of scope, *American Economic Review, Papers & Proceedings*, **71**, 2, 268–72.

Porter, M.E. (1980) *Competitive strategy: techniques for analyzing industries and competitors*. The Free Press, New York.

Reve, T. and Levitt, R.E. (1984) Organization and governance in construction, *International Journal of Project Management*, **2**, 17–25.

Rogerson, W.P. (1983) Reputation and product quality, *Bell Journal of Economics*, **14**, 508–16.

Rounds, J.L. and Warning, G. (1987) Impact of computerizing midsized construction companies, *Journal of Construction Engineering and Management*, **113**, 183–90.

Schulenburg, J.-M. Graf von der (1986) Regulatory measures to enforce quality production of self-employed professionals: a theoretical study of a dynamic market process, J.-M. Graf von der Schulenburg and G. Skogh (eds), *Law and Economics and the Economics of Legal Regulations*. Kluwer, Dordrecht, pp. 133–47.

Shapiro, C. (1983) Premiums for high-quality products as returns to reputations, *Quarterly Journal of Economics*, **98**, 659–79.

Smyth, H. (1985) *Property companies and the construction industry in Britain*. Cambridge University Press, Cambridge.

Statistics Sweden (1988) *New firms in Sweden 1986 and 1987*, F15 SM8801, Stockholm.

Synnott, W.R. (1987) *The information weapon: winning customers and markets with technology*. John Wiley, New York.

Tatum, C.B. (1988) Classification system for construction technology, *Journal of Construction Engineering and Management*, **114**, 344–63.

Williamson, O.E. (1970) *Corporate control and business behavior*. Prentice Hall, Englewood Cliffs, N.J.

Williamson, O.E. (1985) *The economic institutions of Capitalism: firms, markets, relational contracting*. The Free Press, New York.

Wilson, R. (1975) Informational economies of scale, *Bell Journal of Economics*, **6**, 184–95.