2

A Review of Research and Practice for the Industrial Networks of the Future

Rob Dekkers[1] and David Bennett[2]

[1] University of the West of Scotland, Paisley PA1 2BE, UK
Email: rob.dekkers@uws.ac.uk

[2] Aston University, Birmingham B4 7ET, UK
Email: d.j.bennett@aston.ac.uk

Abstract
Academic researchers have followed closely the interest of companies in establishing industrial networks by studying aspects such as social interaction and contractual relationships. But what patterns underlie the emergence of industrial networks and what support should research provide for practitioners? First, it appears that manufacturing is becoming a commodity rather than a unique capability, which accounts especially for low-technology approaches in downstream parts of the network, for example, in assembly operations. Second, the increased tendency towards specialisation has forced other, upstream, parts of industrial networks to introduce advanced manufacturing technologies for niche markets. Third, the capital market for investments in capacity, and the trade in manufacturing as a commodity, dominates resource allocation to a larger extent than was previously the case. Fourth, there is becoming a continuous move towards more loosely connected entities that comprise manufacturing networks. Finally, in these networks, concepts for supply chain management should address collaboration and information technology that supports decentralised decision-making, in particular to address sustainable and green supply chains. More traditional concepts, such as the keiretsu and chaibol networks of some Asian economies, do not sufficiently support the demands now being placed on networks. Research should address these five fundamental challenges to prepare for the industrial networks of 2020 and beyond.

2.1 Introduction

In recent years, practitioners and researchers have started to look increasingly at companies as part of networks within which they operate. The emergence of manufacturing networks is often associated with the possibilities offered by information technology and data-communication for collaboration and coordination, the globalisation of markets and the increasing tendency of companies to specialise, *e.g.* [2.1]. These possibilities provide firms with easier access to the capabilities and resources of others, moving them further away from the traditional logic behind the make-or-buy decision; even though this particular manufacturing decision still attracts attention from researchers to develop appropriate models, *e.g.* [2.2–2.4]. Additionally, the world of management has seen an abundance of theories that might have been adequate to deal with the contemporary challenges for some enterprises, but not for many others [2.5, 2.6]. The notion of core competencies and the concept of *lean production* serve as examples of such theories that address questions relating to supply chain management in the context of industrial networks; but it could be questioned whether they really deal with the characteristics of networked organisations. Capello [2.7] (p. 496) supports this statement by noting that not enough is known about the failure of networks. In this chapter, we argue that industrial networks require the adaptation of existing theories to fit their particular characteristics as well as the development of grounded theories based on the unique characteristics of industrial collaboration.

2.1.1 Brief History of Industrial Networks

Although the study of industrial networks has attracted recent attention among researchers, there was already an awareness of the implications associated with the particular characteristics of networked organisations [2.8, 2.9]. In particular, academic interest has centred on two periods in the past. The first of these is in the 1970s and 1980s, when attention was focused on Japanese manufacturing concepts and techniques, including just-in-time (JIT), co-production and 'keiretsu' networks. The second period starts in the 1990s, after the bursting of Japan's 'bubble' economy, as a consequence of the drive for even lower cost, greater efficiency, and responsiveness to customer demands. This resulted in a more formal recognition of the networked organisation as a follow-up to the paradigm of core competencies and the consequent escalation in outsourcing. Mayntz [2.10] acknowledges networks as capable of solving complex tasks and exceeding the capability of individual firms. The earlier overview by Miles and Snow [2.11] illustrated the move from the simpler paradigms to more complicated forms of network-based organisations that subsequently have been witnessed in recent years (see Table 2.1) and consequently have attracted academic deliberation.

The establishment and emergence of industrial networks is closely related to the subject of manufacturing strategy. Since Skinner's seminal work in 1969 [2.12], manufacturing has been recognised as a fundamental cornerstone for achieving corporate competitive advantage. Although it recognises the traditional and limited perspective of considering low cost and high efficiency as dominant objectives within manufacturing strategy, this earlier work of Skinner is still rooted in the tradition that economies of scale provide competitive opportunities (see pp. 260–265 in [2.13]). That tradition gave rise to the monolithic company driven by forward and backward integration [2.14], which implied an emphasis on the coordination of operations. Only later, in 1986, does Skinner consider the role of smaller-scale units that may now be regarded as elements of an industrial network [2.15], while subsequently questioning the traditional effort towards productivity improvement through making large capital investments in manufacturing [2.16]. According to Sturgeon [2.17] (pp. 8–10), American firms – compared with most Asian and many European companies – have generally placed manufacturing in a low position on the

Table 2.1. Evolution of organisation forms [2.11]. This indicates the evolution of organisation forms that are both internally and externally consistent. Miles and Snow [2.11] state in their paper that a minimal fit is necessary for survival, and that tight fit associates with corporate excellence, and early fit provides a competitive advantage. Therefore, dynamic networks (industrial networks) require both internal fits and external fits, giving early adopters a competitive advantage.

Period	Product-market strategy	Organisation structure	Inventor or early user	Core activating and control mechanisms
1800–	Single product or service. Local/regional markets	Agency	Numerous small owner-managed firms	Personal direction and control
1850–	Limited, standardised product or service line. Regional/national markets	Functional	Carnegie Steel	Central plan and budgets
1900–	Diversified, changing product or service line. National/ international markets	Divisional	General Motors, Sears, Roebuck, Hewlett Packard	Corporate policies and division profit centres
1950–	Standard and innovative products or services. Stable and changing markets	Matrix	Several aerospace and electronic firms	Temporary teams and lateral resource allocation devices such as internal markets, joint planning systems, *etc*.
2000–	Product or service design. Global, changing markets	Dynamic network	International/ construction firms. Global consumer goods companies. Selected electronic and computer firms (*e.g*. IBM)	Broker-assembled temporary structures with shared information systems as basis for trust and co-ordination

hierarchy of corporate esteem. However, in contrast to Sturgeon’s belief, it is argued here that this is also the case for European firms. For example, most companies still regard efficiency as the main objective of their production departments in a survey amongst Spanish companies [2.18]. Consequently, during the 1960s and 1970s the make-or-buy decision was at the heart of operations management research. Then, in the 1980s, the interest in Japanese manufacturing techniques, including partnerships with suppliers, sparked the next step towards models for collaboration and supply chain management using JIT principles, while in the early 1990s the concept of core competencies led to renewed interest in outsourcing models. Later the over-the-wall tactics of outsourcing made companies examine the networks they had created while managing these from a traditional cost perspective [2.19]. In the end, the increasing attention paid to networks has not challenged the proposition of Skinner that manufacturing is of paramount importance to industrial performance; and it has not altered that the most common view of manufacturing (including manufacturing networks) is the one taken from the traditional cost perspective.

