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International Operations Networks

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Contents

Relating the Firm's Global Production Network to Its Strategy

Kasra Ferdows

Abstract This chapter provides a high-level review of the literature on global production networks and suggests that this area offers a fertile ground for future research. An important issue deserving attention is the relationship between the firm's strategy (particularly its manufacturing strategy) and the structure of its global production network. The chapter offers a model for this analysis. The model allows delayering the production network into clusters of plants based on the characteristics of the products they produce and the production processes they use to produce them, and gauges whether each cluster has the appropriate level of resources to carry out its strategic mission. The chapter also reviews the literature on transfer of know-how in global production networks. This is another area that deserves attention, particularly the choice of appropriate mechanism for this transfer under different conditions.

Keywords Global production networks · Transfer of production know-how · Global manufacturing strategy · Rooted and footloose production networks

Production networks in multinational companies are complex structures. It takes years to put them in place and it is difficult to change them quickly. Many variables, often outside the control of the firm, affect the configuration of these networks and make it a challenge to control their evolution. Therefore, if well managed, a firm's production network can be a formidable source of competitive advantage; if not, it can significantly limit the firm's strategic options. To borrow the famous analogy suggested by Skinner (1969), a firm's global production network can become a "millstone in corporate strategy."

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In spite of an abundance of literature on global production, there is a shortage of models on how multinational companies should assess, monitor, adjust, and generally manage their production sites around the globe. Scholars in diverse fields have studied how production networks are affected by a long list of factors, such as: changes in foreign exchange, new trade agreements, changes in tax rates and incentives for foreign direct investments, industrial policy at the national and regional levels, economic development, technology, sustainability, social responsibility of business, and other factors. They offer valuable insights, but there is still a gap between these broad and often policy-level perspectives and operational guidelines for how multinationals should ensure their global production network evolves in line with their business strategy. We need more research to fill this gap, particularly by scholars in our field of operations management. Studying how production should be organized and managed is at the core of what we do.

In the following pages, I discuss some of the inherent challenges in studying global production networks. These challenges can be daunting, especially to young scholars in our field, but as the contributions in this book demonstrate, this is fertile ground for research. I show this by providing a brief, high-level review of the literature on this topic and identify some of the gaps that need to be filled. Among the unexplored areas an important one is the relationship between the role of manufacturing in the firm's business strategy and the characteristics of its production network. As a step towards investigating this fundamental relationship, I propose a typology for categorizing the production networks based on the characteristics of the firm's products and production processes. This framework suggests how a firm's production network should change as its strategy for the mix of products it offers and the production processes it uses change. It identifies new propositions that need to be tested empirically.

Since several contributions in this book focus on the transfer of knowledge in global production networks, I also present a brief review of the literature on this important topic. This area, too, needs new research, especially on how to transfer production know-how in a firm's globally dispersed plants. Operations scholars should play a leading role in this investigation.

1 The Challenge

Studying global production networks is a challenge for at least three reasons. First, global production networks are particularly susceptible to *detail complexity*, with a very large number of factors directly affecting them. These range from changes in demand patterns (due to the emergence of new geographical markets, introduction of new products, discontinuing existing products, economic recessions or booms, and other reasons), changes in local laws and regulations (e.g., introduction of new tariffs, new intellectual property protection laws, new environmental rules, new labor laws or other legislation), to changes in the local competitive situation (e.g., entrance of new local or foreign competitors, changes in cost of energy, changes in national and regional logistics infrastructures, ports and customs, currency fluctuations, and changes in local wages, taxes, rate of local inflation, and availability of new subsidies). These are compounded by other factors, such as mergers and acquisitions, changes in technology (e.g., new process technologies, including 3-D printing or "additive manufacturing," and new Internet and communication technologies), and changes in political risks (e.g., unrest, regime changes, and security issues).

All this is compounded by the fact that a firm's production network is always embedded in a larger industrial network of suppliers, subcontractors, and often value-adding customers. Production networks of many of these suppliers and customers are also subject to similar levels of detail complexity, and as they change, they necessitate adjustments in the firm's production network, which creates additional complexity. This daunting list of variables can dissuade scholars who need quick publications to advance their careers to venture into this area. It is a lot safer to focus on more tractable areas.

The second reason studying production networks is a challenge is due to their inherent *hysteresis* (i.e., delayed response to stimuli). It may take months to adjust production allocations in a global network in response to changes in the value of local currencies; it takes even longer to close a factory or open a new one because of changes in demand for specific products or after a merger or acquisition. In the interim, other factors also continue to change and compound and confound the effects.

Hysteresis makes empirical research difficult. The researchers must collect sufficient longitudinal data to be able to observe the effects of any variable. Furthermore, they need to track evolution of a large number of metrics, such as changing production costs, quality, delivery, safety, automation level, as well as contextual variables, including national and organizational cultural traits, and macro-economic factors. All this takes time and energy.

An alternative to empirical research is to do analytical modeling. However, the detail complexity and hysteresis make many such analytical models often too confined or unrealistic. The third challenge, therefore, is that unlike many other areas in operations management (e.g., inventory management, quality management, scheduling, or stylized buyer-supplier transactions), we still do not know enough about the relationship between changes in global production networks and the variables that affect it to be able to do much credible modeling in this area.

As a result, while no one seems to dispute the importance of studying global production networks, only a few scholars in operations management have focused their research on this topic. These challenges—detail complexity, hysteresis, and limitations of non-empirical research—also explain why many operations scholars who have focused on global production networks have relied on case-based research (Eisenhardt 1989; Voss et al. 2002; Yin 2003).

2 Perspectives on Global Production Networks

Several overlapping streams of research provide the context for studying the broad topic of production networks. The first stream is the rich literature on multinational companies. In the last three decades, research on the structure and organization of multinationals has shifted from a focus on a hierarchical view of relationships between the company's headquarters and its subsidiaries towards a perspective of a web of diverse inter- and intra-firm relationships. Theories that have been used to examine these relationships include network theory (Ghoshal and Bartlett 1990; Gulati et al. 2000), evolutionary theory (Kogut and Zandar 1993), learning organization (Grant 2010; Nonaka 1994) and knowledge transfer (Grant 1996; Szulanski 1996). A common theme among these theories is that multinational organizations can benefit greatly from transferring resources and competencies developed in different locations within their company. These approaches provide useful contextual knowledge, but in general, stay at a high strategic level and seldom delve deep into how factories should be organized, managed, and work together.

The second stream is the literature on industrial networks. The focus here is on the external, mostly vertical, networks in which the firms—especially original equipment manufacturers (OEMs)—operate. Relationships with suppliers (Dyer and Nobeoka 2000), subcontractors, and contract manufacturers (Plambeck and Taylor 2005), in particular, have received considerable attention in recent years. There is a general consensus that increased data, information, and knowledge transfer in the "extended enterprise" can be beneficial to all parties. However, there are also warnings against excessive outsourcing and reliance on others for the production and design of the firm's core products (Arrunada and Vázquez 2006; Pisano and Shih 2009).

At a more abstract level, Håkansson (1990) views the industrial networks as interplay between *actors, resources,* and *activities* that reside in different firms that comprise the network (where actors have knowledge of activities and control resources, and activities change or exchange the resources). A key implication of this view, as Dekkers and Van Luttervelt (2007), Karlsson (2003), and Karlsson and Sköld (2007) also observe, is that manufacturing strategy is best defined in the *context* (i.e., industrial network) in which the firm operates. In other words, manufacturing strategy should extend its reach beyond the firm's boundaries and clarify the level of dependence on long-term suppliers, alliance partners, contractors, design labs, distributors, arms-length suppliers, and other key actors in the relevant industrial network. This is exactly what (Pisano and Shih 2009) mean by "industrial commons," and how their presence or absence can completely alter the options for locating global production sites.

The third stream of research has focused directly on the intra-firm production networks. An early article in this stream is Hayes and Schmenner's (1978) "How Should You Organize Manufacturing?" They suggested that a firm's production network can be organized along products, processes, or a combination of the two, and show under what conditions a product-oriented versus a process-oriented network would be more effective. There were also other perspectives for viewing production networks and, among them, I suggested that factories in a network have different strategic roles which define their relationships to headquarters and to each other, to other functions in the firm (especially research and development, procurement, and distribution), and to other entities outside the firm (Ferdows 1989, 1997). Vereecke et al. (2006) provided additional empirical support for different roles of factories in a network.

A subgroup of this stream of research uses the *network*—as opposed to factories within the network—as the unit of analysis (Colotla et al. 2003; De Meyer and Vereecke 2009; Ferdows 2008; Shi and Gregory 1998; Vereecke et al. 2006). An important premise here is that intra-firm manufacturing networks can develop capabilities that go beyond factory-level capabilities, and especially with the advent of new communications and transportation technologies, companies must pay more attention to the design and management of their production network as a whole. We need more research in this area and many contributions in this book extend this line of research.

Combined, these streams of research provide valuable insights into how to spread the firm's production network globally and assess and chart a strategic course for individual factories in the network. However, they do not seem to link their findings directly to the rich literature on the role of manufacturing in corporate strategy (Hayes et al. 1996; Pisano and Shih 2009; Skinner 1969; Wheelwright and Hayes 1985, among others).

This is an important relationship that has not been sufficiently investigated. Perhaps a reasonable way to proceed is to use the well-known Wheelwright and Hayes (1985) "four stages" for the roles of manufacturing in a firm's strategy (ranging from stage one, "internally neutral," where manufacturing does not contribute to the firm's competitive strategy, to stage four, "externally supportive," where manufacturing is a prime source of competitive advantage in the firm's strategy). It is not clear how these stages affect the shape of the firm's global production network. Furthermore, given the possibility of a production network becoming a "millstone in corporate strategy," distinguishing between the cause and effect is not always clear (i.e., does the stage determine the network or vice versa?). Most likely, the process is an iterative interplay between the role of manufacturing in the firm's strategy and the shape of its production network. We do not know with certainty yet.

In short, despite an abundance of literature on international production, there are still many gaps in our knowledge of how to plan and operate global production networks. Given the growing complexity of these networks, it helps to focus on the basic questions in managing them.

3 Basic Operational Questions

When a company produces its products in more than one production site, its managers face three new basic questions:

1. Are we producing (and sourcing) our products in the right places?
2. Does each production site have the required resources to do what is expected of it?
3. How do we transfer know-how among production sites and improve their operations?

These are deceptively simple questions but are difficult to answer. The most difficult one is the first, which also largely determines the answers to the second and third questions. The main reason for this difficulty is that, because of *detail complexity,* too many variables affect the optimal allocation of products to production sites.

Even a well-configured production network must be reexamined constantly to adjust for the adoption of new process technologies, the introduction of new products and changes in the product mix, changes in local wages, tariffs, and regulations, fluctuations in foreign exchange rates, changes in logistics costs, arrivals or departures of important suppliers, new concerns for sustainability and ethical supply chains, acquisitions, and many other factors.

The problem is exacerbated by the fact that the answer to the second question can also affect the answer to the first question. If a company does not allocate sufficient resources to a production site, after a while it can justify reducing its production volume and allocating less complicated products to it. This can lead to a subtle but vicious cycle of continuing decline in a plant's capabilities and effectiveness.

How a firm allocates resources in its global production network is, therefore, a critical decision, which is both affected by and affects the role of manufacturing in its strategy. In other words, firms that do not consider manufacturing to be a source of their competitive advantage often rely on others to produce their products and are not likely to allocate many resources to develop their own global plant networks; conversely, firms that invest heavily in their own plants depend on superior manufacturing capabilities as a source of their competitive advantage.

In an earlier paper, (Ferdows 2008) I suggested that the former is likely to have a "footloose" and the latter a "rooted" production network:

> There are two seemingly irreconcilable models for building production networks. One advocates staying footloose—that is, continuing searching the world for a better factory inside or outside the company and moving production there as soon the firm finds one; the other advocates developing deep roots—making long term commitments to each production site and giving it the resources to reach its full potential.
>
> Both models have their own logic. Those in search of more agility in an increasingly uncertain and volatile world usually argue for more footloose networks; and those who want more stability to develop unique production capabilities, ironically to cope with the same uncertain and volatile world, argue for more rooted networks. The first group wants to leverage the capabilities of others and conserve its own resources for other functions like design and marketing; the second group wants to use its own production capabilities as a competitive weapon. (Ferdows 2008, p. 150)

I suggested that production networks are being constantly pulled in different directions, particularly in one of these two directions. Sometimes, this pull is abrupt and visible—like a decision to close a factory and outsource production of a product; other times, it may be gradual and subtle—like continuing to reduce (or increase) new capital investments in factories. The cumulative effect of these movements can cause the production network to evolve in an unintended direction. It is logical to hypothesize that the higher the role of manufacturing in the firm's strategy (e.g., closer to stage four of Wheelwright and Hayes 1985), the more likely that firm would move towards the rooted network. We need new research to see if, indeed, higher roles of manufacturing in a firm's strategy lead to more stable global production networks.

In the same paper (Ferdows 2008), I also suggested a simple framework which can be used to categorize different production networks (or sub-networks). A slightly modified version of this framework is shown in Fig. 1 (Ferdows et al. 2013).

