

# ELECTRONIC INTERACTION IN CONSTRUCTION: WHY IS NOT A REALITY?

Antonio Grilo, Martin Betts, Miguel Mateus

*ABSTRACT: The achievement of CIC requires that electronic links between parties in a construction project are accomplished. While there has been substantial research on the technical issues of electronic communications between construction firms, the absence of electronic links in practice suggests that research is needed related to the implementation issues. Such work is partially described in this paper where the approach is in context of the network industrial organisation paradigm. This paper aims at contributing to a better understanding of the lack of electronic links in construction project networks. This is done through the presentation of the CONNET model.*

*KEYWORDS: Networks, Electronic Trading, Inter-Organisational Systems (IOS), EDI, Process Innovation, Buyer-Supplier Relationships, CONNET Model*

## 1. - CONTEXT

A crucial step towards Computer Integrated Construction (CIC) is the deployment of electronic trading within construction. However, CIC can not be accomplished if firms within construction do not communicate electronically. While IT has long been a necessary and indispensable part of the internal operations of construction companies (consultants, designers, contractors, material suppliers, etc.), the use of IT for electronic communications within the construction project has been scarce (mainly experimental research work). Researchers have been focusing essentially on the technical aspects of the problem, developing integrated databases, communication protocols, etc., with emphasis on the design stages of the construction process (see e.g. Brandon and Betts, 1995). Little attention has been giving to better understand the issues that hinder the initiation and dissemination of electronic trading practices in construction.

The co-ordination by large main contractors of their suppliers (which refers to material suppliers, subcontractors, tool hirers, etc.) has great scope for electronic trading. In other industries, like retailing, automotive, transport, etc., large buyers have long been establishing electronic links with their suppliers in order to improve supply management. Common explanations advocate that the industrial structure and organisation of construction does not encourage electronic links: its industry fragmentation; fragmented clients; unique nature of each project; and lack of IT standards are often blamed (see e.g. Construct IT - Bridging the Gap, HMSO, 1995; or Baldwin et al, 1995).

In our perspective, a more coherent and robust theoretical explanation is required in order to better understand the lack of electronic links between main contractors and their suppliers, but also to pave the way forward. Thus, it is important to analyse *how and why electronic trading within the network of buyers (hubs) and suppliers is initialised and developed, in general, and in the construction project in particular*. The approach used is based on the development of a generic model that explains the initialisation and dissemination of electronic links between



large buyers and their suppliers, regardless of the industry. The explanation of the construction case is made by comparison with successful cases. Research is currently being carried out in order to validate the model and the propositions put forward in this paper.

## **2. - ELECTRONIC INTERACTION**

There are several technologies that enable computer-based linkage between firms, including electronic data/information transfer, like EDI, e-mail, EFT, PDI, interactive on-line databases, etc. (Jayachandra, 1994). Electronic trading is often used in service industries to designate collectively these technologies. In this work we prefer the designation electronic interaction, as trading is too much in linked to a commercial context.

In order to clarify this matter in this work we adapted the definition by Cunningham and Tynan (1993):

*Electronic interaction is defined as any business interaction which relies upon the use of Information Technology for organisational communications involving telecommunication links. Electronic interaction systems exploit IT capabilities to improve the efficiency of information flow and/or to fundamentally alter the nature of the inter-organisational transactions.*

## **3. - PRODUCTION NETWORKS**

In this work the network perspective for describing the industrial organisation structure of firms is adopted. Network forms are characterised by having intermediate forms between markets (competitive arm's-length supply) and vertical integration (Powell, 1990).

An interesting theory of networks is put forward by Harrison (1994). According to him, a typology of classes of production networks is beginning to emerge.

- 1) Small firm-led industrial districts. A classical example are the Italian industrial districts, where small firms co-operate and collaborate on project basis, assembled by an intermediary, on a wide range of industries.
- 2) Agglomerated big firm-led production system. Examples are the networks of Toyota, Benetton, General Electric, Toshiba, Tesco.
- 3) Strategic alliances. These are most common between big companies that decide to enter in new businesses.
- 4) Craft-type industries. Where work tends to be organised around a specific project rather than around bounded firms. The most classical example is the construction project, or also the organisation of large main contractors. Other examples are computer programming, textile manufacturers, etc.

Regardless of its typology, the network form is a way to handle tasks and environments that demand flexibility and adaptability, caused by uncertainty, fragmentation, time compression, demanded by contemporary competition (Miles and Snow, 1992; Baker, 1992).