2.1.2 The Impact of Globalisation

The awareness that has been created that manufacturing strategy comprises more than cost-driven objectives, *e.g.* also meeting customer demands, has created a wider array of perspectives for manufacturing; these perspectives on manufacturing strategy, complemented by the influence of advances in information and communication technology together with globalisation and specialisation, foster the specific characteristics of industrial networks, *i.e.* collaboration to deliver products and services, decentralisation of decision-making among the agents and inter-organisational integration across companies involved to meet imposed performance requirements in competitive markets (adapted from O'Neill and Sackett [2.20], see p. 42). In these three fields, each change in itself requires adaptations by companies and the influence of several of these shifts leverage the need for adequate responses. For example, collaboration not only requires solutions in advanced software, it should also account for the management of industrial networks in an international context whereby individual companies set their own course and develop over time (decentralisation). Conversely, efficient international collaboration depends on the appropriate deployment of information and communication technology. The intricate interdependencies of these characteristics transform industrial networks into dynamic, collaborative efforts that have a large number and wide variety of continuously evolving resources at their disposal especially to meet a greater range of customer demands.

This has caused a change in the prevailing attitude towards resource allocation due to the emergence of the industrial network paradigm. The need for proximity of supply, following the theories about co-production, has required a strong interaction between customers and suppliers. Consequently much research has focused on the need for economic clusters, *e.g.* [2.21]. Carter and Narasimhan [2.22] (pp. 17–20) note that already co-location of suppliers has become one of the least significant trends and there are examples from industry of these tendencies changing, like Daimler Chrysler's announcement in 2000 that suppliers need to deliver in six days (rather than 1–2 days previously, with close geographical proximity). It illustrates the different approaches towards supplier selection and purchasing management that are now emerging; these attitudes allow a greater independence of suppliers to some extent. These different views support the notion that the supplier base should be considered as a network rather than a set of individual actors linked to one firm (which also follows from Carter and Narasimhan's study).

Not only has the scene for suppliers to any industry changed but many more countries have also followed an active path towards developing relevant economic and industrial competencies, reinforcing the establishment of supply networks. For example, the Thai government has deliberately set out to strengthen its automotive sector by attracting foreign companies in that industry [2.23]. By contrast, during the

1990s, MIT undertook a study that led to a warning about the decline of manufacturing industry in the USA [2.24]. However, more recently the USA has adopted a more progressive approach with the study on visionary manufacturing challenges [2.25], the UK government has stimulated the creation of innovative manufacturing research centres [2.26], and for the first time the Dutch government set out a research strategy to support the manufacturing industry [2.27]. Consequently, a complex pattern has emerged with the industrial base undergoing shifts by moving to developing countries, emerging countries entering the manufacturing arena, and a revival of some traditional industrialised countries, thus making the situation more dynamic than ever before. In the end, these national policies have only encouraged more extended industrial networks.

At the same time, the make-up of industrial network has also undergone changes. The external drivers (such as the move from make-or-buy to co-production or alliances and the drive for flexibility of manufacturing), as well as the internally oriented concepts (such as the attempts to apply computer integrated manufacturing and the use of production cells), demonstrate a continuous move towards more loosely connected industrial entities for manufacturing. See also Brown *et al.* [2.28] for arguments and examples and Smith *et al.* [2.29] for geographically dispersed capacity and OEMs. The requirement for greater flexibility also impacts on the trend to increase the amount of customisation and production of goods on-demand [2.30]. Contemporary changes in industries point to a further repositioning along the dimension of loosely connected entities, with increasing pressure to respond to market opportunities and to increase flexibility.

2.1.3 Scope of Chapter

Following the moves made by companies that have been previously identified, this chapter explores the concept of industrial networks for manufacturing. It aims to visualise an approach for industrial networks of the future, *i.e.* for the next 15 years and beyond, based on ongoing research and additional considerations. Firms are operating increasingly as parts of industrial networks, *e.g.* [2.1, 2.31]. Although the situation is extremely fluid and the stage has not yet been reached where networks are configured optimally and network operations have reached a stage of maturity. Ritter *et al.* [2.32] (p. 118) even state that current understanding of networks is limited and consequently, the chapter also aims at contributing to the research agenda and making a contribution to foundations for generating grounded theory about industrial networks.

Initially, in Section 2.2, this chapter examines the types of traditional networks that have been identified, together with the reasons they have been formed and their advantages and weaknesses. This includes a critique of the traditional keiretsu and chaibol networks based on conglomerate structures that formed the basis of Japan's and Korea's economic success. Section 2.3 addresses how future networks will be shaped by discussing four contributory and related topics, *i.e.* network configuration, manufacturing as commodity, added value within networks and sustainability of supply chains. The chapter then moves to present the outlines of a research agenda in Section 2.4 and implications for practice in Section 2.5. This contribution to directing research into industrial networks uses a blend of illustrations (from the business literature) and findings of previous studies by others, together with results from research by the authors, to construct a picture of how future networks might look and behave.

2.2 Traditional Views about Networks

The study of networks as a key aspect of industrial organisation goes back to the 1980s with the seminal work of Håkansson at Uppsala University who defined networks as sets of more or less specialised, interdependent actors involved in exchange processes [2.8, 2.33]. Around the same time the study of urban, networked organisations in the industrialised regions of northern Italy recognised the importance of networks for improving logistical efficiency [2.34, 2.35]. Simultaneously, writings appeared on *strategic networks*, which are defined as long-term, purposeful arrangements among distinct, but related, for-profit organisations that allow members to gain or sustain competitive advantage over their competitors outside the arrangement [2.36] (see also p. 32 in [2.37,]). According to this view, strategic networks are merely a superior method of managing the process necessary for the generation and sale of a chosen set of products like in [2.38]; this applies also to innovation and new product development, *e.g.* [2.39]. It should be noted that some authors associate the term strategic networks with the concept of networked organisations in general, *e.g.* [2.40], and some with supply chains, *e.g.* [2.41]. The participation of companies in these networks depends on managing product development, both at the level of the network and the individual companies, and on managing manufacturing processes.