According to this framework, networks (or sub-networks) can be categorized on the basis of *what kind of products* they produce and *how* they produce them. The

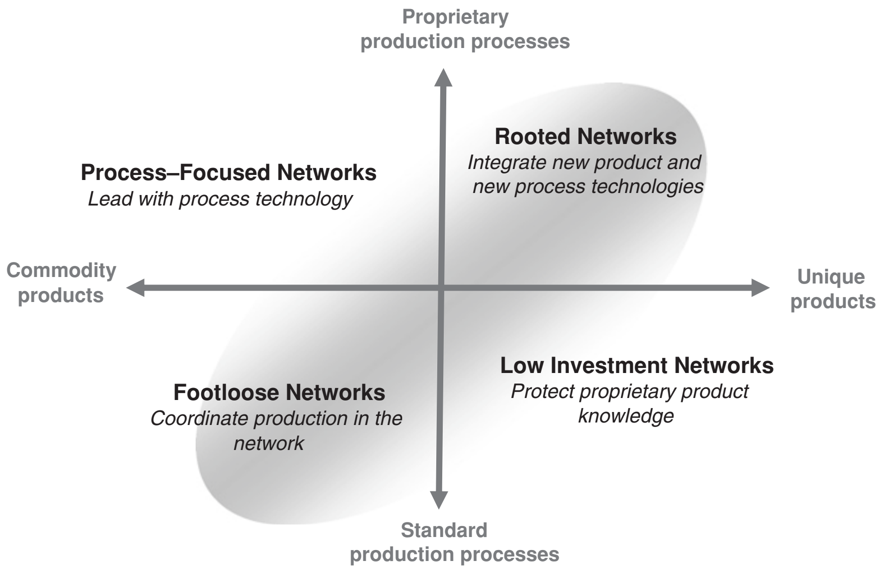

Fig. 1 A typology of production networks

scales, ranging from "commodity products" to "unique products" and "standard processes" to "proprietary processes," can be defined relative to the business unit, the firm, or the industry—depending on the level of granularity desired in the analysis.

If the scales are chosen relative to common industry practices and if we make an analysis from a pure manufacturing perspective, it is logical to expect the networks on the diagonal to be more stable than those that are far above or below it. Each quadrant poses a different managerial challenge. In the top right quadrant, you find production networks that produce fairly complicated products with proprietary processes. Production networks of companies like Intel or Steinway Piano are generally in this quadrant. These networks have distinct capabilities in most of their factories, supported by production know-how that is mostly in tacit form and not easy to transfer from one factory to another, especially one outside the firm. Therefore, these networks are usually rooted in the sense that most of their factories are likely to stay in place for long periods. They need the stability and continuity of having deep roots in order to build the requisite expertise and production capabilities.

The networks in the bottom-left quadrant produce fairly simple products with standard processes, such as those producing IKEA components or Dell personal computers. Relative to rooted networks, these are generally more footloose, in the sense that it is easier to shift production from one of their factories to another (belonging to the firm or its suppliers or subcontractors). The reason, of course, is that the requisite know-how to produce a standardized product is usually more codified and production processes are more widely available; hence, transferring production from one factory to another inside or even outside the company is not as difficult.

It follows that the position of the network on the diagonal also gives an indication of the aggregate level of competence in its factories. Factories in the rooted networks that are higher on the diagonal generally perform more skilled and value-adding functions than those in lower positions. They design, customize, or upgrade their machinery more often, do more process improvements, engage in more technical collaboration with their key suppliers, and generally participate more actively in product and process development activities. Networks on the lower positions on the diagonal become more footloose. The ultimate footloose network sources all its products from suppliers at arm's length. In the middle of the diagonal are the networks that produce or procure their products from a mix of sources: own factories with some product and process development activities, suppliers that engage in some product and process development activities, and suppliers that supply products at arm's length.

Networks can also be off the diagonal. The position can reflect a deliberate strategic choice. For example, the production network of a company like Lego, which produces rather simple products (Lego bricks and other plastic pieces) with advanced and proprietary processes, or Nucor, which produces simple steel products with rather sophisticated production processes, fall above the diagonal, in the top-left quadrant. Mastery of process technology and large economy of scale can in such cases be important sources of competitive advantage. However, it is also possible for a network to find itself in this quadrant because of strategic negligence—by continuing to produce products that have turned into commodities that can be produced with simpler processes. In general, a position far above the diagonal makes the network unstable.

Alternatively, a network can be below the diagonal. If a network of factories is producing a relatively complicated and proprietary product using production processes that are standard in the industry (e.g., factories producing high-fashion apparel or cell phones), it is operating in this region, in the bottom-right quadrant. Many factories in the networks in this quadrant often belong to contract manufacturers, subcontractors and suppliers. A network in this quadrant, again, can reflect a deliberate strategic choice or possible underestimation of the strategic role of production in the business strategy of the company. These networks, like the ones above the diagonal, are also unstable, especially if they are far from the diagonal.

This typology offers an organized approach for future research into the fit between the firm's products and processes and the architecture of its production network. Such research would help in answering the first and second basic questions mentioned earlier; that is, are we producing our products in the right plants and do these plants have adequate resources to do what is expected of them? However, answering the third basic question—how to transfer production know-how among plants and improve their operations—needs a different line of research.

4 Improving Operations in Global Production Networks

One would expect that transferring production know-how between plants, especially two that belong to the same company and produce rather similar products, should not be difficult. Yet, it often is. There is rich literature about the transfer of knowledge that provides a long list of reasons. The reasons range from the difficulty of transferring tacit know-how (Gupta and Govindarajan 2000; Leonard and Swap 2004; Polyani 1967;

Szulanski and Winter 2002; Zandar and Kogut 1995), to insufficient *absorption capacity* at the receiving plant (Allen 1977; Bjorkman et al. 2004; Cohen and Levinthal 1990; Gupta and Govindarajan 2000; Tsai 2001), and resistance to change and organizational inertia (Kotter 1996) and reluctance to share knowledge at the source plant (Minbaeva et al. 2002; Leonard and Swap 2004). Still other reasons stem from a poor choice of transfer mechanisms (Ferdows 2006) and, more generally, inadequate attention to the role of knowledge management in the firm's strategy (Grant 1996).

It is important to differentiate between the different types of knowledge that need to be transferred. With today's communication technology, it has become relatively easy to collect up-to-date data about operations of each plant and make it widely available to managers both at the headquarters and in the plants. It has simplified the transfer of information about best practices and benchmarks in the network, as well as assessing the gaps in individual plants. The literature usually refers to this type of knowledge as *declarative knowledge* (Kogut and Zandar 1993). It is different from production know-how, often referred to as *procedural knowledge* or, more broadly, "organizational practices" (Jensen and Szulanski 2004). Procedural knowledge is a recipe for action, arguably the most valuable type of knowledge for a plant. Knowledge about *how* to produce is different from information about things or situations (i.e., *declarative knowledge*) or scientific knowledge about how one variable affects another, usually referred to as *causal knowledge* (Dhanaraj et al. 2004; Leonard-Barton 1995). These three types of knowledge are, of course, complementary, and sometimes packaging them together helps their transfer (Lapré and Van Wassenhove 2003; Szulanski 1996), but, in general, transferring one does not necessarily transfer the others (Nonaka and Takeuchi 1995).

A notable trend in recent years is the emergence of corporate lean programs in large multinational manufacturing companies (Netland 2013). Almost all of these programs are based on the famed Toyota Production System with the goal of inculcating good production practices in every plant in the company's network. This requires a massive transfer of knowledge from the headquarters to the plants, and from the plants to other plants (sometimes including those belonging to the firm's major suppliers and customers).

As several chapters in this book show, transferring production know-how in a globally dispersed network is a challenge. The issues range from the micro level of how to transfer appropriate knowledge from one plant (or the headquarters) to another plant efficiently and quickly, to the macro level of how to transfer know-how to multiple plants or an entire production network simultaneously. The chapters in this book address some of these issues, but there are still many more for future research.

5 Final Word

With the increasing fragmentation of global production and supply chains, the need for research into the design and management of global production networks can only escalate in the foreseeable future. With many unexplored areas, it offers a fertile ground for future research. There is a unique opportunity to make significant contributions to expand our knowledge in this critical area. We, in operations management, should be at the forefront of this research. We need more books like this one.

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The Whole Picture: Integrating Site and Network Dimensions in Site Roles

Maike Scherrer-Rathje, Patricia Deflorin, Simone Thomas and Maria Fischl

Abstract In this chapter, we develop a site classification framework that combines manufacturing site advantages with manufacturing network-level targets. This framework is the first step for a company-specific site role portfolio. The framework helps to visualise site strengths and weaknesses from a capability- and knowledge-based perspective. Further, it highlights the site's contribution to the network targets and combines site- and network-level dimensions. To develop the site classification framework, we extend Ferdows' (1997) introduced dimensions of location advantages and competences with the interconnection of sites from a knowledge-based view. We use a single case study to refine the theoretically derived framework. We add to existing theory because we apply a multi-level perspective and derive methods to measure a sites contribution to the network. In addition, we provide global site managers with a helpful visualisation tool.

Keywords Site role · Manufacturing network · Site classification framework

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1 Exploiting the Network Potential

The global spread of manufacturing activities provides an international manufacturing company (IMC) with opportunities to achieve a competitive advantage. By exploiting the geographic location of its manufacturing sites, the IMC can benefit from access to local markets, low labour cost, favourable taxes or natural hedging. As additional benefit, foreign manufacturing sites are consistently recognised as a valuable source of "fresh" knowledge or skills (cf. Ferdows 1997). To maximise profit, however, the IMC must transform local advantages into global advantages. Therefore, globally dispersed sites in the network have to be coordinated (Kogut 1990) and aligned to the strategic targets of the network (Shi and Gregory 1998). Although each site contributes its specific characteristics and individual competences, fulfilment of network targets requires the concerted effort of the sites as a running network rather than the optimisation of single sites (Miltenburg 2005). To achieve maximum performance, the IMC needs to coordinate and optimise its sites from the site- and network-level perspectives. We introduce a framework that describes and classifies sites in order to optimise site advantages as well as network-level targets.

Site characteristics and competences define the site's specific role in the network. The best known typology of site roles in operations management is the site role typology of Ferdows (Feldmann et al. 2010; Ferdows 1997). It classifies manufacturing sites along two dimensions: (1) location advantage and (2) level of competence (Ferdows 1997, 1989). Other scholars (e.g. Johansen and Riis 2005; Vereecke et al. 2006) have applied different dimensions for the classification of manufacturing sites and have derived their own typologies of site roles. Although the advantages of site role typologies are recognised, there has been some criticism. Typologies are based on different dimensions without building on each other or being connected (Kutschker and Schmid 2005). Furthermore, typologies are primarily derived from an aggregation of data from sites of various IMCs. The definition and allocation of site roles within a single network of one IMC has largely been neglected (Kutschker and Schmid 2005). To understand how a single site can optimise its contribution to network targets, we need to obtain insight from a single network of one IMC. Thus, we focus our approach on the intra-firm network, i.e. a single organisation consisting of multiple sites (Rudberg and Olhager 2003).

From a network-level perspective, four strategic targets may be goals in international manufacturing networks (Shi and Gregory 1998): (1) resource accessibility, (2) thriftiness, (3) mobility, and (4) learning. Accessibility results directly from the geographic location of the sites, but thriftiness, mobility, and learning are obtained from network coordination activities (Colotla et al. 2003). These targets define the cornerstones that compose a site role portfolio. A site role portfolio outlines which competences should be present within the network to fulfil its targets and how each site contributes to the network. Hence, we need to obtain a better understanding of how the network level has to be linked with the site-level perspective.

Our research approach addresses the described shortcomings. Although we ultimately need to construct and define a site role portfolio, which would allow deriving an optimisation plan for each site and with this to coherently develop the network, we first need to develop a framework that classifies site competences and contributions to network targets. We first review existing literature on site role typologies in operations management and derive relevant dimensions to classify sites based on their competences and network target promotion. Second, we review manufacturing network literature and add relevant dimensions that cover site connectedness and help unlock network potential, which generates a classification framework that combines site- and network-level dimensions. Fourth, we show how this framework is applied within an IMC. We conclude with a discussion and ideas for further research.

2 Describing Site Characteristics from a Site- and Network-Level Perspective

To derive a site classification framework that combines site advantages and network level targets, we start with Ferdows' typology of site roles. Ferdows classifies sites along two dimensions; sites are distinguished by their strategic reason of location and level of competences (Ferdows 1997). The first dimension represents whether sites provide access to low-cost production, proximity to market, or access to skills and knowledge (Ferdows 1997). Site competences, ranging from manufacturing, procurement to product or process development, are described by the second dimension (Ferdows 1997). Ferdows' model is widely recognised in operations management (cf. Feldmann et al. 2009, 2010; Fusco and Spring 2003; Maritan et al. 2004; Meijboom and Voordijk 2003; Meijboom and Vos 2004; Turkulainen and Blomqvist 2010, 2011; Vereecke and Van Dierdonck 2002). However, several scholars state that the model "put a little too much emphasis on strategic role of separate factories rather than functions of the integrated or coordinated network" (Shi and Gregory 1998, p. 197). Ferdows' dimension of site competences has been extended to comprise the interaction between sites (cf. Feldmann et al. 2009, 2010; Maritan et al. 2004). In their work, Feldmann et al. (2009, 2010) and Maritan et al. (2004) highlight that the interconnection of sites in a network is a constituent element in the definition of site roles from a network perspective. This argument is supported by findings in the field of multinational company research, where various contributions to the integration of subsidiaries in the network have been made (cf. Andersson et al. 2002; Birkinshaw and Morrison 1995; Gupta and Govindarajan 1991; Jarillo and Martinez 1990; King and Sethi 1999; Prahalad and Doz 1987; Roth and Morrison 1992). Vereecke et al. (2006) have captured this idea and derived a new typology of manufacturing sites. Site integration in the knowledge network serves as the basis for classification. Roles are defined along the flow of innovations, frequency of communication, and exchange of people within the network (Vereecke et al. 2006).

For the purpose of our work, we combine the site-level perspective with the perspective of the site's integration in the network, labelled as network-level perspective. We extend the dimensions of (1) location advantages and (2) competences introduced by Ferdows (1997) with the interconnection of sites from a knowledge-based view. This extension is termed "embeddedness" and represents the third dimension of our framework. Similar to Vereecke et al. (2006), we incorporate a fourth dimension describing a site's position in the network as defined by its knowledge provision to and receipt from other sites in the network—the transceiver degree.