According to Harrison, production networks have the following characteristics.

*Input-Output structure* - a set of transacting production units of various sizes. An I-O system is a collection of activities that lead to the production of a specific marketable output, e.g. a building, a bridge, an aeroplane, a car, etc. In construction this includes both the on-site and off-site activities.

*Territoriality*. This concerns the spatial dimension of the production units. Thus, a territorial agglomeration is a collection of production units within a limited area. Construction projects are by their nature dispersed, but on each project local suppliers (agglomeration) are usually assembled.

*Governance structure*. These are the authority and power systems and respective relationships. The power systems lie in a continuum. At one extreme, core systems, power is highly asymmetrical, and a large buyer (core firm) can determine and strongly influence suppliers (ring). This is likely to be found in big firm-led production systems. At the other extreme, ring systems, where there is no enduring lead firm, firms do not exert power through medium- or long-term influence over others (only during a short interaction) and power is symmetrical. This is the general case with construction projects as firms entering the project do not have much power over others, except during the period of the project. Large main contractors do not have much influence upon their suppliers before and after the project.

The relationships are also best seen as lying in a continuum with at one extreme Arm's-length Contractual Relations (ACR) and on the other Obligational Contractual Relations (OCR) (Sako, 1992). ACR-type relationships mean that competitive, "free-market", adversarial and short-term relationships are the norm. Seeking alternative trading partners is an easily available option when a contract comes to an end. This is the type of relationships that exist in construction production networks. At the other extreme, firms enter into OCR-type relationships if they prefer trust, co-operativeness, with a commitment to trade over the long term.

#### **4. - THE CONNET MODEL**

The CONstruction NETwork - CONNET - model was developed in order to better understand the lack of initialisation and development of electronic interaction within construction production networks. However, the model was developed considering that it is important to compare production networks which have electronic interaction (such as the retailing, automotive, some textile, etc.) from those who have not (construction projects, main contractors, some textile manufacturers, etc.).

The CONNET model considers three distinct levels of analysis, which are interrelated (Figure 1). The first level, the Dyadic level, addresses the issues concerning each specific electronic interaction, i.e. the individual link between the hub and each supplier. In construction terms, it is related with, e.g. the link that a main contractor establishes with each supplier, on each project. On the second level, the Production Network level, the impact of the network characteristics on each individual interaction and on the dissemination of the electronic links within the network is addressed. Also, the impact of the dissemination of electronic links on the network characteristics is analysed. In construction, it is about e.g. the characteristics of the network of suppliers that a main contractor compounds for each project. Finally, on the Environmental level, the impact of the environmental factors on each individual interaction and on the production network characteristics are briefly addressed. In construction this

represents how the culture, structure, trends of the industry are reflected on the construction project network and on each link between contractor and suppliers.

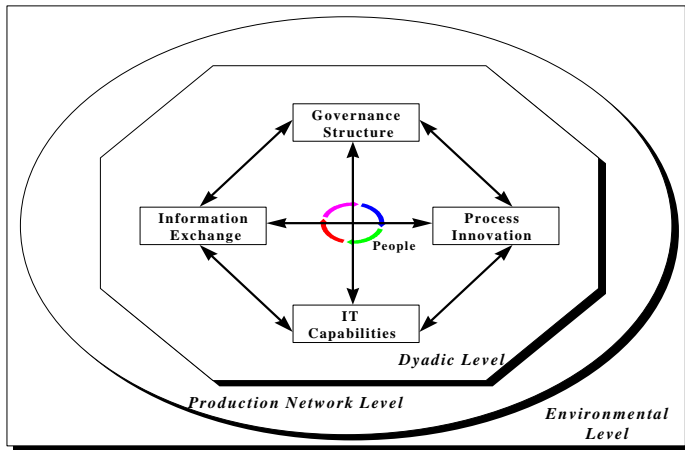


Figure 1 - The CONNET Model

This paper focus essentially on the dyadic level of the CONNET model, and thus the interdependence with the production network and environmental levels are only briefly addressed

#### 4.1. - Conditioning Factors

At the dyadic level there are four main conditioning factors of the individual electronic interaction: the governance structure; the information exchange; the IT capabilities; and the process innovation.

*Governance structure.* Relates to the power dependence and the type of relationship on the individual hub-supplier interaction.

Power dependence:

1. Hub firm highly dominant over supplier.
2. Hub firm with some power over supplier.
3. Hub firm has no power over supplier.