Within the overall primary process of most companies the connection between product development and manufacturing strategy has yet to result in conceptual approaches for establishing this vital link, with only Sharifi *et al.* [2.42] connecting a product strategy to conceptual design of the supply chain. Conducting a study into sequential and simultaneous approaches to engineering new products, Riedel and Pawar [2.43] highlight that the concepts of design and manufacturing are not linked in the literature and that the interaction of product design and manufacturing strategy is under-researched. Spring and Dalrymple [2.44] came to a similar conclusion when examining two cases of product customisation, where manufacturing issues received little attention during design and engineering. The only concept that addresses these issues so far is the one of order entry points (more commonly known as order decoupling points; see Figure 2.1). Order entry points and modular product architecture typically concern the optimisation of make-to-order production concepts and might include product development and engineering activities [2.45]. Introducing a different perspective, Smulder *et al.* [2.46] proposed a typology of intra-firm and inter-firm interfaces, therewith also connecting product development and production; yet this typology has still to be adopted in practice. Henceforth, the emerging paradigm of industrial networks, if it is to be successful, should address this matter of creating a link between manufacturing strategy and product development.

But do we find this link included as part of the current concepts for industrial networks? Four mainstream operations management and logistic concepts in this area dominate thinking about the industrial network paradigm: core competencies, agile manufacturing, keiretsu and chaibol arrangements and supply chain management. Other concepts such as strategic networks and the resource-based view come about through strategic concepts and can be associated with the thinking about core competencies (see pp. 4–5 in [2.47]). As it appears in the next four subsections, these concepts focus mainly on issues of manufacturing and less on product development, except in general terms.

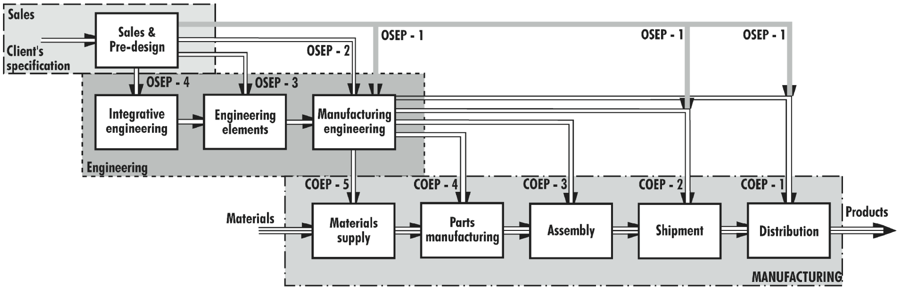

Figure 2.1. Position of the order entry points in the primary process of design, engineering, manufacturing and logistics. To simplify the figure, points of stock (inventory) have been omitted. OSEP-1 (order specification entry point) indicates that customer requirements are directly transferred into production instructions, while OSEP-4 points to engineering-to-order. Similarly in the material flow: COEP-1 (customer order entry point) tells that orders are delivered directly from stock, while COEP-5 marks make-to-order.

2.2.1 Core Competencies and Outsourcing

According to Friedrich [2.48], focusing on core competencies [2.49] and outsourcing [2.50] raises the key issue of which areas of production are needed to maintain the value chain and on which areas the company should concentrate for achieving optimal performance. Prahalad and Hamel [2.49] subtly expand the view of technology from a broadly described concept, the importance of which is determined by its support of the corporate mission, to a specific source of corporate uniqueness. In Prahalad and Hamel's view, core competencies represent the collective learning of the organisation, especially concerning how to coordinate diverse production skills and integrate multiple streams of technology. However, the application of this theory does not lead directly to a clearly defined strategy for global manufacturing or manufacturing networks. And often this thinking about core competencies leads to outsourcing mostly based on a cost perspective for manufacturing (as present in [2.51]). Only when core competencies are linked to decision-making will a manufacturing strategy be found that offers guidelines on decision-making for resource acquisition and capacity management [2.52].

Given the (often unquestioned) popularity of the concept of core competencies and its implications, how does industry manage the increasing scope of outsourcing? A study by Dekkers [2.53] based on six case studies (four in the Netherlands, one in China and one in Indonesia) points to poor control of outsourcing by industrial companies. Most of the case companies, with primary processes based mainly on engineering-to-order and make-to-order, experienced problems with implementing manufacturing strategies. Ideally, the manufacturing strategy of these companies should address their core competencies and opportunities for outsourcing. All the case companies, except one, had done so, implicitly or explicitly; but mostly this strategy had not been transferred to guidelines for implementation, which is why decision-making occurred at random or opportunistically. There was no feedback to the stages of design and engineering about suppliers' performance, so sometimes problems would recur regularly. None of the companies followed an active approach towards supplier networks for the purpose of expanding their technological capabilities. Operational control posed additional challenges, although not all companies were aware of the impact this caused. In two cases the in-house production of some manufacturing processes proved more beneficial than outsourcing, although this was only discovered with hindsight. All the companies reported problems with on-time deliveries by suppliers, with some of these problems arising from reactive interventions rather than pro-active securing of purchase orders. In summarising these case results, it can be concluded that operational control in these companies created a wide variety of problems. That is evidenced by poor operational control and poor integration between design, engineering, purchasing and manufacturing; additionally, it indicates that the simplified view of core competencies and outsourcing might have strong limitations.

Still today, even though insight into effective manufacturing strategies has progressed, many approaches for outsourcing rely on the deployment of criteria derived from traditional make-or-buy decisions. However, the rise of industrial networks creates the need for frameworks that take account of early supplier involvement, collaboration, and inter-organisational integration. Also, decision-making concerning the allocation of resources has shifted from making one-time decisions to continuous evaluation and reallocation. Current outsourcing approaches rarely account for this, and hence there is a need for expansion of criteria to include those suitable for networks. Practices for management and control of outsourcing still focus largely on minimising costs and meeting delivery schedules, while research into outsourcing has not yet investigated the specific impact of industrial networks [2.19].

2.2.2 Keiretsu and Chaibol Networks

Unlike the networks of Western companies that resulted from the make-or-buy decision and later outsourcing, the keiretsu and chaibol networks that formed the basis of Japan's and Korea's economic success were based on conglomerate structures. However, more recently these structures have proved less capable of meeting the need for speed of change, flexibility, and cost reduction that have been the key aspects of industrial management following the Asian economic crisis of the late 1990s [2.54]. At the same time, organisations that attempted to replicate the keiretsu concept outside Japan have encountered severe problems, making them rethink their plans to create similar supply networks [2.55].