2.1 Location Advantages

Multifaceted advantages originate from the geographic location of a site (cf. Colotla et al. 2003; Feldmann et al. 2010; Ferdows 1997, 1989; Turkulainen and Blomqvist 2010, 2011; Vereecke and Van Dierdonck 2002). Vereecke and Van Dierdonck (2002) have proposed a comprehensive set of advantages, including proximity to markets, suppliers, or competition; the availability of labour, skills and know-how; and socio-political or infrastructural advantages (Vereecke and Van Dierdonck 2002). However, empirical testing validated Ferdows' (1997) assumption that three main factors exist: (1) proximity to market, (2) access to low-cost manufacturing, and (3) access to skills and knowledge (Feldmann et al. 2010; Vereecke and Van Dierdonck 2002).

2.2 Level of Competences

Ferdows (1997) differentiates a site's manufacturing competences, which range from manufacturing alone to serving as a global hub for product or process knowledge. He combines aspects of the bandwidth of site competences and the reach of competences. The bandwidth of site competences expresses the diversity of competences, ranging from production to the development of products or processes. To focus on the role of a site as a constituent part of the network, we assume that competences are heterogeneously distributed across sites. Sites may need the support of other sites' competences to perform a task, which concurs with Maritan et al. (2004). The reach of competences indicates if the respective site uses its competences to perform an activity for the site alone (e.g. machine maintenance at shop floor), for a number of selected sites (e.g. the bundling of procurement orders), or for the whole network (e.g. a global hub for product and process knowledge and provision of this knowledge to the network's sites). Accordingly, we propose to distinguish between (1) the bandwidth of competences a site incorporates and (2) the reach of its competences.

2.3 Level of Embeddedness

The interconnection of sites through flows of knowledge determines the site's embeddedness in the network (Andersson et al. 2002; Dyer and Hatch 2006; Vereecke et al. 2006). In a case study of eight manufacturing companies, Vereecke et al. (2006) showed that sites differ fundamentally in their degree of involvement in knowledge exchange and found that sites that are actively and frequently engaged in knowledge exchange have deeper roots in the network (Vereecke et al. 2006). In addition to the exchange of knowledge, we suggest that sites cooperate with one another to execute activities needed to produce their products. Sites with strong cooperation are assumed to have a higher degree of network integration and greater contributions to the spread of skills within the network. Thus, we distinguish between (1) the degree of knowledge exchange of a site and (2) its involvement in cooperation with other sites.

2.4 Transceiver Degree

Following the reasoning of Vereecke et al. (2006) a site's position in the network of an IMC is defined by its relationships with other sites in the network. Thereby, the relation is not always mutually balanced with respect to knowledge inflow and outflow. If knowledge outflow is higher than the amount of knowledge received by the site, the site is considered to be a sending or transmitting site. A receiving site has less knowledge outflow than inflow. The sending and receiving of knowledge is closely related to the degree of knowledge exchange. However, the degree of knowledge exchange only indicates the overall intensity of knowledge flow and therefore the level of embeddedness. It does not give any information on the main direction of knowledge flow. Thus, we add the fourth dimension, the transceiver degree, to mirror the site's dominant knowledge flow direction. The transceiver degree further represents site importance within the network as competences tend to develop around knowledge hubs (Riis et al. 2007), i.e. the more active transmitting sites.

3 Introduction of the Site Classification Framework

To classify sites in an IMC network, we integrate the above dimensions in a framework. The framework consists of four elements: (A) the competence triangle, combining the bandwidth and reach of competences, (B) the embeddedness triangle, combining the degree of cooperation and the degree of knowledge exchange of the respective site with other sites, (C) the transceiver degree, which considers the site's knowledge transmitting and receiving activities, and (D) the location advantages inherited by a site. The four elements will be introduced in more detail in the following paragraphs (see also Fig. 1).

(A) Each site inherits a variety of *competences*, some of which contribute to network targets. To classify the sites, we focus on the competences that contribute to network targets. To classify the site competence level, we first need the overall set of competences required to fulfil network targets (e.g. sales, product development, prototyping, or product testing). Each competence is displayed along two axes: (i)

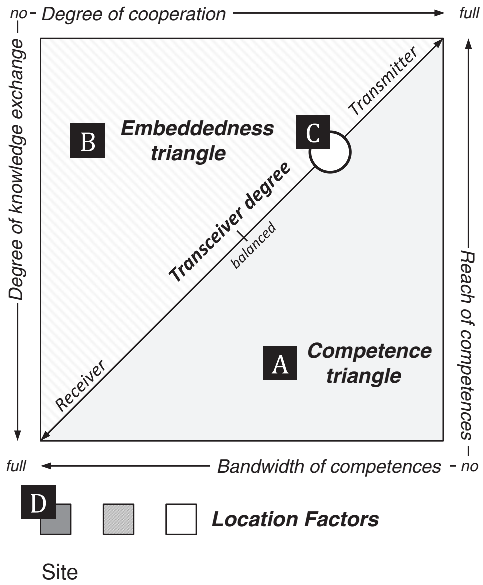

Fig. 1 Elements of the site classification framework

bandwidth of competence and (ii) reach of competence (Fig. 1, A). Site bandwidth of competences describes the actual competences of the site, whereas the reach of competences indicates for whom the site executes its competences in the network.

We use normalisation factors to evaluate the position of the bandwidth and the reach of competences of a site in the classification framework (Fig. 1) and to enable comparison of the competences of the sites in the network.

The bandwidth of a site can range from 0 to 1. A site with a bandwidth of 0 provides no useful competences for the network, and a site with a bandwidth of 1 possesses the full set of competences that contribute to network targets. Accordingly, the bandwidth of competence (b_{site}) can be understood as the sum of site competences (c_i) in relation to the total number of competences required in the network ($c_{network}$I), as shown in Eq. (1).

$$b_{site} = \frac{\sum_{i=1}^{I} c_i}{I} \quad (1)$$

with I := total number of competences.

A task can be executed by one site or in cooperation with another site. Tasks that can be performed independently by a site represent a full competence level in regard to a certain competence and therefore are rated with the value 1. Tasks that are executed in cooperation with a site indicate a lower level of competence. Since in practice the exact distribution of competences between the sites can hardly be determined, shared competences get the rating value of 1/number of cooperating sites. In practice, the standard case is the collaboration of two sites and therefore the value 0.5 can be often used. We illustrate the calculation of the bandwidth with an example. A company might need 18 different competences in a network to fulfil the targets. The site under investigation exclusively holds 10 competences. Additional, one competence is held at another site, and the respective task is achieved in cooperation. The overall bandwidth of competence of the site is:

$$b_{site} = \frac{(10 \cdot 1) + (1 \cdot 0.5)}{18} = 0.58 \tag{2}$$

Reach of competences is the second competence axis. Similar to the bandwidth of competences, the reach of competences takes a value between 0 and 1; a value of 1 symbolises that a site holds the full reach of competences needed in the network and executes activities with these competences for the entire network. To calculate the reach of competences (r_{site}), each competence (c_i) is multiplied with its reach value (r_i). The mathematically exact reach value depends on the number of sites for whom the activity with the respective competence is executed as well as the total number of requiring sites. In some previous studies we found, however, that collecting these exact numbers is at the expense of data quality. Practitioners often give diverging and inconsistent answers. Satisfying data validity can in most cases not be achieved. Taking this into account, we decided to use a more rough calculation and differentiate only between the three cases: A site can use its competences to perform an activity only for its own site, for selected sites, or for the entire manufacturing network. Assuming an evenly divided scale, the first case is represented by a reach value of $\frac{1}{3}$. A value of $\frac{2}{3}$ means that the activity is performed for selected sites and a value of $\frac{3}{3} = 1$ indicates that the activity is performed for the whole network. The formula to calculate and normalise the reach of competences is shown in Eq. (3).

$$r_{site} = \frac{\sum_{i=1}^{I} (c_i \cdot r_i)}{I} \tag{3}$$

with I := total number of competences.

We clarify this calculation with a continuation of the above example. We still have 18 network capabilities, and the analysed site has 10 exclusively held competences and 1 competence where corresponding activities need to be performed in cooperation with a second site. Out of the 10 exclusive competences, 6 corresponding activities are performed for the site alone, 3 are performed for selected sites and 1 is performed for the whole network. The competence held in cooperation is performed for selected sites. The corresponding normalised reach of competences is calculated as shown in Eq. (4):

$$r_{site} = \frac{\left(6 \cdot 1 \cdot \frac{1}{3}\right) + \left(3 \cdot 1 \cdot \frac{2}{3}\right) + \left(1 \cdot 1 \cdot \frac{3}{3}\right) + \left(1 \cdot 0.5 \cdot \frac{2}{3}\right)}{18} = 0.30 \tag{4}$$

(B) The execution of competences generates knowledge that is valuable for the respective site and other sites of the network often benefit from this knowledge. Hence, knowledge exchange between sites is central from a network-level perspective. A higher degree of cooperation with other sites and a higher degree of exchanged knowledge deepen the respective site's embeddedness in the network. The *embeddedness* of a site in the network is defined through two dimensions:

(i) site degree of knowledge exchange and (ii) site degree of cooperation (Fig. 1, B). The degree of knowledge exchange is measured as the knowledge inflow and outflow of the site, i.e. the knowledge the site receives from and sends to other sites in the network. The degree of cooperation is quantified by the amount of cooperative activities that the respective site accomplishes with other sites in the network.

The degree of knowledge exchange of a site can range from 0 to 1. A site that is not participating in knowledge exchange receives a value of 0. In contrast, a site that is fully engaged in knowledge exchange is assigned the maximum value of 1. The overall degree of knowledge exchange of a site (k_{site}) can be measured by its total amount of knowledge exchange and expressed as the weighted intensity of the knowledge inflow ($k_{in\ j}$) and outflow ($k_{out\ j}$), which are each measured on a 5-point Likert scale ranging from 1 = very little knowledge flow to 5 = very high knowledge flow. If there is no knowledge flow at all for a certain item, it is valued as 0. The weights ($w_{in\ j}$ and $w_{out\ j}$) represent the normalised reach of the knowledge flows. Again the ratio between number of sites that send or receive knowledge and the total number of sites that require the knowledge would depict the mathematically correct value. Experience in practice, however, shows that such an exact measurement does not result in a valid data basis. Therefore, we choose a rougher division of the scale and distinguish between knowledge that is exchanged with selected sites and knowledge that is exchanged with the whole network. The corresponding values are $\frac{1}{2} = 0.5$ for knowledge exchange with selected sites and $\frac{2}{2} = 1$ for knowledge exchange with the whole network. If knowledge is not exchanged with any other site in the network, the weight is consequently valued as 0.

To aggregate the weighted knowledge flows, the relative closeness to the maximum amount of possible knowledge exchange is calculated (Eq. 5a, Fig. 2). This closeness is defined as the Euclidian distance to the minimum value (s^-) over the sum of the Euclidian distance to the minimum value (s^-, Eq. 5b) and to the maximum value (s^+, Eq. 5c). Due to the usage of the 5-point Likert scale and the default value 0, the minimum value is represented by 0 and the maximum value by 5. When calculating the Euclidian distance, these values represent fixed reference points, i.e. the minimum and maximum amount of knowledge exchange and must be subtracted in Eqs. 5b and 5c.

$$k_{site} = \frac{s^-}{s^- + s^+} \tag{5a}$$

$$s^- = \sqrt{\sum_{j=1}^{J} ((k_{in\ j} \cdot w_{in\ j} - 0)^2 + (k_{out\ j} \cdot w_{out\ j} - 0)^2)} \tag{5b}$$

with J := total number of areas to which knowledge is exchanged

$$s^+ = \sqrt{\sum_{j=1}^{J} ((k_{in\ j} \cdot w_{in\ j} - 5)^2 + (k_{out\ j} \cdot w_{out\ j} - 5)^2)} \tag{5c}$$

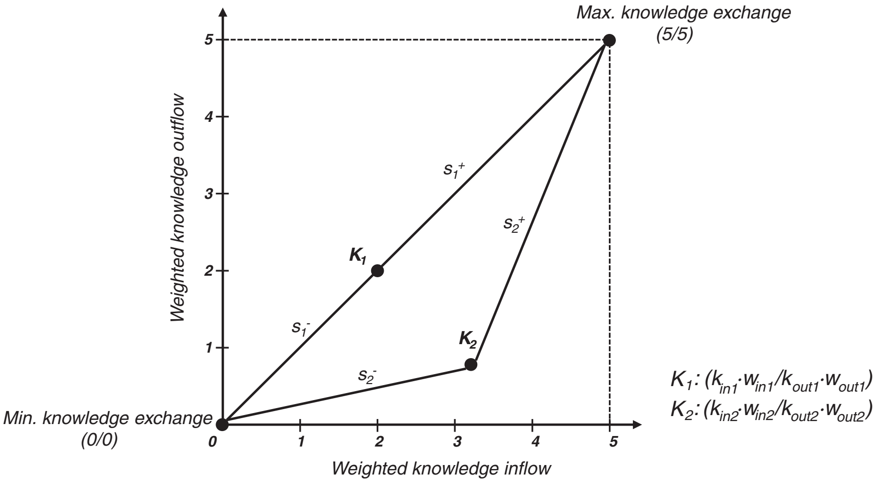

Fig. 2 Euclidian distance to the maximum and minimum knowledge exchange

with J := total number of areas to which knowledge is exchanged.

The second axis displays the degree of cooperation ($coop_{site}$) and relates the number of cooperative activities (a_k) to the number of required activities of a site ($a_{site}a_{req}$). Cooperative activities are understood as the activities that require certain interaction between sites. This interaction may either be the case for activities executed in cooperation with other sites in the network or activities provided by other sites in the network. Additionally, cooperation might be necessary if specialised resources (e.g. special manufacturing equipment) are only held at certain sites in the network. Compared to the bandwidth of competences the cooperation axis has greater sole responsibility for the activities accomplished based on aggregated competences.

$$coop_{site} = \frac{\sum_{k=1}^{K} a_k}{a_{req}} \quad (6)$$

with K := total number of activities that are executed in cooperation.