A construction main contractor usually has low power over a supplier. This power is restricted to the duration of the project (Latham, 1994).

Relationships:

1. Competitive, free-market, adversarial, non-trustful, short-term.
2. Co-operation, collaborative, trustful, commitment to the long term.

Construction inter-firm relations in general, and between main contractor and supplier in particular are characterised by little collaboration, more discord than harmony, and short-term commitment (Latham, 1994).

*Information exchange.* Refers to the information/data that is transferred between the hub and supplier.

#### Information sharing

1. Administrative, i.e. payments, sending enquiries, receiving quotations, sending orders, order tracing, invoicing, delivery notes, etc.
2. Operational, relating to specific projects, like inventory control, delivery schedules, resource capacity planning and allocation, etc.
3. Tactical, relating to internal and common processes, like logistics management, purchasing policy, R&D management, production procedures and rules, etc.
4. Strategic, relates to the whole production network, like overall business strategy, alliances and joint ventures, new products and markets, etc.

Construction firms share mainly the administrative and operational type of information (Bresnen, 1990).

Information quality, refers to the accuracy, timeliness, adequacy and transparency of the information. The quality of the information exchanged between main contractor and supplier is low (Atkin and Potthecary, 1994).

#### Communication channels

1. Wide or multiple points of contact. i.e. top management, technical personnel, sales and purchases, etc.
2. Single point of contact, i.e. sales and purchase

Main contractor and supplier have usually narrow communication channels.

Transfer medium, through which information is exchanged, e.g. electronic, fax, letter, phone, face-to-face.

*Process innovation.* Refers to any changes which occur on internal business processes and related with electronic links.

Timing, of the changes, which can be before, simultaneously or after the electronic links deployment

#### Scope

1. Incremental changes, like automation of manual tasks, elimination of tasks, etc.
2. Radical, like re-engineering the logistics and purchasing functions, implementation of JIT systems, etc.

Construction culture is much adverse to innovation, either incremental or radical, specially when does not concern the production process (Atkin and Potthecary, 1994).

#### Benefits

1. First-order, desired effects from specified changes, like cost reductions, reduction of personnel, etc.
2. Second-order, unintentional benefits, not specifically predicted, like e.g. more and better trade, more available information, etc.
3. Operational, like cost reductions, better quality, reduced cycle time, etc.
4. Strategic, like more flexibility and responsiveness, better relationships, more and better trade, barriers to entry, strategic alliances, etc.

5. Hindrances, issues that may hinder benefits, like high cost of development, lack of critical intensity of transactions, lack of critical mass users, co-existence of parallel systems, etc. Main contractor and supplier do not foresee major benefits from improving inter-firm coordination through IT (Betts et al, 1995). Many factors, related with network and environmental characteristics seem to hinder possible benefits.

*IT capabilities.* Refers to the technological issues of the electronic interaction.

Technology, like EDI, EDE, EFT, interactive on-line databases, CSCW, etc. Despite positive forecast (KPMG and CICA, 1993), these technologies seem to be emerging very slowly in construction (Baldwin et al, 1995).

Maturity, refers to the experience of the firms with IT in general and with the technology for electronic interaction in particular. Main contractors have in general terms much more “experience” with IT than suppliers. However, referring to communication technologies both are highly immature.

Specificity

Proprietary, or common systems, i.e. IT systems commercially available. There are not many commercially available technologies specifically to construction in general and for contractor and supplier in particular.

The CONNET model considers that the human factor, with their values, beliefs, actions is reflected in the pattern of the conditioning factors. Another important consideration that has to be made is that the pattern of the conditioning factors may be different from hub to supplier firms.

#### **4.2. - Dynamics of the Conditioning Factors.**

The pattern of the conditioning factors shifts overtime, due either changes on the production network, environment or due the interplay of the conditioning factors as these are interdependent. .

- Trustful relationships lead to information sharing on the tactical and strategic levels. In construction, adversarial relationships, lead to low information sharing, with inaccurate, inadequate, and non-transparent (Bresnen, 1990).
- When technologies require collaboration between hub and supplier in order to be deployed, are more likely to developed in trustful collaborative relationships. Immature technologies require more collaboration than mature technologies (O’Callaghan, 1995). Thus, the collaboration required by construction firms in order to deploy EDI is much higher than with automotive firms which are quite mature with EDI.
- Hub firms with buying power over supplier can coerce these to use specific technologies, like EDI, interactive on-line databases, etc.
- Many other possible interplay exist which are not listed here for simplification.