A major weakness of the traditional keiretsu and chaibol networks has been their domestic focus and cross-ownership between companies in the network. This has hindered how they can respond effectively to the globalisation of manufacturing

[2.56]. It has also created difficulties as end-product manufacturers have moved offshore and taken them beyond the reach of domestically based network members. Also, the burden of debt resulting from borrowing to support cross-ownership has restricted their ability to develop and fully support international operations. As a consequence of this situation, Renault, on taking a controlling interest in Nissan, sought to dismantle its keiretsu supplier network by selling off most of its financial stakes in almost 1,400 companies [2.57]. This indicates that companies deploying traditional networks are searching for different concepts to manage their suppliers.

However, despite these concerns, a study by McGuire and Dow [2.58] still shows that throughout the first half of the 1990s the keiretsu system remained strongly in place. At the same time, they conclude that the continued move towards globalisation of capital markets in Japan and ongoing regulatory change may potentially impact networking and performance implications. Apart from the problems that can arise when there is cross-ownership between companies, the main criticism of the keiretsu relates to its lack of flexibility and responsiveness. The answer to this criticism has therefore been to propose the creation of agile networks [2.59].

2.2.3 Agile Manufacturing Networks

In contrast to the concept of outsourcing and keiretsu and chaibol networks, the approach of agile manufacturing relies more strongly on the exploitation of loosely connected networks than earlier concepts such as lean production [2.60–2.62]. Co-makership (and subsequently lean production) had already introduced a higher degree of outsourcing and improved control through supply chain management, although here the networks used were more closely connected keiretsu or chaibol types involving cross-ownership. In contrast to the internal focus of lean production, the paradigm of agile manufacturing has an external focus and is concerned primarily with the ability of enterprises to cope with unexpected changes, to survive against unprecedented threats from the business environment, and to take advantage of changes as opportunities [2.63]. Similarly, Kidd [2.64] recognises two main factors within the concept of agility, *i.e.* responding to changes in appropriate ways, and in due time, taking advantage of the opportunities resulting from change. This means that an agile manufacturing enterprise marshals the best possible resources to provide innovative (and often customised) products, with the flexibility to adjust the product and offer rapid delivery, and with the high level of efficiency required to be competitive and profitable (see p. 19 in [2.65]. The concept of agile manufacturing stresses two interconnected main processes:

1. the development of innovative products;
2. the manufacturing and distribution of these products.

These two processes should meet lead-time requirements (time-to-market, time-to-volume and delivery time) and flexibility requirements (to meet market opportunities and respond to market demands) [2.66]. A reconfigurable structure becomes a prerequisite for optimising the capabilities of an organisation for each business opportunity [2.67], which itself requires more loosely connected entities.

However, even the new types of agile manufacturing networks often are not designed within an international context and may still be suboptimal where acquisitions have taken place resulting in an inherited supplier base. Therefore, the notion of building international manufacturing networks is now a prevalent concern where competitiveness derives from an ability to garner and integrate resources from a number of different geographical sources. The basic principles for building a manufacturing network have been described by Mraz [2.68] who identifies four categories of resources (*i.e.* players) that can be used within the network: industrial design consultants, product development consultants, contract manufacturers, and original equipment manufacturers (OEMs). These last two players also demonstrate the options available for the production of complex products and their relative advantages and disadvantages, with the contract manufacturing approach typically involving external industrial design and product development, and the OEM approach typically retaining these activities in-house. A hybrid of these two forms can be found in the case of the Brazilian aircraft manufacturer Embraer (Empresa Brasiliera de Aeronáutica SA), which, with its network of risk sharing partners, was able to greatly accelerate the development and launch of the ERJ-170/190 series of regional jets. Hence, adequate suppliers' bases, with possibly an international dimension, reinforce performance during product development (reduced time-to-market) and manufacturing (improved performance to deliver) to the advantage of OEMs and their supplier networks.

The international dimension to designing agile manufacturing networks is also considered by Lee and Lau [2.30], who use the example of firms in Hong Kong and the Pearl River Delta to provide a factory-on-demand concept within the context of manufacturing networks. Shi and Gregory [2.69] have contributed by proposing the mapping of configurations for international manufacturing networks as a means of providing support for decision-making. Presentations by companies at the 9th Annual Cambridge International Manufacturing Symposium in 2004, organised by the University of Cambridge, have shown that there are two strategic directions for international manufacturing networks: rationalisation (with manufacturing units, sometimes including product development, specialising on product ranges) and globalisation (taking the opportunity to outsource operations or establish alliances). As frequently evidenced in the literature, *e.g.* [2.70], the current drive for globalisation by companies places its emphasis more on optimisation within existing conditions and less on capturing new market opportunities, even for the opportunities these international manufacturing networks offer.

2.2.4 Supply Chain Management

Likewise, within the concepts for supply chain management, agility has become a major issue. For example, Helo *et al.* [2.71] (p. 1059) see agility as the key for customisation within supply chains. In addition, Towill and Christopher [2.72] (p. 308) contend that agile and lean contribute to meeting performance demands imposed by the market. Gunasekaran [2.73] states that key enablers of agile manufacturing include: (i) tools and metrics for virtual enterprise formation; (ii) physically distributed manufacturing architecture and teams; (iii) tools and metrics for rapid partnership formation; (iv) concurrent engineering; (v) integrated information systems for products, manufacturing and business; (vi) rapid prototyping tools; and (vii) electronic commerce. Sanchez and Nagi [2.74] in their review of 73 papers reiterate these points, albeit in a different way. These works are all building on the concepts for agility introduced by Goldman and Nagel [2.65] and Goldman *et al.* [2.63]. Within the context of this chapter about networks, it is worth mentioning that the relation to engineering has a central role (see order entry points in the introduction to this section) and that collaboration in relation to information and communication technology seems pivotal.

So far, concepts for supply chain management rely heavily on applications of information and communication technology. For example, Akkermans *et al.* [2.75] present results from an exploratory study on the impact of enterprise resource planning (ERP) systems on supply chain management. They report the following key limitations of current ERP systems:

1. their insufficient extended enterprise functionality in crossing organisational boundaries;
2. their inflexibility to ever-changing supply chain needs;
3. their lack of functionality beyond managing transactions;
4. their closed and non-modular system architecture.

As they state, these limitations stem from the fact that the first generation of ERP products has been designed to integrate the various operations of an individual firm. However, since the unit of analysis, in their words, has become a network of organisations, these limitations render ERP products inadequate for the challenges that are posed; in this respect, Stadtler [2.76] (p. 586) draws a similar conclusion for inter-organisational integration in supply chain management. The open source solution from Helo *et al.* [2.71] is a step in this direction, given its flexibility to operate in conjunction with ERP, WMS (warehouse management system) and EDI (electronic data interchange). But that is only one step in the direction of decentralised decision-making and inter-organisational integration as key characteristics of industrial networks.