(C) Embeddedness shows the depth of integration of a respective site in the network. However, embeddedness does not show the direction of the exchanged knowledge. The knowledge can flow from the respective site to one or several other sites (knowledge outflow), and/or the knowledge can flow from other sites to the respective site (knowledge inflow). Both directions of knowledge flow are important. Whereas outflowing knowledge helps to develop other sites, inflowing knowledge helps to develop one's own site. We display the level of knowledge inflow and outflow as the *transceiver degree* of the site (Fig. 1, C). Depending of the amount that knowledge flows in and out of the respective site, the site is positioned on the transmitting or receiving side.

The transceiver degree is calculated as the normalised sum of knowledge outflow intensity ($k_{out\ j}$) minus the corresponding knowledge inflow intensity ($k_{in\ j}$) (Eq. 7).

$$t_{site} = \frac{\sum_{j=1}^{J} (k_{out\ j} - k_{in\ j})}{J} \tag{7}$$

with J := total number of areas to which knowledge is exchanged.

(D) Site geographic locations reflect the basic network set up. With these locations, the network can achieve certain advantages. *Location advantages* (Fig. 1, D) display if the sites offer (1) access to markets, (2) access to skills and knowledge, or (3) access to low cost manufacturing. These location advantages are inherent characteristics of the respective site. Contrary to Ferdows (1997), we do not see that these location advantages are mutually exclusive. Instead, we assume that a location can provide more than one advantage, e.g. access to market and low cost manufacturing.

4 Methodology

This research seeks to make a theoretical contribution and help managers make decisions concerning their site role portfolios. We engage in middle range theory development (Merton 1968) by studying a company consisting of multiple sites with different competences and differing network integration. Middle range theory merges theory with empirical work, which we accomplish by deriving dimensions for a theoretical framework and refining the dimensions based on our case study data. Thus, we follow a grounded theory building approach (Eisenhardt 1989; Eisenhardt and Graebner 2007; Stuart et al. 2002; Voss et al. 2002; Yin 1994) to gain a better understanding of the relationships between the site- and network-level perspective and the characterisation of a site and its contribution to network targets.

4.1 Case Company

Our case describes the manufacturing network of the ELMA Electronic Group. ELMA is a global manufacturer of electronic packaging systems used as black boxes in trains or aircrafts. The company is headquartered in Switzerland. Most of ELMA's products are engineered to customer requirements. Individual constructions and batches with 1–10 pieces are not unusual. The ELMA manufacturing network consists of 12 manufacturing sites spread across the globe. Case selection was conducted in three steps with an adaptation of Miles and Huberman's (1994) sampling suggestions. First, we selected manufacturing companies with at least three manufacturing sites and a willingness to participate in research. Based on information provided by the company, we excluded all companies without a clear manufacturing network strategy in a second step. In the last step of sample selection, we excluded companies without clear knowledge of competences, integration, and location advantages of the sites in the network. We identified five companies that would have been interesting to study and willing to provide the needed information. Due to the effort needed to conduct case studies and to meet the study purpose to develop a framework and test its applicability, we decided to conduct a single case study (Eisenhardt 1989). In this case, we considered the advantages of gaining deep insight into one company more important compared to a broad but superficial data set.

4.2 Data Collection

The purpose of our data collection was to obtain in-depth insight at two different levels, the network and the site level. At the network level, we wanted to gain insight about company network setup, manufacturing network strategy, expectations towards the contribution of each site to the network targets and site coordination. At the site level, we wanted to gain insight regarding the bandwidth and reach of competences, the type of knowledge the sites shared, the recipients of shared knowledge, and the providers of knowledge. Additionally, we wanted to identify location advantages provided by the site. Network-level information was gathered from interviews held with company management from December 2011 to April 2013. During this research period, we conducted 12 interviews with the CEO, the managers of the two major divisions, the chief financial officer, and the regional network managers.

Three operations management researchers conducted the interviews. The duration of each interview was between 2 and 4 h. The interviews were recorded and minutes were written. Researchers compared the notes and overall impressions after each interview. Following Eisenhardt (1989), detailed minutes were compiled within 24 h of each interview, including the interview data, overall impressions, and conclusions. In some cases, follow-up interviews were conducted to clarify responses or obtain additional details. The interview data were supplemented by examining other sources of information, including archival data, industry publications, manuals, and company documents.

Site-level information was gathered by sending a standardised questionnaire to each site, and the respective site manager answered the questionnaire. If questions were unclear or additional explanations were needed, one researcher was available over the phone to answer these open questions. The sites mailed the questionnaires directly to the researchers, who analysed and combined the answers with the results of the network-level interviews.

All results were discussed with the whole group of interviewees from the network-level to verify the site answers and to discuss differences in the network-level expectations and opinions as well as the site-level perspectives.

4.3 Data Analysis

We used Miles and Huberman's (1994) four-step approach for data analysis. The first step was development of a contact summary sheet to record the main themes in each interview. One researcher identified the main themes, while the other two researchers checked these themes with the interview minutes. Second, a complete theme list based on the contact summary sheet was developed. Third, all interviews were coded with selected coding (Strauss and Corbin 1990) to categorise the answers into main themes. One researcher was responsible for coding the interview minutes, while the other two researchers checked the coding. In the event of disagreement, the point was discussed until agreement was reached. If no agreement was reached, the point was referred to the interviewee for clarification. This procedure assured a high level of inter-rater reliability (Voss et al. 2002). The fourth step consisted of writing the case study, followed by a final validity check that presented the results to the interviewees.

5 The Case of ELMA: An Example for a Differentiated Network

The ELMA manufacturing network consists of 12 globally dispersed sites, which are displayed in Fig. 3. Each site in the network has a clear, specific characteristic. This characteristic visualises the site uniqueness in the network and reveals site strengths as well as current and possible future network roles. Notably, ELMA's network is divided into three regions: EMEA, Asia, and the Americas. While EMEA and the Americas are rather mature regions, Asia is in the development stage and is primarily coordinated by the Swiss site (site 1).

A clear pattern emerges in the three regions. Each mature region possesses *lighthouse sites* with rather large competences and embeddedness triangles (site 1, site 6, and site 10 have the highest values for competence as well as embeddedness triangle areas). Moreover, the mature regions stand out as knowledge transmitting sites. In particular, the Swiss site transmits much knowledge to other sites and holds an extraordinary position in the network. The Swiss site supports the new sites in the Asian region as well as newly established Romanian low cost site (site 4). All lighthouse sites in the regarded network provide access to skills and knowledge as well as proximity to markets as main location advantages.

The second group of sites consists of *support sites* (site 4, site 11) that offer low-cost advantages for the network and serve as extended workbenches for the corresponding region. The second group is characterised by a relatively high degree of cooperation and a greater amount of inflowing information and knowledge. Notably, both sites differ in the size of their competences and the embeddedness triangle. This difference may be caused by differences in site maturity stages. While the US site (site 11) is a rather mature network player with much expertise, the Romanian site

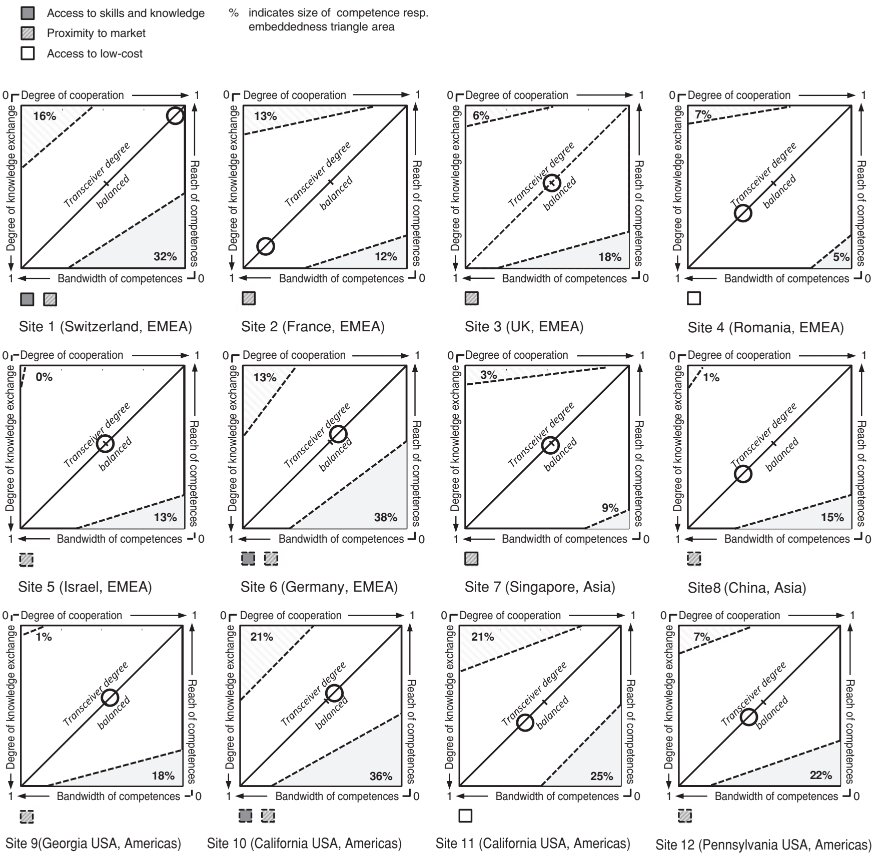

Fig. 3 ELMA network

(site 4), founded several years ago, remains very dependent on the Swiss lighthouse site (site 1). With increasing maturity, the Romanian site is likely to obtain a set of competences and a degree of embeddedness similar to that of the US site.

The third group that can be identified in the sample is the *market producers* (site 2, site 3, site 5, site 8, site 9, and site 12). Its sites are similar in their degrees of location factor proximity to markets and their competence triangle sizes. Three sites (site 2, 3, and 12) possess a medium degree of embeddedness whereas the other three sites (site 5, 8, and 9) are rather isolated in the network. This isolation is primarily caused by site history, state of maturity, legal restrictions due to the product's market requirements, and site product portfolio. The transceiver degree of the isolated market producers tends to be balanced. The Chinese site (site 8) seems to be an exception, which potentially results from the fact that the Asian sites remain in the development stage and receive knowledge from the Swiss Site.

The remaining site is located in Singapore (site 7). The site primarily acts as a sales and trade partner within the network, but the site will be developed into a full manufacturing site, which is mirrored in the rather small competence triangle. In contrast, the degree of cooperation is rather high because the site is new and dependent on the Swiss site.

6 Discussion and Conclusion

The site classification framework helps global site managers to characterise plants. First, the framework helps to visualise the site's capability and knowledge base and its embeddedness in the manufacturing network. Next, the framework shows from which location advantages the network can benefit from. Furthermore, the framework highlights site contributions to the network. Overall, the framework builds the first step for a company specific site role portfolio.

ELMA's site classification shows that different groups can be identified. We assume that similar groups can be found within each company's site classification framework. This site characterisation reveals measures to coordinate the network. To maximise the benefit from the support sites, a site needs continual monitoring and actions should be taken to improve efficiency, if necessary. Additionally, a lighthouse site is a knowledge provider for the network. Closing such a site could negatively influence the performance of the entire network. The specific competences and knowledge of a lighthouse site cannot be easily transferred to another site. Some sites may not belong to a specific group (e.g. Singapore). Such a site raises the complexity level within a network because this site may need different coordination mechanisms. As in the case of the Singapore site, complexity reduction from a network-level perspective may require investment in the plant to improve competences and/or cooperation and knowledge exchange.

The case study exemplifies that all sites in the network need not fully cover the maximum values. In fact, the appropriate combination of sites with different characteristics leads to an effective and efficient manufacturing network. Hence, the framework helps to decide plant development by competency or knowledge.

To unlock the network's potential, global network managers need to combine site specific advantages and network level targets. The classification framework developed in this paper highlights site capabilities and contributions to the network. Furthermore, the framework helps unlock network potential and considers site connections. Additionally, we demonstrate site importance from a knowledge-based view and present the transceiver degree. Visualisation of site location advantages further highlights potential site improvements.

We add to existing theory because we combine the capability perspective introduced by Ferdows (1997) with the network-level perspective mirrored by site embeddedness and transceiver degree. This combined approach permits site classification and supports managers who aim to unlock the network's potential. In addition, this approach is a first step towards a site role portfolio, which defines the required network site characteristics to optimise network level performance. Combining this framework with network targets (access to markets or thriftiness) helps global managers define site role portfolios. A comparison of an optimised site role portfolio with the actual situation allows measure identification. Based on a company's contingency factors, however, optimal site role portfolios differ.

We further add to theory by providing an operationalization which allows comparing the level of competences as well as the degree of embeddedness of sites belonging to **one** manufacturing network.

We labelled identical groups to illustrate the site characteristics found in the case study. However, groups may differ by site specific characteristics and network goal. From our perspective, the defined names for the roles are not as important as the clear definitions of site contributions to the network and its further development path.

From a practitioner view, the classification framework is a visualisation tool that allows continual revision and improvement of the site competences and contribution to the network. The framework helps clarify a site's network position and explains the measures needed from a network perspective. Further research should combine network targets with the classification framework to derive an optimised site role portfolio. A survey would allow the investigation of patterns within the classification framework and among the network targets.

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Exploring Operations of Manufacturing Plant Types in International Context

Krisztina Demeter and Levente Szász

Abstract Internationalized operations are widespread for plants from all over the world. Plants can build their own competitive advantages, but can also rely on location based comparative advantages, such as markets, low cost production opportunities or access to skills and knowledge. International business and strategic management literature offers several studies that focus on the internationalization of manufacturing plants and networks, but they rarely explore operations performed by these plants, may they be single plants of a company or plants within an international manufacturing network (IMN). Operations management literature, on the other hand, has recently started to discover this field. This paper follows this stream by using an international database to analyze plant operations in an international context. Based on the internationalization level of operations (sourcing, manufacturing, sales) we first identify plant types. We provide a deeper insight into the role of these plants by exploring the comparative (country level) and competitive (business unit level) advantages they realize. Lastly, variables of internal (manufacturing) and external (supply chain) operations are also included in our analysis to discover the characteristics of plant operations and to identify differences between various plant types.