#### **4.3. - Pattern of Conditioning Factors on a Successful Dyadic Electronic Interaction**

The interplay and self-reinforcement of the conditioning factors is so complex as to obscure which were the initial patterns, and the causes and effects. Moreover, this interdependence is constrained by the characteristics of the production network and environmental factors. However, there are some generic patterns that seem to emerge after a dyadic electronic interaction has successfully been initialised, developed, and implemented.

- Power system. Electronic interaction seems to reinforce the power of the hub firm over supplier (Cunningham and Tynan, 1993).
- Relationships. Electronic interaction makes a movement towards more co-operative, collaborative, trustful and long-term relationships (Cunningham and Tynan, 1993).
- Information sharing. Electronic interaction lead to higher levels of information sharing, such as tactical and eventually strategic.
- Information quality. Electronic media increases considerably the quality of administrative and operational information exchanged. Other information is exchanged with more transparency (Scott Morton, 1991).
- Communication channels. Electronic interaction seem to widen the communication channels, as there is more contacts between top management and technical personnel
- Transfer medium. Some authors argue that electronic interaction increases the number of face-to-face contact for information exchange (Nohiria and Eccles, 1992).
- Scope. Electronic interaction is usually associated with incremental changes in internal business processes. However, radical changes can occur but are likely to happen only to the hub firm (Bjorn-Andersen and Krcmar, 1995).
- Benefits. Higher benefits are likely to occur to hub firms. Hubs are likely to have first-order benefits and suppliers second-order benefits. Strategic benefits are more relevant for supplier, but hub firm usually obtains both operational and strategic benefits (Bjorn-Andersen and Krcmar).
- Hindrance are more likely to be relevant for supplier. Hub firm is usually more able to overcome problems.
- Technology. EDI, e-mail and interactive on-line databases are the technologies more likely to deployed (Scott Morton, 1991).
- Specificity. Electronic interaction is usually based on common systems (Bjorn-Andersen and Krcmar).
- Maturity. Technology is usually more mature for the hub firm than for the supplier.

The previously defined patterns are rarely in place before the initialisation of any dyadic electronic interaction. In this work we designate *Investment* as the effect for each conditioning factor that a firm (hub and/or supplier) has to make in order to change the patterns of the conditioning patterns before electronic interaction initiation and development to the patterns of the conditioning factors after its full deployment. There are several types of investment required.

1. Capital. It is the most obvious and easiest to measure. Capital investment includes not just the capital for acquiring and/or developing the equipment, but also for maintaining it, training people to use it. Also, it includes the capital spent on management time and effort on establishing terms, methodologies, etc. Finally, it includes the capital related with the development of new procedures and ways of working due internal changes.
2. Information. Higher levels of information sharing and quality may imply giving “proprietary” information about each individual company to another. This may imply

losing the opportunity to opportunistic behaviour. Bresnen refers that in construction firms do not share the required level of information as it can work against them due contractual arrangements (Bresnen, 1990).

3. Power system and relationships. The investment of supplier on power dependence from hub implies satisfying hub's requirements. For the hub imply creating the buyer's power by centralised purchasing, market acquisition, etc. Investment on relationships may imply hub accepting sporadically higher prices and providing periodical workload to the supplier. For the supplier, it means leaving opportunistic behaviour, continuously improving product cost and quality, etc. Overall, it may also mean avoiding conflicting joint problem resolution approaches.

In order to initialise any electronic interaction, firms must have *willingness* to invest. This derives from three main issues:

1. The pressure from environmental factors. Typical factors are : i) competition in highly complex markets over wide geographical areas.; ii) increasing competition; iii) new business practices, like JIT, lean production, quick response, etc.; iv) demanding customers; v) product complexity. Western automotive automakers started to deploy electronic links as a response to Japanese competition pressure and new business practices. Larger firms are more likely to feel pressure from environmental factors (Nelson and Winter, 1983).
2. The "type" of investment. Some firms may be more willing to invest in capital but not on improving relationships and information sharing. Others may be more willing to invest on better relationships but not on power dependence, etc.
3. The "amount" of investment required. The investment required on each type may be considerably different. Thus, for firms with adversarial, short-term relationships, the amount of investments in order to improve relations may be considerable. This is the case of most construction relationships. On the other hand, small suppliers may consider the capital required to invest in technology to high, etc.