2.2.5 Traditional Views on the Wane

Despite the theoretical ability of agile manufacturing to provide greater flexibility and responsiveness than traditional network concepts (supply chain management, keiretsu and chaibol arrangements and networks born out of outsourcing), there are still questions about whether it can address the characteristics of networks, *i.e.* collaboration to deliver products and services, decentralisation of decision-making amongst the agents and inter-organisational integration across companies involved to meet imposed performance requirements in competitive markets. The special issue on dispersed manufacturing networks underlines the fact that progress is being made slowly [2.77]. The questions around the paradigm for networks that consist of loosely connected entities only demonstrate that we still know little about their behaviour. Nevertheless, many developments in information technology and data-communication allow interfacing in networked manufacturing; for example, as Boeing has done for the 787 Dreamliner. The current problems with production in this case can be traced back to selection processes of suppliers (even supported by sophisticated software applications that failed to solve the process of interaction). Generally speaking, the lack of synchronisation between the possibilities of information technology and the limited understanding of the actual behaviour of entities (or agents for that matter) have only increased instability in relationships, giving greater cause for instabilities in relationships. At the same time, inter-relationships have become more demanding and limited the capabilities of parties to operate within each other's constraints. Industrial companies demand partnerships, but these sometimes appear to be forcibly driven by strategy rather than being based on a true bilateral relationship. With the reduced capability to maintain long-term relationships, partners in industrial networks need different ways of interacting, sometimes facilitated by applications in information technology and data-communication (extending to both the domain of manufacturing and the domain of product development and engineering).

2.3 Future Networks

Contemporary manufacturing networks with more loosely connected entities have come about through two mechanisms. First, the manufacturing networks have emerged as a result of collaboration between loosely connected entities, or so-called *collaborative networks* (see p. 439 in [2.78]). This mostly concerns SMEs that coordinate either globally or regionally [2.79] but with the explicit aim to have a wider reach; the latter resembles the regional networks labelled Third Italy by Biggiero [2.80] and Robertson and Langlois [2.81] (p. 549). The second mechanism of manufacturing is the global production networks that come about through OEMs (see Kuhn [2.82] and Doner *et al.* [2.83] for the automotive industry and Smith *et al.* [2.29] for a survey), as similarly described by Ernst [2.84] with his focus on the electronics industry, Riis *et al.* [2.85] for six Danish companies and Sturgeon [2.17] for the American industry. The characteristics of global production networks correspond to those of strategic networks, as discussed in Dekkers [2.47] (pp. 4–5). These networks are often associated with power and trust that dominate these types of network relationships [2.86–2.89]. Hence, these strategic networks came into existence through strategic objectives of one or more of the partners, which makes it necessary to collaborate and which create tensions in inter-organisational relationships. On the dimensions of Robertson and Langlois [2.81], strategic networks and networks evolving from the resource-based view score high on ownership integration (*e.g.* holding companies and the Chandlerian firm). However, contemporary industrial networks rely less on ownership but require some degree of collaboration and coordination. At the heart of this chapter are the challenges these two forms of more loosely connected organisations face as they evolve towards collaborative networks and global production networks.

There are now many emerging possibilities offered by information technology and data-communication methods. Some of these include planning methodologies [2.90], smart supply chains [2.91], globalisation of markets [2.1] and the ongoing specialisation of firms. They drive companies to concentrate on core competencies, even given the flaws in this theory, and, consequently, enable them to move from centralised, vertically integrated and single-site manufacturing facilities to geographically dispersed networks of resources [2.66]. These simultaneous developments foster the specific characteristics of (international) networks, which require adaptations by companies to fit these characteristics.

2.3.1 Network Configuration

The dilemma with these networks extends to the problem of achieving a balance between having independent agents and controlling processes to meet performance, which requires a strong interaction between these agents. Virtual organisations, which can be considered as a further manifestation of networks, might display instability between the model of pure outsourcing and the establishment of more traditional alliances [2.92]. Even alliances, which are perceived as more stable relationships between firms, usually dissolve over time or result in mergers [2.93]. The network is optimised locally and creates power shifts if the balance moves towards independence of agents, depending on the uniqueness of their resources, [2.94]. Also, flexibility might be lost in the short and medium term through the creation of alliances or mergers [2.95]. Therefore, research needs to be undertaken to reveal whether this dilemma of balance between control and change in networks can be resolved.

The principal characteristic of industrial networks is their ability to capture market opportunities and to adapt to changes in the environment. Collaboration with other companies has a significant impact on the capabilities of a network. Hitherto, the dynamic capability has equated to changeability, which Milberg and Dürrschmidt [2.96] define as the sum of (i) flexibility, defined as the capability to operate in a wider space on certain dimensions of business management, and (ii) responsiveness, defined as the ability to handle emerging changes in the environment. Thus changeability is a measure of the total changes the environment demands of an organisation or network [2.9]. That changeability resembles the concept of dynamic capabilities introduced by Teece *et al.* [2.97]. In their paper, Möller and Svahn [2.98] expand on this, although their thinking seems much more directed at strategic networks. Sometimes, the sacrifices in a given production system to obtain flexibility (*i.e.* capturing market opportunities and adapting) exceed the derived benefits.

Each market opportunity requires an adequate response from an industrial network. The flexibility of a network relies on the deployment of resources to capture these market opportunities and thereby needs a control structure and organisational structure that fits the actual demand. Theory about organisational design distinguishes the process structure, the control structure, the organelle structure, and the hierarchy [2.99]; the organelle structure is based on the grouping of (business) process or activities to address performance requirements. The methodology for the design of organisations assumes a linear process when designing each of these structures consecutively (see Figure 2.2), even though this process should be considered iterative. In this approach, the design of the organelle structure is the key to meeting performance demands by customers; that leads Dekkers and van Luttervelt [2.100] (p. 13) to propose a model for reconfiguration of networks (see Figure 2.3). Industrial networks provide the opportunity to optimise each of the four structures independently and that through the connections between

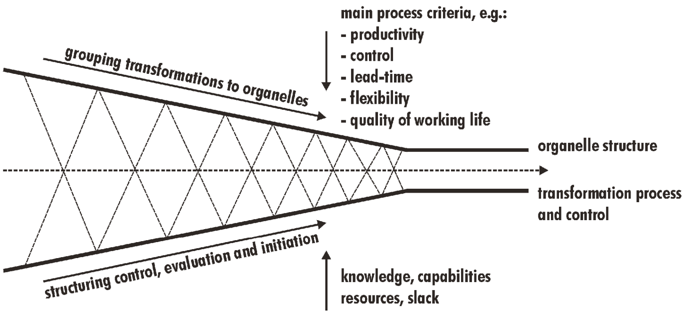

Figure 2.2. Design process for the organelle structure (see pp. 183–188 in [2.101]). The organelle structure affects both the grouping of tasks in the primary process as well as the control processes. By subsequent integration and iteration, the design of the organelle structure meets performance requirements.