Keywords Operations management · Supply chain management · Competitive advantage · Comparative advantage · Location

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1 Introduction

Location of manufacturing plants is an important factor. Although lately globalization is discussed as an overwhelming phenomenon taking place everywhere in the world (Abele et al. 2008), others argue that its level is still very far from stating that we live in a global world. According to Ghemawat (2011) one of the reasons we feel a very high level of globalization is that we do not really measure it. In this paper we use empirical data to support our arguments related to the globalization of manufacturing companies.

Globalization is a complex issue which is difficult to grasp and explain. As soon as we try to simplify it we can lose some key points that might play an important role in globalization processes. Nevertheless, we have to be able to identify and explore the complex reasons behind international company movements in order to understand what is happening in our world.

Although international business and strategic management literature offers quite a few papers about the motives of internationalization, or the modes of becoming international (e.g. Fahy 2002; Malhotra et al. 2003; Hitt et al. 2006), there is much less written about the operations behind (Ferdows 1997). Researchers generally handle plant operations as black boxes within companies (Sirmon et al. 2007). However, operational practices within plants, the depth and width of links they build with their partners should depend on the role they play in the international context. Our paper aims to investigate these operations.

Accepting Ghemawat's (2011) approach we start from the point that the majority of companies organize their operations starting from their domestic possibilities. Many of them have some foreign, usually cross border, short distance links at either input or output side, but very few of them can be considered real global players. Therefore, we first look at the level of domestic operations (sourcing, manufacturing, sales) of a plant, and create typical groups of plants to investigate (a) to what extent host country competitiveness characteristics influence where plants are located, (b) the location advantages they perceive to realize, (c) the typical competitive priorities they select, (d) the internal (operations) and (e) external (supply chain related) practices and improvement efforts they make to keep and develop their competitive stance. Points (a) to (c) help to identify the international position and role of the given plant, while points (d) and (e) aim to investigate the internal and external operations behind. The theoretical framework is illustrated in Fig. 1.

Our research is exploratory. Since the number of globalization related empirical papers in operations management literature is limited, we argue that there are still many areas where we need a better understanding, especially concerning plant operations in international context.

In our paper we first go through the literature and specify our research questions. Then we introduce the empirical basis for the analysis. After generating different categories of plants, we offer a detailed characterization of them. We discuss our findings along the research questions and draw conclusions.

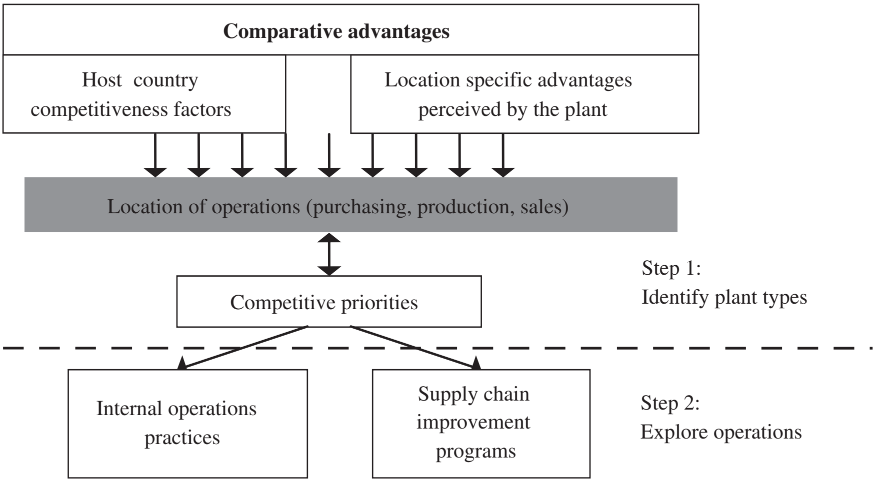

Fig. 1 The theoretical framework

2 Literature Review

There is a lot of literature on why and how companies internationalize (Johansson and Vahlne 1977; Dunning 1980; Bartlett and Ghoshal 1989; Ferdows 1997; Abele et al. 2008). According to Dunning's eclectic theory (Dunning 1980), location is one of the key factors to go abroad. Countries can have comparative advantages, due to resource cost or industry structures, like industrial clusters (Nassimbeni 2003), material availability, labour skills and culture, just to mention some aspects, which make some countries more attractive than others. Relying on a comparative advantage means that by locating a plant in a certain environment it can reach a better performance than by doing exactly the same in another country. DuBois et al. (1993) considers (a) political-legal; (b) educational; (c) socio-cultural; and (d) economic variables, as the major aspects affecting location decisions. We have to add, however, that these potential advantages can be different for various companies, so perceived location advantages are at least as important, if not more important than objective variables. Moreover, these advantages can change over time, due to country and company developments (Vereecke and Van Dierdonck 2002).

Companies, however, can also have specific competitive advantages. That means they are able to organize their internal and external processes in certain areas better than their competitors. Companies are capable to develop their specific internal culture which is unique of that company and used all over the world. Toyota is a good example of that (Dyer and Nobeoka 2000; Liker 2004).

The main drivers for companies to establish plants abroad are to get access to low cost factors, to important markets or to skills and knowledge (Ferdows 1997; Vereecke and Van Dierdonck 2002). These are possible and very different comparative advantages that can be utilized by multinational companies. Furthermore, they can rationalize their manufacturing network configuration by combining comparative advantages. For example, cross boarder activities are very frequent between developed and less developed countries, like the USA and Mexico, Western and Eastern Europe, or Singapore and Vietnam (Reiner et al. 2008; Szász and Demeter 2011). Companies make labour intensive operations in countries with low wages, and locate knowledge intensive activities in countries with large intellectual capital.

These phenomena envision fragmented, puzzle-like processes in order to maximize value, where the members of IMN play different roles, taking into account both territorial (locational) and manufacturing network embeddedness (Coe et al. 2008). Bartlett and Ghoshal (1989) were one of the first to identify drivers and types of subsidiaries. They used the dimensions of (a) the importance of local market (LM) and (b) local resources and capabilities (LRC) as the most important drivers for establishing subsidiaries abroad, and identified four subsidiary types along these two dimensions (2 × 2 matrix): black hole (LM is outstanding, LRC not important), implementer (none of LM and LRC are important), contributor (LM not important, LRC essential) and strategic leader (both LM and LRC are essential). This classification identifies each subsidiary type based on the characteristics of location, indicating the importance of market size, and the kind and level of human and technological resources. However, the paper does not shed light on what kind of operations these subsidiaries generally perform.

Shi and Gregory (1998) used four manufacturing networks as case studies to identify the types and capabilities of these networks. They found two basic orientations: multidomestic and global. The former refers to plants focusing on local needs and having autonomy. Thus coordination among units is weak. Global orientation assumes high level of integration and coordination among plants. Both basic types have four levels from domestic through regional and multinational to worldwide, so location, again, is an important aspect of categorization. Market size, along the local needs, plays also a major role. The paper also offers further insight into coordination and integration issues among plants. It is still not clear, however, what kind of operations lay behind various types of manufacturing plants.

Roth (1992) investigated 126 medium-sized firms competing in nine global industries. Using cluster analysis he identified five distinct archetypes based on the value creating activities (procurement, manufacturing, marketing, sales, product and process design and improvement, finance, accounting, HR) they cover. He called them concentrated hub, local innovator, transnational innovator, regional federation and primary global. Altogether he analyzed the level of centralization and the level of coordination (global, regional, national) among manufacturing network members. This categorization also shows that the level of innovation in different countries impacts the type of value creating activities located there (see, e.g., the types of local innovator or transnational innovator). Similarly to previous categorizations, this approach places the whole network in the centre of the analysis; activities of the individual plants are not studied beyond the value elements they add to the network.

Ferdows (1997) developed a different typology going more deeply into value creating activities within plants and used the perspective of plants instead of the whole network. He identified three strategic reasons for choosing a specific site: (a) access to low-cost production, (b) access to skills and knowledge, and (c) proximity to market. These are quite similar to the reasons identified by Bartlett and Ghoshal (1989), but they also bring low cost labour and material into the picture. Ferdows determined the level of site competence as well. Along the strategic reasons and site competence plants can position themselves into six different roles (outpost, offshore, server, source, contributor, leader). As Ferdows argues, sites can improve their competences, especially by building up knowledge not only in the field of production, but also in purchasing, distribution, customer relationships, and innovation, thereby developing themselves toward "higher" roles. Competence development and roles depend on managerial aspirations as well as on country level factors. Although Ferdows' original article contains only examples, several papers operationalized his work through case studies (Vereecke and Van Dierdonck 2002; Miltenburg 2009; Cheng 2011; Cheng et al. 2011) and surveys (Feldmann et al. 2009; Turkulainen and Blomqvist 2011), and they basically found the framework to be valid.

DuBois et al. (1993) relied on a 16 firms, four-industry analysis to identify the major internal and external factors that may influence international manufacturing configuration decisions. They found that industry structure and characteristics have an important impact on manufacturing strategy, the relationship being moderated by firm-specific characteristics, such as competitive priorities and international experience. Lastly, they also showed that manufacturing strategy affects manufacturing configuration. They identified four basic strategy-configuration pairs: (1) home focus: home manufacturing with limited or extensive export, (2) regional focus: plants to serve foreign markets in a region, (3) regional/global focus: local or regional assembling of globally procured materials or (4) global focus: dispersed production in low cost markets and assembling in different locations. This manufacturing strategy—manufacturing configuration relationship is moderated by environmental variables (political, economic, etc.). Their analysis also provides insight into the characteristics of production processes performed by the business units within these networks.

To summarize the literature presented above the following statements can be outlined:

- Location specific advantages and firms' competitive strategies both affect the international network configuration of manufacturing plants. Thus these factors have to be taken into account when researching plants in an international context.
- In each categorization domestic/national level comes up as an important level of manufacturing configuration; therefore, starting our analysis from a domestic perspective is a meaningful approach.
- The empirical literature on operations' characteristics within manufacturing networks is limited, and they usually use only examples or case studies to support their arguments.

Previous categorizations used the drivers of establishing foreign plants as starting point. They identified these drivers at the level of the parent company (Bartlett and Ghoshal 1989), the manufacturing network (Shi and Gregory 1998; Roth 1992; DuBois et al. 1993), or a single plant (Ferdows 1997), and subsequently investigated resulting plant roles/network configurations. In this paper we adopt a reverse approach: we start from the result of internationalization processes, by looking first at the extent a plant's operations have remained domestic. More precisely, the categorization of plants is based on the extent they are domestic in pursuing sourcing, manufacturing and sales operations, starting from the idea that each company tries first to solve its problems related to its home market and makes its first steps toward internationalization from having well established domestic operations. We approach internationalization processes from the plant level, as our unit of analysis is the plant within a manufacturing network, irrespectively of whether the members of the network belong to the same company or not. Since it is always difficult to empirically measure the real drivers of establishing and operating plants, especially as they change over time (Vereecke and Van Dierdonck 2002), we first look at the realized strategies of plants (instead of intended strategies/drivers), and then aim to trace back the motivations behind typical plant types in international context. Then the key objective of our analysis is to explore current operations structures and improvement focuses behind these plant types.

More specifically, based on the domestic embeddedness of plants and the proposed research framework (Fig. 1), we formulate two basic research questions:

1. What are the typical plant types based on the internationalization level of their operations (sourcing, manufacturing, sales), and what comparative (country level) and competitive (business unit level) advantages do they realize? (see Fig. 1, step 1)
2. How are internal (manufacturing) and external (supply chain) operations organized in different plant types? (see Fig. 1, step 2)

3 Empirical Background

To assess economic context, we use data from The Global Competitiveness Report 2010–2011 published by the World Economic Forum (http://www.weforum.org/issues/global-competitiveness). The 2010–2011 report computes the value of the Global Competitiveness Index (GCI) for 139 economies throughout the world, and is the most comprehensive study in the field of measuring country level competitiveness (Schwab 2010). The reason for using the 2010–2011 report is that it refers to the same timeframe in which empirical data has been collected for this study. Data regarding factors/pillars of country competitiveness is also included in the report, since the GCI is computed as the weighted average of 12 different components, each measuring a different aspect of competitiveness on a 1–7 scale (Sala-I-Martin et al. 2010). The majority of the indicators used to compute the

Table 1 Determinants of economic development

Relevant pillars of the GCI	Notation	Meaning/components of pillars
1. Health and primary education	HealthPrEd	Indicators of health and the quantity and quality of basic education
2. Higher education and training	HiEd	Quantity and quality of secondary and tertiary education and on-the-job training
3. Technological readiness	Techn	Availability and absorption of latest technologies and permeation of ICT use
4. Market size	MktSize	Domestic and foreign market size (with emphasis on domestic markets)
5. Business sophistication	BusSoph	Quality of business networks and quality of individual firms' operations and strategies
6. Innovation	Innov	Public and private support for research and development

pillars of the GCI are derived from the World Economic Forum's Executive Opinion Survey, carried out worldwide by a network of partner institutions. The rest of the indicators are collected from various global organizations, e.g. the World Bank, UNESCO, and the International Monetary Fund (Schwab 2010). The relevant GCI pillars, their notation used in this paper, and their meaning are shown in Table 1.