## **5. - ELECTRONIC INTERACTION BETWEEN MAIN CONTRACTORS AND SUPPLIERS**

From the model, a set of generic propositions are drawn which in our point of view are required if dyadic electronic interactions in construction are to be initialised and developed. The propositions derive from comparison with the pattern of the conditioning factors of successful dyadic electronic interactions. These are much influenced by the characteristics of the production network and environment.

### **5.1. - Generic Propositions**

- Both hub and supplier are willing to invest in a power dependence relation. Main contractors have to emerge as enduring leaders over suppliers .



- Hub and supplier are willing to invest on a collaborative, trust-based, long-term relationship. Relationships between contractors and suppliers have to go beyond project duration, and must be more cooperative and trustful.
- Hub and supplier are willing to invest in sharing more than administrative and operational information, with higher quality, and wider communication channels. Contractors and suppliers must share information about processes common to both, and be more open about internal businesses practices.
- Both firms are willing to invest the necessary capital for technology and process changes. Contractors and suppliers have to increase their expenditure and knowledge on IT, specially on communication technology.
- Both firms are willing to invest in changing their internal processes, in order to obtain operational and eventually strategic benefits. Construction companies in order to take benefits from electronic interaction may need significant changes in their internal business processes, e.g. linking electronically head-offices with sites, etc.
- Both firms are willing to overcome hurdles and hindrances for implementation. Overcoming hindering factors and hurdles requires full commitment from contractor and supplier.

In generic terms, the lack of dyadic electronic interaction within construction projects in general, and between main contractors and suppliers in particular, can now be explained: most of the required investments are not made on dyadic contractor-supplier interactions. The main reasons for this are :

1. The pressure from the environmental factors are not strong enough as to leading to electronic interaction. In construction, environmental factors seem to lead firms to focusing on improving the construction process itself rather than to focus on inter-firm co-ordination.
2. The normal pattern of the conditioning factors on dyadic interaction is quite disadvantageous to both main contractors and suppliers, i.e. it implies substantial investment in order to initiate and develop electronic interaction. Moreover, it requires investment in practices that are contrary to construction culture and current practice which raises even more the barriers to invest.
3. The interplay of the conditioning factors, combined with the characteristics of the production network and environmental factors, make a negative self-reinforcement. i.e. the interdependence does not enable a more advantageous pattern. Moreover, there is no conditioning factor that may provide the impetus for starting a positive self-reinforcement of the system.

## **6. - PRODUCTION NETWORK AND ENVIRONMENTAL LEVELS**

The change to a more advantageous pattern of the conditioning factors of construction companies, which will lead to the wide initiation and implementation of electronic interaction on construction production networks, requires intervention over the characteristics of both production network and environmental levels. On the first case, it is essentially a strategic choice of companies (contractors, suppliers, etc.). On the second case, industrial initiatives are required, like e.g. the Latham initiative (Latham, 1994), the CITE initiative (Baldwin, 1995), etc.

- Construction has to shift from craft-type to big firm-led production networks, with core or core-ring power systems.
- Big clients and main contractors should emerge as enduring leaders of construction production networks.
- Relationships between construction parties have to shift from ACR-type i.e. adversarial, project-based, and non-collaborative to OCR-type, i.e. trustful, long-term, and collaborative.
- Project partnering (Hellard, 1995) has to be extended to strategic partnering (Bennet and Jayes, 1995). This requires new forms of co-ordination other than price-based (O'Brien, 1995).
- Main contractors involved in design and build and turnkey procurement methods are more likely to develop core-ring power systems with long-term, collaborative relationships with suppliers, designers and clients.
- Big clients may also create and develop big firm-led production networks with strong power over their contractors, suppliers, designers but with OCR-type relationships. A good example is provided by the British Airports Authority (BAA) which are in a current process of migrating from a craft-type to a big firm-led industrial organisation (NCE/NB BAA, 1995).
- Standardisation of the construction product and components is a very important step. This will enable contractors to establish more easily long-term and collaborative relationships with their suppliers. This standardisation can be achieved at an industry level by professional and/or government bodies. At the production network level it can be achieved through design and build or turnkey procurement methods, or by big clients.
- A favourable IT environment in the industry through initiatives as the Construct IT, CITE, IAI, etc. has a major role in enabling the development of a construction specific technological environment.