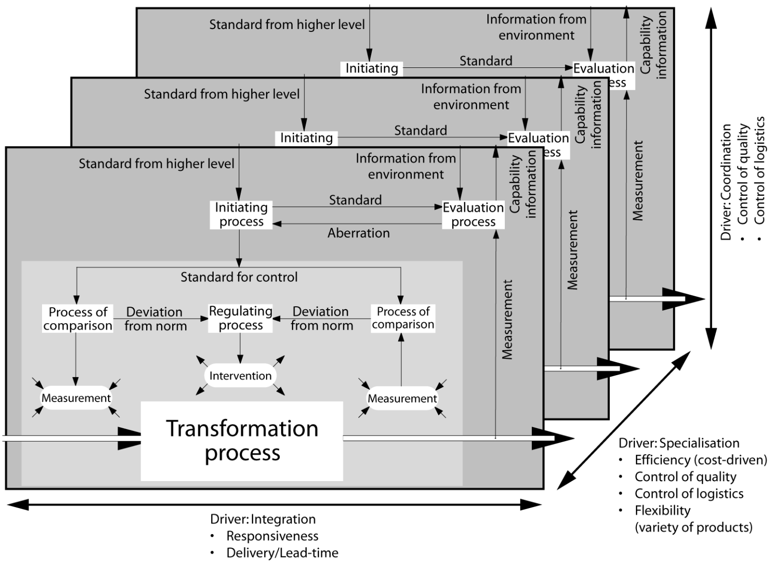

Figure 2.3. Model for reconfiguration within networks. Based on different drivers, market opportunities call for either integration, specialisation or coordination to meet performance requirements. Through predefined organelles for both the primary process and the control processes, reconfiguration becomes a preset decision-making process allowing quick responses to changing conditions.

these structures, as present in the value chain and as individual agents, network optimisation will occur over time.

Another phenomenon is the increasing participation of SMEs in international manufacturing networks [2.102], which has been enabled through the factors identified by Lall [2.103] as contributing to the increase in SME competitiveness. Bennett and Ozdenli [2.104] have studied the role of several SMEs in international manufacturing networks. The SMEs were based in industrialised countries, developing countries and transition economies. The analysis of the cases shows that they are motivated largely by the desire to extend their reach and a wish to begin establishing a global presence. It also shows that control and commitment are two major determinants for SMEs and international manufacturing networks, so managers must think carefully about how much control they want to have (or should have) within the network. This concerns the electronic and virtual integration of companies, so calling on totally new models for dealing with networks [2.105]. These include matchmaking and brokerage through web services [2.106, 2.107] and electronic contracts; these will enable companies to move away from the control paradigm for the monolithic company towards management approaches that fit the emergent properties of networks [2.108, 2.109]. The concept of complex networks with emerging properties strongly relates to the proposed idea of *open innovation systems* [2.110, 2.111]; the increased interaction between actors in networks requires a rethinking how it happens at all [2.112], whether it concerns manufacturing or product development.

2.3.2 Manufacturing as a Commodity

An important development influencing the shift in power within manufacturing networks has been the increasing importance of OEMs and, more recently, brand owners [2.113]. Sturgeon [2.17] argues that the revival of the American industry during the 1990s can be attributed to what he calls turnkey production networks. Essentially, these incorporate the trend towards outsourced manufacturing and an emphasis on branding. To demonstrate this concept, Sturgeon uses the example of the electronics industry, particularly the case of Apple Computer Inc. that contracted SCI Systems for a large part of its manufacturing operations in 1996. A system like a turnkey production network is highly adaptive because it uses turnkey relationships to weave various key production clusters into a global-scale production network based on external economics for OEMs and brand-owners.

With the rise in OEMs, especially in the electronics and automotive industries, the concept of outsourcing the production of complete systems and subsystems started to become a common phenomenon. In this way the idea of tiering in the supply network was created [2.114], with power generally reducing towards the lower tiers (with possible exceptions where suppliers are part of much larger companies involved with leading edge technologies). Along with this trend has also materialised the idea of manufacturing capacity as a commodity rather than a unique capability for "pushing" products onto growing markets. At the same time, the focus of technology has also moved upstream with suppliers increasingly turning to advanced manufacturing technologies as a means of competing for orders, while OEMs, especially those based offshore, have tended largely to rely on low-technology assembly techniques for enabling greater agility.

This trend has been taken further under the more recent, and increasingly dominant, regime of brand ownership. A characteristic is the separation of brand from origin of production and the virtually complete transition of manufacturing to a commodity with power residing almost totally with the brand owner; that often causes the brand to be more dominant than the actual product [2.115]. In turn, this has led to manufacturing becoming increasingly footloose with international mobility being an important aspect of network design. In particular, this has resulted in the transfer of production capital away from the traditional industrial economies to the low factor cost economies of the Far East and the transition economies of Eastern Europe [2.116].

2.3.3 Added Value of Industrial Networks

Collaborative efforts, whether or not they are crossing borders, are not only seen as an approach to decrease manufacturing cost; cooperation between network companies is increasingly seen as a means for lowering development costs, accelerating product and process development, and maximising commercialisation opportunities in innovation projects. The capability of building and maintaining inter-organisational networks, such as joint ventures, license agreements, co-development (between suppliers and customers) and strategic alliances has led to more product and process innovations [2.117]; see Figure 2.4. This also covers the extension of capabilities, with manufacturing services as a newly emerging trend and the capabilities embedded in manufacturing services partly answering the demand for customisation.