We look for and use industrial data, namely from the fifth round of the International Manufacturing Strategy Survey (IMSS V), to assess plant level operations. The IMSS is carried out by an international network of researchers focusing on the manufacturing strategies, practices and performances of companies from all around the world (www.manufacturingstrategy.net). IMSS V was carried out in 2009 and included responses from 19 different countries. In early 2010 two additional countries joined the survey. The data collection process was administered in each country by local coordinators on the level of individual manufacturing plants. Wherever needed, English language questionnaires were translated into local language by manufacturing strategy academics. Plants were chosen from a base of manufacturing organizations of each country, belonging to the ISIC Rev. 4 Divisions 28–35 (manufacture of fabricated metal products, machinery and equipment). The questionnaire was filled in by Manufacturing/Operations Managers. The unit of analysis was the plant, also including some business unit level data on competitive position. Data were collected from 725 companies. The response rate for the total sample was 18.3 %, varying between 5 % (in the UK) to 39 % (in Germany). An important drawback of the data employed is that individual country samples are not statistically representative. However, the relatively high number and diversity of countries enable us to search for general relationships and tendencies connected to manufacturing plants in international context. Table 2 presents key information about the IMSS V sample. Due to missing data we could use 590 plants in our analysis. ANOVA test did not show any significant difference between the study sample and the original IMSS V sample in respect of size, production process type and industry structure. Therefore, unused responses can be viewed as a random subsample of the complete population (da Silveira 2005).

Table 2 IMSS V subsample composition by country used in this research

No.	Country	No. of plants	Pct. of total (%)	No.	Country	No. of plants	Pct. of total (%)
1.	Belgium	30	5.1	12.	Korea	30	5.1
2.	Brazil	33	5.6	13.	Mexico	17	2.9
3.	Canada	17	2.9	14.	Netherlands	41	6.9
4.	China	51	8.6	15.	Portugal	8	1.4
5.	Denmark	13	2.2	16.	Romania	27	4.6
6.	Estonia	21	3.6	17.	Spain	32	5.4
7.	Germany	29	4.9	18.	Switzerland	30	5.1
8.	Hungary	61	10.3	19.	Taiwan	26	4.4
9.	Ireland	6	1.0	20.	UK	14	2.4
10.	Italy	42	7.1	21.	USA	40	6.8
11.	Japan	22	3.7	Total		590	100.0

Since often even a single plant may perform a variety of very *different* manufacturing activities, all questionnaire items were targeted at the dominant activity of the plant. The questionnaire defined dominant activity as "the most important activity, which is considered to best represent the plant". For example, for a car parts producer "manufacturing car bodies" might be considered dominant activity if car bodies represent the most important product category of the plant, which also account for the largest share in total sales. For all the original IMSS questions used in this study see Appendix 2.

4 Data Analysis

4.1 *A Typology of Plants and Their Comparative and Competitive Advantages (RQ1)*

In order to categorize plants in international context we have taken the following three aspects into consideration: (a) the ratio of domestic sourcing of raw materials, parts/components and subassemblies related to the plant's dominant activity, (b) the ratio of domestic sales of products/services, resulting from the plant's dominant activity, and (c) the ratio of domestic manufacturing, meaning that if the plant belongs to an IMN (i.e. other plants are also involved in the investigated plant's dominant activity), then the ratio of domestic manufacturing will be lower than 100 %. Based on these three ratios we performed hierarchical cluster analysis using Ward's method in SPSS. This method enables us to identify the most adequate number of clusters. We found this solution at 5. Then using k-means cluster analysis with 5 initial solutions we could identify five relatively different operational models. The ratios of domestic sourcing, manufacturing, and sales are described in Fig. 2. Regarding the levels of internationalization it can be clearly seen that even "Domestic players" have some international sourcing and sales.

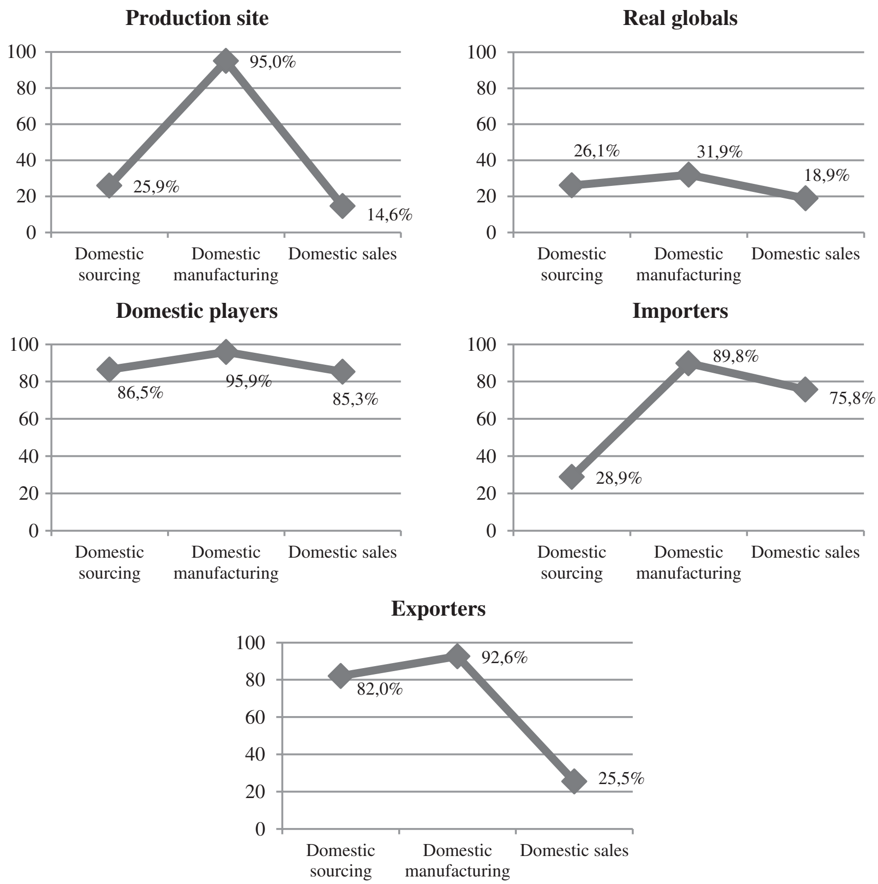

Fig. 2 Domestic purchasing-production-sales ratios in various clusters

On the other hand, there is only one group, "Real globals", that have a very low ratio of domestic manufacturing; they clearly have more than one plant involved in the production of the same products/services. However, the overall research sample contains a considerable number of plants (225 plants out of 590, representing 38.1 % of the sample) that have a domestic manufacturing ratio below 100 %, meaning that these plants are clearly members of an IMN, where multiple plants from different countries are involved in the manufacturing of the same products/services. It has also to be noted that plants with 100 % domestic manufacturing ratio could also be IMN members (e.g. if suppliers of parts or subassemblies are foreign plants of the same company), but the questionnaire did not enable to verify this aspect, which is an important limitation of this study.

In the following the identified clusters are characterized. Detailed results for clusters can be found in *Appendix 1*. ANOVA with Scheffe post hoc test was used to discover significant differences between each pair of clusters. The Scheffe test is the most conservative post hoc test available in SPSS, therefore providing the most reliable results.

4.1.1 Production sites (123 companies)

Production sites can usually be found in less developed countries where innovation and business sophistication is still less present. These are usually smaller countries which do not provide large enough market for investors. Production sites do not possess any specific competitive priorities. Actually, many of the potential priorities are less emphasized than in other clusters. Only price, conformance and flexibility (order size flexibility, wide product range) seem to be relatively important which indicates a less sophisticated manufacturing strategy behind. This strategy is consistent with the fact that this is the only cluster where low cost labour is among the three most important location advantages. These plants do not really integrate into the business environment they operate in. Since inputs for their operations are provided from abroad, probably delivered by the parent company, and they sell their finished products abroad, proximity to business partners, or material costs do not really matter for them. They are just isolated islands within the given countries.

4.1.2 Real globals (69 companies)

Real globals prefer more developed countries. Accordingly, customer service and innovative products are more important competitive priorities than in other clusters. Intuitively, we would expect that the IMN these real global plants belong to have plants in less developed countries, as well. And it might indeed be the case, but those plants show different picture about themselves due to the environment they operate in, but also due to the role they have to play within the IMN. Skills and know-how are extremely important in selecting location for real globals. Material costs are also a relevant factor, probably because in these more developed environments it is more difficult to get access to low cost materials. Due to the complexity and business sophistication of their role these plants prefer a stable social and political environment which provides long term conditions to stay.

4.1.3 Domestic players (202 companies)

They seem to be the opposite of real globals. They rely on the large market size they find in the country they operate in. This group seems to be relatively diverse. First, they emphasize basic priorities, such as conformance and delivery reliability, indicating that generally in these countries there is still room for improvement in these areas (that is why plants can still win orders with them). Second, they also emphasize customer service, which already assumes a higher level of business sophistication. Third, since these plants are embedded in their local environment, both environmental issues and CSR are important priorities for them. Costs, both labour and material, are overwhelmingly important location factors, probably because of the relatively low purchasing power of local customers located in these less competitive countries.

4.1.4 Importers (74 companies)

Plants in this group operate in an environment of relatively high development and innovation level which constantly urges them to search for new solutions, new materials and products abroad. Nevertheless, price is the most important in this group compared to others, which shows that not only the innovativeness of products, processes and materials but their low cost is also relevant.

4.1.5 Exporters (122 companies)

Exporters seem to be sophisticated production plants that emphasize quality in the wider sense: customer service is in the top three of their priority list beside product quality and conformance. They prefer to be close to suppliers (that probably deliver customized products to them). It seems that these plants can operate anywhere, irrespective of country competitiveness factors. Price is the least important factor for them.

4.2 Operations and Supply Chain Characteristics of Different Plant Types (RQ2)

4.2.1 Production sites

These plants are usually more upstream in the supply chain than others. They usually buy raw materials and parts/components and deliver their products to finished products producers or distribution centres. Since they have to respond to the orders placed by other manufacturers downstream, they rarely use a make-to-stock policy. One of a kind is more usual than mass production in this group, which indicates that they might have several different customers with specific requests. These aspects also imply that they should possess a certain level of proficiency to be able to satisfy their customers. Plants in this group do not pay a particular attention to supply chain management improvement. Probably they have the relevant contacts on both supply and demand side, and they do not need to further develop them, it is simply not in their focus.

4.2.2 Real globals

Real globals prefer mass production coupled with assemble-to-order or make-to-stock policies. They buy highly processed part/components or subassemblies from their suppliers, and perform only a narrow scope of activities, as the level of processing does not increase considerably on the supply side. All this provides a vision that these real globals are part of a value based, highly fragmented manufacturing network, where different phases of production take place at the point where the most value can be added. According to the fragmented nature of the network plants in these networks need well developed and fast improving supply chain processes.

4.2.3 Domestic players

They provide subassemblies for manufacturers or sell finished goods directly to their local customers, which is consistent with the higher order size flexibility they aim at. These plants use batch instead of mass production.

4.2.4 Importers

A large portion of their products is sold to finished product manufacturers and distributors. Therefore they do not waste too much effort to find direct pathways to the end users. Accordingly, distribution strategy and coordination with their direct customers, as well as being close to these partners are important for them.

4.2.5 Exporters

They follow an engineer-to-order or batch production policy. They excel in production but not in organizing their supply chains. Accordingly, they mostly sell their products through distributors on foreign markets.

5 Discussion of the Results

5.1 Comparative and Competitive Advantages of Different Plant Types (RQ1)

Country location is indeed an important factor to determine a plant's type (Bartlett and Ghoshal 1989; Ferdows 1997; DuBois et al. 1993). Real globals prefer to stay in more competitive countries, where they can find both market and skills, by taking the role of strategic leaders. According to Bartlett and Ghoshal's typology they become servers; contributors or leaders according to Ferdows's typology; global focused according to DuBois et al. (1993); and globally integrated and coordinated as in Shi and Gregory (1998). Domestic players are usually located in less competitive but large countries, where plants are not forced to internationalize their operations due to the large market that offers plenty of purchasing and sales opportunities. Since these plants do not internationalize, they cannot be categorized in the international configuration typologies accepted in the literature. Small, less developed countries provide location for Production sites. The major reason plants settle in these countries is to utilize the low production costs. Since these plants import inputs for production, material costs in the local market are not important for them. Depending on the level of competence these plants are in the offshore or source positions according to Ferdows' typology; they are contributors in Bartlett and Ghoshal's typology; and they are part of the regional/global focused strategies in DuBois et al. (1993). Irrespective of the differences at country level, perceived location advantages are quite similar. Skills and know-how, as well as transportation and logistics are among the first three most important perceived advantages for each plant type. Proximity to customers is the most important for importers, and the least important for exporters. Importers can be plants that followed their customers in the globalization process: they import their materials and deliver products to the nearby major customer. Exporters, on the other extreme, rely on local resources, embedded in the local environment, utilizing comparative advantages, and deliver to several foreign customers.

Altogether, domestic players and exporters show the signs of being embedded local producers. The other three types are probably plants of IMNs. Production sites are the islands for low-cost production, real globals are value based manufacturers with fragmented but well connected processes, while importers are tied to large customers, probably importing materials and components from their own IMN, e.g. from production sites.

5.2 Internal and External Operations of Different Plant Types (RQ2)

We examined two features to characterize *internal operations* of plants: the production process type used, and the ordering policy followed. According to Hill (1993), the selection of the production process type is a core structural decision in OM, which determines other structural and infrastructural decisions.

Each plant type indicated the batch system as the most frequently used one. There are numerical differences in the one of a kind and mass production ratios: mass production is more often used by real globals and importers, while one of a kind is more usual for exporters, domestic players and production sites, but these differences are not statistically significant. The same holds for ordering policies, where MTO is the most frequently used ordering policy irrespective of the plant type.

Altogether, this paper suggests that operations are not inherently different in various plant types. This result can stem from the fact that manufacturing plants change over time, constantly building new capabilities (Ferdows 1997; Reiner et al. 2008). Plants perform new and new tasks, and receive more and more complex products from their suppliers or the IMN. Consequently, differences between plants can quickly erode, and a less developed unit might become the leader of the network in a short period of time (Cheng 2011). Knowledge sharing also helps the members of an IMN to quickly become professional in production (Dyer and Nobeoka 2000; Vereecke et al. 2006). However, an alternative or complementary explanation for the non-significant results is the vague difference between the definitions of mass production and batch production. It is difficult to exactly determine the point where a production line, capable of producing large variety of products, turns from batch to mass.