## 7. - CONCLUSIONS

This paper addressed the problem of the deployment of electronic interaction within construction production networks, with a special focus on main contractor-suppliers production networks. A generic model, the CONNET model, was presented, which aims to explain how and why electronic interaction is initialised and developed within production networks. The model considers three different levels of analysis: the dyadic level, the production network level, and the environmental level. This paper analyses only the dyadic level. From the model, a set of propositions were drawn which are the basis for explaining the lack of electronic links in construction.

In generic terms, construction production networks do not have electronic interaction because the investment on tangible and intangible assets is considerable and firms are not willing to invest. The deployment of electronic links would require that firms invest on power dependence systems; long-term, collaborative, trustful relationships; more and better information exchange; change in internal processes; and acquisition of IT knowledge. These investments are generically hindered by the characteristics of the production network and environmental factors. As environmental pressure does not lead to improving inter-firm co-ordination, firms are not willing to make the required amount and type of investments.

## **Acknowledgments**

The authors are grateful to Junta Nacional de Investigação Científica e Tecnológica (JNICT) for funding the research work.

## **References**

- Atkin, B. and Potheary, E. (1994). *Building Futures*, University of Reading, Dept. of Construction Management and Engineering
- Baker, W.E. (1992). *The Network Organisation in Theory and Practice*, in *Networks and Organizations: Structure, Form and Action*, edited by Nohiria, N. and Eccles, R.G., Harvard Business Press
- Baldwin, A.N.; Thorpe, A. and Carter, C.D. (1995). *Data Exchange In Construction: EDI, MFE or IE? in Developments in Computational Techniques for Civil Engineering*, pp 11-15, B.H.V Topping, Civil-Comp Press, Edinburgh, UK
- Bennet, J. and Jayes, S. (1995). *Trusting the Team: The Best Practice Guide to Partnering in Construction*, Centre for Strategic Studies in Construction, University of Reading
- Betts M., Atkin, B. Clark, A. (1995). *Best Practice Report: Supplier Management, Construct IT - Centre of Excellence*,
- Bjorn-Andersen, N. and Krcmar, H. (1995). *Looking Back - A Cross-analysis of 14 EDI Cases*, in *EDI in Europe: how it works in practice*, edited by Krcmar, H.; Bjorn-Andersen, N. and O'Callaghan, R., John Wiley & Sons
- Brandon, P.B. and Betts, M. (1995). *Integrated Construction Information*, E & FN Spon
- Bresnen, M. (1990). *Organising Construction, Project Organisation and Matrix Management*, London, Routledge
- Cunningham, C. and Tynan, C. (1993). *International Journal of Information Management*, 13, pp 3-28
- DoE. (1995). *Construct IT: Bridging the Gap*, HMSO
- Harrison, B. (1994). *Lean and Mean: The changing Landscape of Corporate Power in the Age of Flexibility*, BasicBooks
- Hellard, R.B. (1995). *Project Partnering: Principle and Practice*, Thomas Telford Publications
- Jayachandra, Y. (1994). *Re-Engineering the Networked Enterprise*, McGraw-Hill
- KPMG and CICA (1993). *Building on IT For Quality*, HMSO
- Latham, Sir M. (1994). *Constructing the Team*, HMSO
- Miles, R.E. and Snow, C.C. (1992). *California Management Review*, Summer
- NCE/NB BAA (1995). *World Ambitions*, Supplement May
- Nelson, R.R. and Winter, S.G. (1982). *An Evolutionary Theory of Economic Change*, Harvard Business Press
- Nohiria, N and Eccles, R.G. (1992). *Face-to-Face: Making Network Organizations Work*, in *Networks and Organizations: Structure, Form and Action*, edited by Nohiria, N. and Eccles, R.G., Harvard Business Press

O'Brien, W., Fischer, M. and Jucker, J. (1996). Economic View of Project Coordination, Unpublished paper

O'Callaghan, R.(1995). EDI in Procurement and Flexibility Strategies - The Case of Alcatel Bell Telephone in Belgium, in EDI in Europe: how it works in practice, edited by Krmar, H.; Bjorn-Andersen, N. and O'Callaghan, R., John Wiley & Sons

Powell, W.W. (1990). Neither Market nor Hierarchy: Network Forms of Organization, in Research in Organizational Behavior, pp 295-336, Greenwich, Conn., JAI Press

Sako, M. (1992). Prices, Quality and Trust: Inter-Firm Relations in Britain and Japan, Cambridge University Press

Scott Morton, M. (1991). The Corporation of the 1990s: Information Technology and Organisational Transformation, Oxford University Press