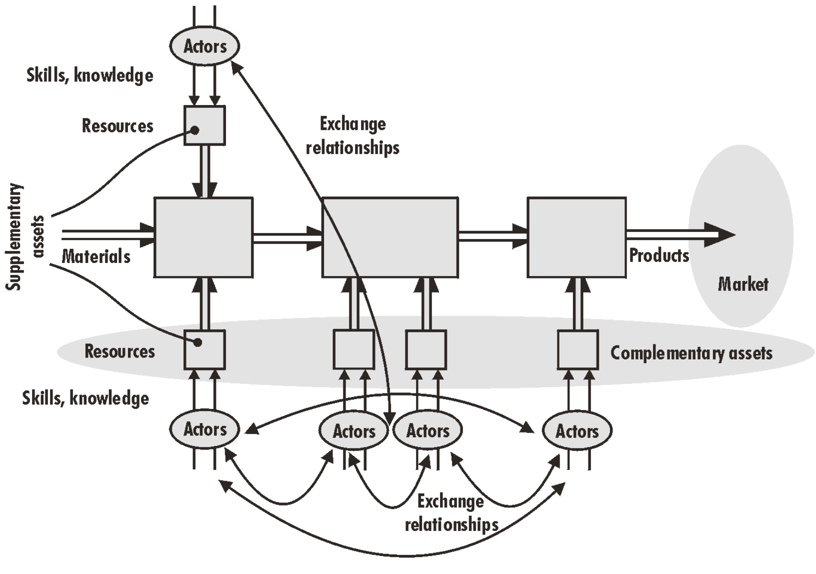

Figure 2.4. Collaboration model for the value chain (see p. 330 in [2.118]). Vertical collaboration indicates the capability of actors to manage the supply chain. Horizontal collaboration contributes to the dynamic capability of the network by reallocating resources or creating substitution.

Both horizontal and vertical collaboration require managing the relationships between actors in the network. Burt [2.119] and Uzzi [2.120] have demonstrated the general mechanisms by which relationships between firms in supply chains and networks can be explained. As starting point, they use two different aspects of networks, namely the positioning of firms in the structure of the network and the nature of the mutual relationships. Burt's reasoning implies that the chance of achieving completely radical innovations may decrease if companies establish strong mutual contractual links, such as in supply chains. Links with other companies in the supply chain might be so strong that they prevent a company from successfully implementing an innovation, even if it is in a strategic position to do so. Typically, a successful cooperation strategy consists of three basic elements, *i.e.* selection of a suitable partner, formulation of clear-cut agreements (getting the project underway) and management of the ongoing relationship. Carefully selecting future cooperation partners can prevent many problems and, according to Hagedoorn [2.121], the aim should be similarity balanced by complementarity, with similarity referring to the firm's size, resources and performance. However, of more importance are the required complementarities offered by the cooperation partner, *i.e.* the combination of complementary activities, knowledge and skills to realise the desired synergy. The literature on strategic partnerships offers many models to evaluate potential cooperation partners, *e.g.* [2.122]. Based on a study of 70 UK-based firms in different industry sectors, Bailey *et al.* [2.123] even concluded that selecting partners based on their track record in previous collaborations turns out to be a poor basis for future collaboration. These signals indicate that how collaborations can be exploited effectively has not yet been settled.

2.3.4 Sustainability of Supply Chains

For the more loosely connected networks that are even emerging in supply chains, but nevertheless call on collaboration, the key to managing the business processes is the monitoring of the capability of individual participating entities (see pp. 45–47 in [2.79]); this is called self-criticality by Kühnle [2.124] (pp. 62–66). It comes back in the central role of hubs that enabled by information and communication technologies exert that capability; the distributed plant automation, PADABIS, is an example [2.124], based on the notion of spaces-of-activity. Montreuil *et al.* [2.125] also propose a framework that they call NetMan but they are less explicit about the central role of monitoring. That capability of monitoring facilitates learning of the network and adaptation to changing circumstances; it strongly resembles the concept of process capability in the steady-state model that is mentioned by Dekkers [2.118] (p. 431). That then calls for reconfiguration, either by self-similarity based on fractals (see p. 67 in [2.124]) or by optimisation of the organelle structure (Section 2.3.1); note that the base for those reconfiguration approaches – the integration of business processes: physical flows and information flows – is the same. Therefore, the self-criticality in relation to reconfiguration constitutes a core capability of industrial networks and might be even the dynamic capability. However, these concepts of hubs and spaces-of-activity could become the cornerstone of future information and communication technologies for managing the supply chain; such a development will enhance collaboration and coordination across these chains as more loosely connected networks.

In the context of supply chains, Barratt [2.126] (p. 39) makes a similar remark: 'many of the problems related to ... collaboration are due to a lack of understanding'. Seuring [2.127] (p. 1069) places this notion in the context of environmental issues for supply chains: integrated supply chain management and understanding of interaction between actors in that chain are a prerequisite for achieving sustainability. Zhu and Cote [2.128] (p. 1033) report a similar finding for their case study of the Guitang Group in China. In addition, Srivastava [2.129] (p. 70) remarks that a paradigm shift is needed for *green supply chain management*. Even though sustainability might be linked to performance improvement, according to Rao and Holt [2.130], many have viewed green supply chain management as a constraint rather than an opportunity or a different *modus operandi* (see p. 70 in [2.129]). The calls for a more integrative framework for supply chain management seem to coincide with the rethinking necessary for concepts that address collaborations in the supply chains as networks. Collaboration might constitute that paradigm shift that is needed for sustainable and green supply chains based on integrative supply chain management and interaction between agents in the networks.

2.4 Research Agenda for Industrial Networks

The four themes described in the previous section – network configuration, manufacturing as commodity, added value of networks, and sustainability of supply chains – appear not to be congruent with most of the ongoing research into industrial networks. Nassimbeni [2.131] (p. 539) remarks that the bulk of available research on networks is devoted to the contractual aspects and social dynamics of inter-organisational relationships, while the dynamic forms of communication and coordination have been neglected, so requiring more attention from researchers. Most likely this originates in the conversion from the hierarchical firm, with direct control of resources and a cross-ownership strategy towards suppliers, to networks with more loosely connected entities, which is a view also found in Smulder *et al.* [2.46].