On the other hand, however, there are significant differences between plant types in respect of *supply chain* operations. Real globals buy products that are much more processed than at any other plant type. Domestic players are on the other extreme, buying mainly raw materials. On the selling side, however, the differences are not significant. Real globals add only a small value to the inputs procured, either by making the last steps of assembling or by performing a specialized step and sending the product further downstream to other plants. Accordingly, managing the supply chain is a key issue for them in order to eliminate as much waste as possible that might be created during frequent deliveries among plants. Domestic players, on the other hand, add significant value to the product, as one third of their products goes to end users. The level of vertical integration is much larger at domestic players compared to real globals. Exporters have a similar purchasing and sales structure to that of domestic players. None of these two vertically integrated groups invests too much effort in supply chain management programs. While higher levels of vertical integration might be more characteristic for less developed countries (Szász and Demeter 2011), it does probably apply only for plants that are not part of an IMN: productions sites are the clearest exception with only very few downstream operations. Importers are the closest to real globals, but they rather seem to be the suppliers of other large multinational plants. Consequently, they pay a particular attention to develop their supply chains in that direction.

6 Implications

From a theoretical point of view, the main distinctive feature of our study is that, contrary to the majority of papers in the operations management literature, the plant types identified in this study do not depend on the Ferdows (1997) model. Our categorization starts from the actual internationalization level, and then looks at the competitive and comparative advantages, as well as at some key features of internal and external operations. On the basis of this categorization the differences in supply chain management practices are much larger for plant types than the differences in internal operations. Actually, these results do not contradict the Ferdows model, as the differences identified between his plant roles are exactly in the level of the activities of external links (sourcing, distribution, supply chain), and in the level of innovation (Feldman et al. 2009). However, our categorization offers an additional perspective relative to the Ferdows typology, by showing the relationship of some contingency factors, such as the level of country development, or the location advantage, with different plant types. For example, our results show that different plant types exploit different country or location based advantages.

From a practical point of view our results also indicate that for companies operating in less developed, small countries it might be more difficult to join the supply chains of international plants, as these international plants are in many cases production sites, thus being isolated from their local environment. Therefore, economic policy in these countries should be very cautious in supporting and attracting foreign plants to these countries: there is a high chance that they will not be able to reach the expected spin off effect on employment rates and SME growth, if these plants remain isolated. Attracting exporter plant types is a better choice for governments. These plants need close collaboration with their suppliers to serve their customers with unique products. This is a good business opportunity for skilled SMEs to join. Well developed industrial clusters can attract this plant type.

Finally, many domestic players seem to have good capabilities to establish subsidiaries in other less developed countries and governments should support this. The location advantages and country characteristics are similar, and they could utilize the advantage of becoming an international company, especially the aspect of learning. Although internationalization in itself does not bring better financial results, but a good strategy behind is predestination for success (Demeter 2013).

7 Conclusions

In this paper we identified typical plant types in international context based on the ratio of domestic purchasing, manufacturing and sales operations. The main objective was to examine how location affects the internal and external operations of plants. This subject is particularly relevant, because the discussion of plant operations in international context is relatively underdeveloped in the literature. We used an international database to support our arguments.

Five major plant types were identified: (1) production sites, (2) real globals, (3) domestic players, (4) importers, and (5) exporters. While production sites operate as independent islands within less developed countries focusing on price, real globals are fragmented, puzzle-like plants adding only little value to the products, and sending them further to other players in their networks. Importers are probably also part of an IMN, but they deliver products to important local customers. Domestic players and some exporters are local companies. However, in contrast with exporters, domestic players are operating in large domestic markets, and are not (yet) forced to go abroad.

The analysis of plant types shows that the characteristics of internal operations included in our study are not significantly different between various role types. In each type batch production and MTO systems are the dominant features. Supply chain operations, however, show some significant differences. Real globals are the most keen to improve their supply chains due to the fragmented nature of the network they operate in, followed by importers, who place a special emphasis on the customer side. Supply chain operations and improvement receives less focus in the remaining three plant types.

An important limitation of this study is that we could not clearly separate IMN plants from single plants within a company. While the vast majority of the plants involved in this study operate (source, manufacture, sell) to at least some degree in an international context, and *at least* 38.1 % of sample plants are IMN members, based on survey data we were not able to clarify for each particular case whether they were IMN subsidiaries or single plants within companies. This feature could represent an important contingency factor. The next round of the IMSS survey is designed to be able to handle this drawback.

Appendix 1

	Production site (PS)	Real globals (RG)	Domestic player (DP)	Importers (IM)	Exporters (EX)
Country competitiveness factor (7-point scale)					
HealthPrEd	6.24 (DP)	**6.35** (DP)	*6.12* (PS, RG, EX)	6.19	6.26 (DP)
HiEd	5.14 (DP)	**5.30** (DP)	*4.90* (PS, RG, EX, IM)	5.16 (DP)	5.11 (DP)
Techn	4.81 (DP)	**5.05** (DP)	*4.46* (PS, RG, EX, IM)	4.92 (DP)	4.77 (DP)
MktSize	*4.79* (RG, DP, IM, EX)	5.19 (PS, DP)	**5.81** (PS, RG, EX, IM)	5.19 (PS, DP)	5.18 (PS, DP)
BusSoph	*4.68* (RG)	**5.14** (PS, DP)	4.75 (RG)	4.92	4.84
Innov	*4.20* (RG)	**4.64** (PS)	4.34	4.42	4.42
Perceived location advantage (5-point scale)					
Proximity to suppliers	*2.21* (DS, EX)	2.72	2.80 (PS)	2.65	**2.94** (PS)
Labor costs	2.72	2.75	**2.84**	2.59	*2.52*
Material costs	*2.29*	**2.78**	2.70	2.51	2.48
Skills & know-how	3.40 (RG)	**3.97** (PS, DP, EX)	*3.28* (RG)	3.46	3.43 (RG)
Transport & logistics	*3.14*	**3.46**	3.37	3.18	3.21
Proximity to customer	2.51 (DP, IM)	2.88	3.12 (PS, EX)	**3.41** (PS, EX)	*2.33* (DP, IM)
Competitive priorities (5-point scale)					
Price	3.78	3.70	3.84	**4.16** (EX)	*3.64* (IM)
Product quality	*4.06*	**4.32**	4.23	4.27	4.28
Conformance	4.10	4.09	**4.31**	*4.05*	4.16
Reliable delivery	*3.88*	4.10	**4.18**	4.06	3.95
Fast delivery	*3.51* (DP, EX)	3.67	**4.04** (PS)	3.81	3.95 (PS)
Customer service	*3.53* (DP, EX)	3.97	3.94 (PS)	3.81	**3.96** (PS)
Wide product range	3.20	3.28	**3.37**	*3.15*	3.34
New product introd.	*2.79*	3.15	**3.17**	3.14	3.07
Innovativeness	*3.22*	**3.72**	3.51	3.62	3.45
Order size flexibility	3.16	*3.00*	**3.47**	3.41	3.28
Environment	*2.98*	3.17	**3.28**	3.11	3.16
CSR	*2.64* (DP)	3.15	**3.20** (PS)	2.86	2.97
Operations: production process type (one of a kind, batch, mass—% of total)					
One of a kind	28.78	24.12	29.36	*17.04*	**32.10**
Batch production	51.12	*45.30*	45.44	**55.26**	52.61

(continued)

Appendix 1 (continued)

	Production site (PS)	Real globals (RG)	Domestic player (DP)	Importers (IM)	Exporters (EX)
Mass production	20.10	**30.58**	25.21	27.70	*15.30*
Operations: order policy (Engineered-to-order, manufactured-to-order, assembled-to-order, make-to-stock—% of total)					
ETO	13.27	*9.79*	17.55	11.19	**21.47**
MTO	46.29	*35.86*	**49.67**	43.67	41.87
ATO	25.45	**29.54**	*16.60*	18.25	20.43
MTS	*15.00*	24.81	16.18	**26.92**	16.23
Supply chain: purchasing (raw materials, parts/components, subassemblies/systems—% of total)					
Raw materials	51.37	*40.02* (DP)	**55.25** (RG)	51.61	53.86
Parts/components	38.27	**39.53**	*31.50*	35.90	34.29
Subassemblies/systems	*10.36* (RG)	**20.45** (PS, DP, EX)	13.25 (RG)	12.49	11.86 (RG)
Supply chain: selling (to subassembly producers, finished product manufacturers, distributors, end users—% of total)					
Subassembly producer	14.14	**17.42**	16.91	14.81	*13.62*
Finished products m.	**38.32**	30.83	30.16	32.00	*28.17*
Distributors	25.83	27.14	*20.96*	31.26	**32.97**
End users	*21.71*	24.61	**31.97**	21.93	25.24
Supply chain: improvement programs (implementation effort in the last 3 years, 5-point scale)					
Supply strategy	*2.91*	**3.25**	2.99	2.94	2.97
Supplier development	2.95	**3.46** (EX)	3.10	3.06	*2.88* (RG)
Coord. with suppliers	*2.65* (RG)	**3.34** (PS, EX)	2.90	2.85	2.76 (RG)
Distribution strategy	*2.22*	**2.66**	2.58	**2.66**	2.29
Coord. with customers	*2.51*	2.85	2.84	**2.94**	2.62
Environmental impact	*2.27*	**2.69**	2.67	2.56	2.37
Risk management	2.58 (RG)	**3.15** (PS, EX)	2.83	2.89	*2.57* (RG)

Bold—highest value in row, *Italic—lowest value in row,* (PS, RG, DP, IM, EX)—significant difference ($p < 0.05$) between the category in the column, and the ones in parentheses (ANOVA, Scheffe post hoc test)

Appendix 2: Questionnaire Items

Domestic Sourcing, Manufacturing and Selling Ratios

G1. Where do you *source* the raw materials, parts/components, subassemblies/systems and *manufacture* and *sell* the finished products/services resulting from your plant's dominant activity (answers should add up to 100 %):

	Sourcing	Manufacturing[1]	Sales
This country	_______ %	_______ %	_______ %
Within your continent	_______ %	_______ %	_______ %
Outside your continent	_______ %	_______ %	_______ %
Total	100 %	100 %	100 %

[1]In case there are other plants in your company involved in your plant's dominant activity

Location Advantages

B7. What is the importance of the following advantages provided by *the location of the plant*?

	None			High	
Proximity to suppliers	1	2	3	4	5
Availability of low cost labor	1	2	3	4	5
Availability of low cost material and/or energy sources	1	2	3	4	5
Availability of skills and know-how	1	2	3	4	5
Access to transportation & logistic facilities	1	2	3	4	5
Proximity to customers	1	2	3	4	5

Competitive Priorities

A4. Consider the importance of the following attributes to *win orders* from your major customers

	Importance in the last 3 years				
	Not important			Very important	
Lower *selling prices*	1	2	3	4	5
Superior *product design and quality*	1	2	3	4	5
Superior *conformance to customer specifications*	1	2	3	4	5
More *dependable deliveries*	1	2	3	4	5
Faster deliveries	1	2	3	4	5

	Importance in the last 3 years				
	Not important			Very important	
Superior *customer service* (after-sales and/or technical support)	1	2	3	4	5
Wider *product range*	1	2	3	4	5
Offer *new products more frequently*	1	2	3	4	5
Offer *products that are more innovative*	1	2	3	4	5
Greater *order size flexibility*	1	2	3	4	5
Environmentally sound products and processes	1	2	3	4	5
Committed *social responsibility*	1	2	3	4	5

Operations—Production Process Type and Order Policy

B8. To what extent do you use the following *process types* (% of volume)? (percentages should add up to 100 %):

One of a kind production	Batch production	Mass production	**Total**
___________ %	___________ %	___________ %	**100 %**

B9. What proportion of your *customer orders* are (percentages should add up to 100 %):

Designed/engineered to order	Manufactured to order	Assembled to order	Produced to stock	**Total**
___________ %	___________ %	___________ %	___________ %	**100 %**

Supply Chain—Purchasing and Selling

SC1. What is the percentage of spending on the following categories of goods purchased (your answers should add up to 100 %)?

Raw materials	Parts/components	Subassemblies/systems	**Total**
__________ %	__________ %	__________ %	**100 %**

SC4. Indicate the percentage of sales in the following categories of *customers* (your answers should add up to 100 %):

Manufacturers of subassemblies	Manufacturers of finished products	Wholesalers/ distributors	End users	**Total**
__________ %	__________ %	__________ %	__________ %	**100 %**

Supply Chain—Improvement Programs

SC9. Indicate the effort put into implementing the following action programs in the last 3 years

	Effort in the last 3 years				
	None			High	
Rethinking and restructuring *supply strategy* and the organization and management of supplier portfolio through e.g. tiered networks, bundled outsourcing, and supply base reduction	1	2	3	4	5
Implementing *supplier development and vendor rating* programs	1	2	3	4	5
Increasing the level of *coordination* of planning decisions and flow of goods *with suppliers* including dedicated investments (e.g. information systems, dedicated capacity/tools/equipment, dedicated workforce)	1	2	3	4	5
Rethinking and restructuring *distribution strategy* in order to change the level of intermediation (e.g. using direct selling, demand aggregators, multi-echelon chains)	1	2	3	4	5
Increasing the level of *coordination* of planning decisions and flow of goods *with customers* including dedicated investments (e.g. information systems, dedicated capacity/tools/equipment, dedicated workforce)	1	2	3	4	5
Improving the *environmental impact* generated by transportation of materials/products and outsourcing of process steps	1	2	3	4	5
Implementing *supply chain risk management* practices including early warning system, effective contingency programs for possible supply chain disruptions	1	2	3	4	5

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A Cumulative Model of Evolving Plant Roles: Building Production, Supply Chain and Development Competences

Andreas Feldmann and Jan Olhager

Abstract We present and test a model of the accumulation of plant competences. Fundamentally, the cumulative model consists of three building blocks: production competences, supply chain competences, and development competences, which are added successively. First, the basic production competence bundle comprises manufacturing, technical maintenance, and process development. Second, supply chain competences can be added, which include logistics, procurement, and supplier development. Finally, development competences are added (if needed, from the manufacturing network perspective), consisting of product development, new product technologies and new process technologies. We test this model using structural equations modeling based on data from 109 Swedish plants. The results support the cumulative model. We also test the impact on performance, and find that higher degrees of plant competences have positive impacts on some operational performance measures.