However, the shift towards more loosely connected entities requires additional theory, models and tools to cope with issues of collaboration, inter-organisational integration and decentralisation of decision making. It is probably more than a decade since the beginnings of academic research into the networked organisation (which initially looked at the extended enterprise, *etc.*). This research mainly has used models from the monolithic company – decision-making on make-or-buy and social dynamics – to further research. Reported findings of research argue that studies should pay more attention to modelling the interaction between agents [2.81], meaning that a more integrated approach becomes necessary. Therefore, research should consider taking different routes:

- The recent insights in natural sciences and the application of principles of complex systems theory to collaborative enterprise networks as socio-technical systems might yield these complementary approaches. Six themes emerge from this point of view (see pp. 71–73 in [2.105]):

  i. the dynamic description of networks (to respond to market opportunities and shifting demands and to capture the stability of networks themselves);
  ii. coordination possibilities (the networks consist of loosely connected

entities, each with their own strategy, and dependent on each other for delivery of products and services);

iii. radical and integrative innovation (the capturing of new market opportunities and technological prospects, and at the same time taking advantage of individual agent's knowledge and skills);
iv. path dependency in the evolution of networks (the concepts of evolutionary approaches and concepts like co-evolution and symbiosis applied to industrial networks);
v. sharing of information across agents (the network as a community of entities that evolve together);
vi. modelling and representation of industrial networks (to stretch beyond taxonomies and static approaches).

This might serve as a base for an interdisciplinary research approach, answering the call of Camarinha-Matos and Afsarmanesh [2.78] (pp. 443–444) for new approaches.

- Networks operate in dynamic environments and require dynamic approaches, so reflecting Ashby's law of requisite variety [2.132]. Perhaps even instability rather than stability is a rule, which requires that optimisation models should rely on insight from other sciences. Although neural networks incorporate some of these ideas, the explicit criteria of optimisation, dispersal, and bifurcation describe the evolution of networks [2.47]. In that perspective, industrial networks could be viewed as complex adaptive systems, similar to Biggiero [2.80] and Andriani [2.133] do for regional networks in Italy. Kühnle [2.124] builds on the proposal for the behaviour of complex systems by adding self-criticality and self-similarity as essential ingredients; *e.g.* Song *et al.* [2.134] consider self-similarity as a keystone for scale-free networks. Dekkers [2.112] offers an outlook on how to combine this complex systems view with evolutionary models, co-evolution, game-theoretical approaches and network theories. During the years to come, we might expect that further elaboration of the complex systems view in its widest sense will add to the understanding of agents' behaviour in industrial networks (*e.g.* Iansiti and Levien [2.135] (pp. 55–58) and Surana *et al.* [2.136] follow similar reasoning) and to the improvement of coordination mechanisms between loosely connected entities.

- The efficacy of industrial networks relies on the use of information and communication technology for collaborative engineering, computer-aided production planning, supply or value chain management and communication [2.137, 2.91], so exceeding the need for logistics integration, which is the main argument of Stock *et al.* [2.66]. Also, the optimisation of structures can be supported by information technology. Helo *et al.* [2.71] propose an integrated web-based logistics management system for agile supply demand network design, allowing interfacing different scheduling agents from different actors. The concept of hubs and spaces-of-activity might even lead to new generations of ERP or new information technologies that fit with the characteristics and coordination possibilities of industrial networks. Nevertheless, a lot of development work needs to be done to obtain methodologies, methods and tools to sustain industrial networks as loosely connected entities [2.47].

- Reconfiguration, for which a method still should be developed, allows a more appropriate approach for capturing market opportunities and optimising performance of networks (see Dekkers and van Luttervelt [2.100] (p. 19) and Section 2.3.1).
- The link between product development and manufacturing needs to be investigated more closely. So far research has concentrated on Order Entry Points, product families, *etc*.; but these concepts have limited reach, although they are addressing an important capability of networks: (mass) customisation. Particularly, the impact of the interface between product development and manufacturing on networks has not been well-researched.

Although the specific research into approaches for networks has progressed, further advances should create insight into optimisation and tools to support industrial networks; this is congruent with the remark of Camarinha-Matos and Afsarmanesh [2.78] (pp. 443–444) that research into collaborative networks constitutes a new interdisciplinary domain.

2.5 Implications for Practice

For managerial practice it follows that industrial networks requires a change in mind-set from three perspectives. First, the concepts embedded in the thinking about networks as an extension of the monolithic company will yield only marginal benefits. Besides it carries the danger that this management approach will result in issues of power and trust for industrial networks (see, *e.g.* [2.87]), much like the thoughts of the strategic network perspective and resource-based view (Section 2.2). Otherwise, the management of networks might suffer from fragmentation and its impact on decreasing the effectiveness of networks, as is so characteristic for the construction industry [2.138]; even though others take a contrasting position [2.139]. Second, the distribution of private and common benefits needs attention, where traditionally pricing and costs are focus of managerial attention. Although for part, it resembles the embeddedness in networks, *e.g.* see pp. 54–61 in [2.120], it does not imply that companies need to sacrifice. Rather they might benefit from the increased reach and responsiveness the networks offer on the long-term, albeit again through different mechanisms than traditional methods applicable for the Chandlerian or monolithic firm. Third, collaboration in networks has in some sense put smaller and bigger companies at equal footing. That implies that both smaller and bigger companies compete at a global scale with a greater flexibility and changeability. That in itself has accelerated the necessity to operate within networks: the emergence of networks going hand in hand with the necessity. Henceforth, networks have become a reality for many companies. Despite the changes that these three perspectives bring about, methods and tools have not fully been settled, that way calling also on managers to contribute to further insight and to collaborate with academics to advance both practice and theory.

2.6 Conclusions

There is little doubt that the issue of industrial networks has been an important concern to companies needing to compete in the dynamic competitive climate that has demanded greater flexibility, responsiveness and variety as well as responding to pressure on costs. The traditional networks of the past, especially those based on keiretsu or chaibol principles, have less use in today's business conditions and, as a consequence, more loosely connected agile networks have emerged. However, there has been very little research aimed at establishing the patterns that underlie their emergence and there remains the question of what support such research should provide for practitioners.

This chapter has identified a number of key issues concerning the future of networks, which have been based on a review of the relevant literature and additional considerations. First, network configurations require a control structure and organisational structure that fits actual demand, so companies have started to move away from the control paradigm of the monolithic company towards managing the emergent properties of networks. Second, with the move towards OEMs as network players there has been a greater tendency for manufacturing to become a commodity, which has accelerated under the regime of brand ownership. Third, the added value of industrial networks includes more product and process innovations and the extension of capabilities with manufacturing services. Fourth, the emergence of industrial networks has a strong impact on underlying theory, methods and tools, including applications of information and communication technology; researchers and practitioners should direct their efforts to develop more adequate approaches that fit the characteristics of industrial networks. Finally, a number of different routes have been identified that research should take if it is to properly reflect and support the real needs of industrial networks in the coming decade and beyond.

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