Keywords Cumulative competences · Plant roles · Structural equations modeling

1 Introduction

When manufacturing and selling products globally, companies face more complexity than what they did when only acting on the home market. There are also opportunities to be gained if the network can be managed in a way that supports the overall corporate and manufacturing strategies. In the beginning of

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international manufacturing, there was generally a too narrow view of foreign plants. There was a tendency to view the foreign plants as simply sources of low cost production or a way to access closed markets. In response to this, a model for the strategic roles of plants in a manufacturing network was developed by Ferdows (1989, 1997). One key aspect of determining the strategic role of each plant in the network is the competence that the plant possesses. In this paper we refer to competences as they are defined in the literature on plant roles (Ferdows 1989, 1997), where competences relate to the extent to which certain technical activities or functions are performed at a plant. As opposed to the theory on core competences (see e.g. Prahalad and Hamel 1990) and manufacturing capabilities (see e.g. Stalk et al. 1992; Shi and Gregory 1998; Teece et al. 1997) this does not necessarily imply that the related activities are performed well. According to the plant role model, plants can change their role both by changing the strategic reason for location and changing the level of plant competence. The former is generally regarded as being a large shift in the plant strategy while the latter is a natural evolution of maturing plants. However, there is still need for research in how plant competences should be built and this paper addresses that gap.

2 Related Literature

Ferdows (1989, 1997) introduced the notion of plant roles within a manufacturing network. Even though such a network does not necessarily have to be global, the examples used in Ferdows (1997) are all taken from the international arena. The role of a factory has two dimensions according to Ferdows. On the one hand there is the strategic reason for the location of the plant and on the other hand there is the competence level at the plant. Ferdows defined location advantage as "the strategic reason for establishing and exploiting the plant". He identified three classes: access to low-cost production, access to skills and knowledge, and proximity to market. Plant competence refers to the scope of the current activities at the plant. Ferdows (1997) discussed ten different plant competences (see Table 1), ranging from "assume responsibility for production" (at the low site competence end) to "become global hub for product or process knowledge" (as the highest individual site competence). Together, the ten plant competences are positioned along a continuum from "low competence" to "high competence". He described a natural evolution of plants in the direction of increasing plant competence. Using the two dimensions (strategic reason for plant location and plant competence) in a matrix, six factory roles were identified, labeled "offshore", "outpost", "server", "source", "lead", and "contributor"; see Fig. 1. A "lead" factory is considered to be the ultimate role; being the global hub for product or process knowledge. Ferdows acknowledged that some factories may combine two or more roles. For instance, a factory may be a server for a specific region and an offshore plant for the production of certain components (Ferdows 1997, p. 77). He suggested that this simple framework is helpful in articulating the strategic contributions of most factories.

Table 1 Types of competence areas at a plant, with reference to related literature (based on Feldmann and Olhager 2013)

Types of competence areas at a plant	Ferdows (1989, 1997)	Vereecke and Van Dierdonck (2002)	Fusco and Spring (2003)	Meijboom and Voordijk (2003)	Meijboom and Vos (2004)	Maritan et al. (2004)	Vereecke et al. (2006)	Feldmann and Olhager (2013)
Become global hub for product or process knowledge	X	X	–	–	–	–	–	X
Supply global markets	X	–	–	–	–	–	–	X
Assume responsibility for product development	X	X	X	X	X	X	X	X
Make product-improvement recommendations	X	X	–	X	X	X	X	X
Assume responsibility for process development	X	X	–	X	X	X	X	X
Assume responsibility for the development of suppliers	X	–	–	–	–	–	–	X

(continued)

Table 1 (continued)

Types of competence areas at a plant	Ferdows (1989, 1997)	Vereecke and Van Dierdonck (2002)	Fusco and Spring (2003)	Meijboom and Voordijk (2003)	Meijboom and Vos (2004)	Maritan et al. (2004)	Vereecke et al. (2006)	Feldmann and Olhager (2013)
Make process-improvement recommendations	X	X	–	X	X	X	X	X
Assume responsibility for procurement and local logistics	X	–	–	X	X	–	X	X
Maintain technical processes	X	X	–	–	–	–	–	X
Assume responsibility for production	X	X	–	X	X	–	–	X

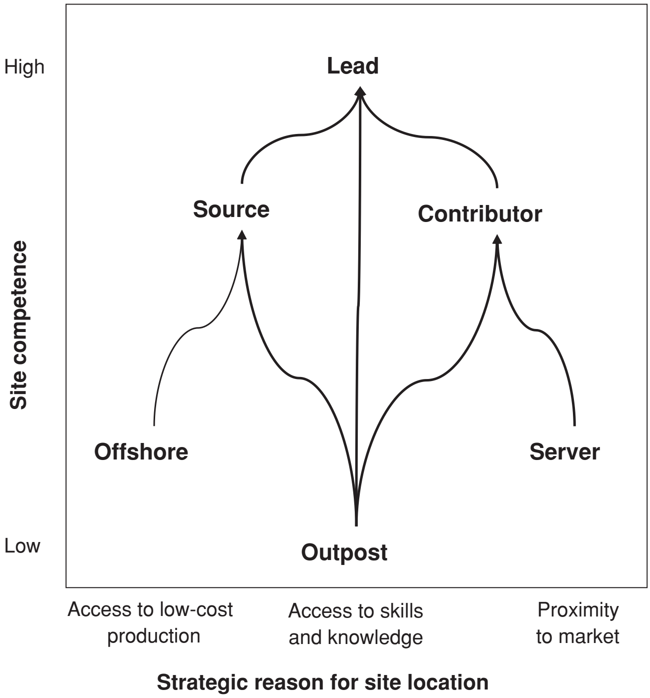

Fig. 1 Plant roles and expected paths of plant development (Ferdows 1997)

Ferdows (1997) discussed ten areas that build up the total plant competence. It is assumed that these can be added successively (from bottom to top of Fig. 1 and Table 1), to develop the strategic role of the plant. Previous research has used different subsets of these, as seen in Table 1. Meijboom and Vos (2004) included production planning and production scheduling, while Vereecke et al. (2006) included choice of technology, decision to introduce a new planning and control system, and choice of standards, goals, and performance measures for quality management. The competences suggested by Vereecke et al. (2006) are more related to strategic autonomy than activities performed at a plant, which is how Ferdows defined competences. All researchers indicate a need for further research to enhance the understanding of plant competences.

Feldmann and Olhager (2013) made an exploratory study to investigate patterns in plant competences, based survey data from Swedish plants. This lead to a grouping of Ferdows' original 10 plant competences into three bundles with production, supply chain and development competences. In contrast to the classification made by Fusco and Spring (2003), they show that all competences can be present at a plant irrespective of the strategic reason for location. This means that development competences are not necessarily an indicator of a lead plant. They further see that there are three types of plants in their sample, which are illustrated in Fig. 2. The first group has fundamentally only production responsibilities. The second group has both production and supply chain responsibilities but little or no development responsibilities. The final group of plants has all three types of responsibilities.

Feldmann and Olhager (2013) suggested that there can be a cumulative sequence of the three bundles, i.e. first production, then supply chain, and finally development responsibilities. In a longitudinal case study, Feldmann et al. (2013) showed that competences are accumulated over time in a new factory and how this relates to the manufacturing network. Feldmann and Olhager (2013) found that plants with all three types of plant competences outperformed plants with only production in terms of cost efficiency, quality, and the rate of new product introductions. The group of plant types with both production and supply chain responsibilities was also found to outperform the plants with only production in the rate of new product introductions.

3 Research Design and Methodology

The aim of this research is to test the cumulative theory with respect to plant competences. Most research on plant roles either assume or suggest the possibility of cumulative plant competences. With reference to the bundling structure of plant competences (cf. Fig. 2) identified by Feldmann and Olhager (2013), we formulate hypothesis 1. Plants are expected have a base of production competences before they take on responsibility over the supply chain and similarly they are hypothesized to have a strong base of supply chain and production competences before development competences are added.

H1: Plant competences are added cumulatively in bundles, in the sequence of production, supply chain and development.

The second part of the analysis is to investigate the impact this model has on operational performance. Therefore, hypothesis 2 is formulated.

H2: Competences added cumulatively lead to better operational performance.

Compared to Feldmann and Olhager (2013), which is an exploratory study based on the same data set, we here explicitly address the issue of accumulation of plant competences by testing the cumulative model suggested by Feldmann and Olhager (2013) using structural equations modeling (SEM). The survey questions related to plant competence are perceptual with a Likert scale ranging from "no local authority" (=1) to "full local authority" (=7). This study included nine measures of operational performance; cf. Table 2. Operational performance was measured using a Likert scale ranging from "much worse than competitors" (=1) to "much better than competitors" (=7).

Although perceptual measures are subjective, these kinds of measures are frequent in the literature, often due to the difficulties in collecting comparable and objective data about the performance. Past studies have demonstrated that perceptual measures are useful for empirical research that relate to managerial evaluations. Response rates can be improved since the respondents can more easily give estimations and are not forced to communicate any sensitive performance information. Also, the use of perceptual measures facilitated comparisons of measures due

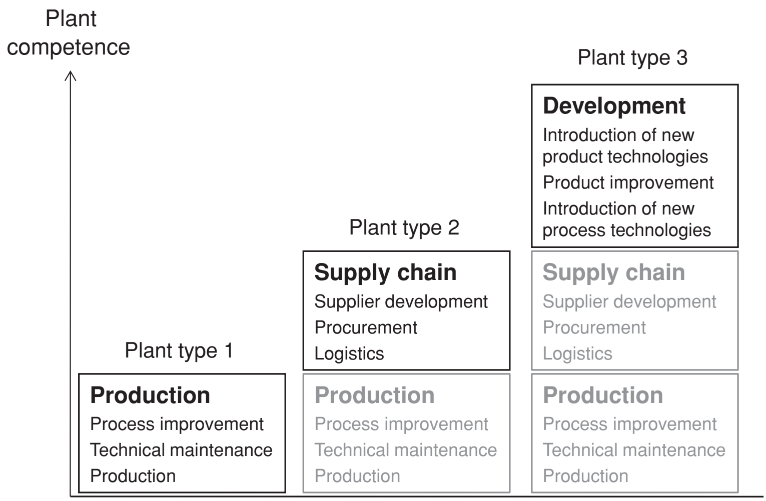

Fig. 2 The three plant types, with different types and levels of plant competence, according to themes (Feldmann and Olhager 2013)

Table 2 Indicators of operational performance

Operational performance indicators
Cost efficiency
Quality
On-time deliveries
Delivery speed
Volume flexibility
Design flexibility
Product mix flexibility
After-sales services
Rate of new product introductions

to the common range of values for each, and do not suffer from missing values to the same extent as objective measures (Flynn and Flynn 2004).

In order to test Hypothesis 1, Model 1 (see Fig. 3) was built in AMOS 19. Each of the three constructs (Production, Supply Chain and Development) is composed of three items each. The model tests whether production competences is an antecedent to supply chain competences, which in turn is an antecedent to development competences.

The mediating effect of supply chain competences was further explored by adding a direct link between Production and Development (see Model 2 in Fig. 4) and then comparing the two models. If supply chain competences have a full mediating effect on development competences it means that development competences are not added unless there are supply chain competences, indicating that Model 1 is a good description of the sample. The added link between Production and Development is expected to be non-significant if Supply Chain has a full mediating effect.

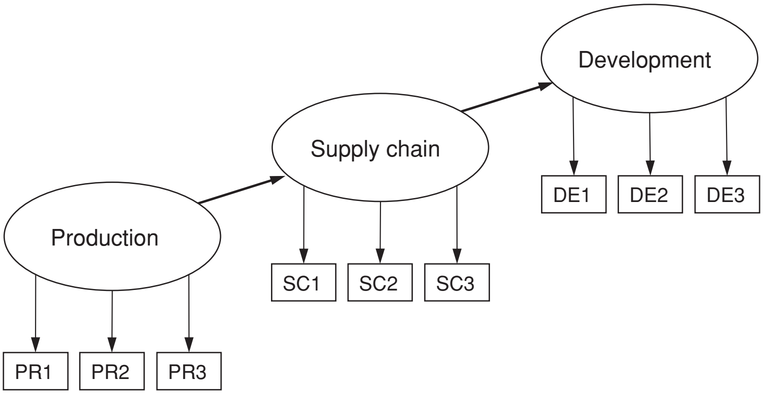

Fig. 3 Model 1: model of cumulative plant competences

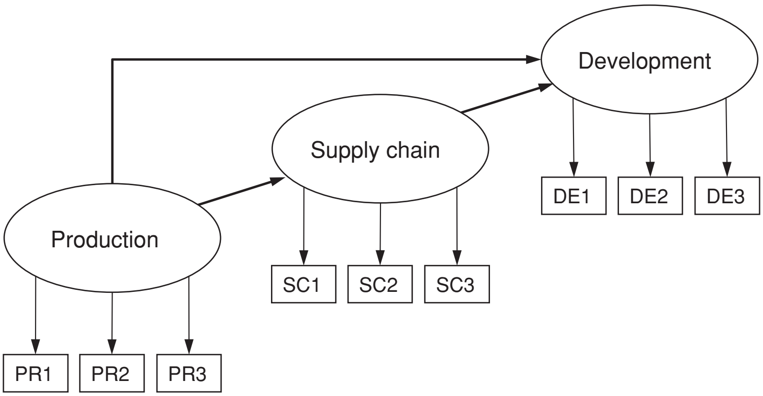

Fig. 4 Model 2: model with both direct and indirect links between production and development

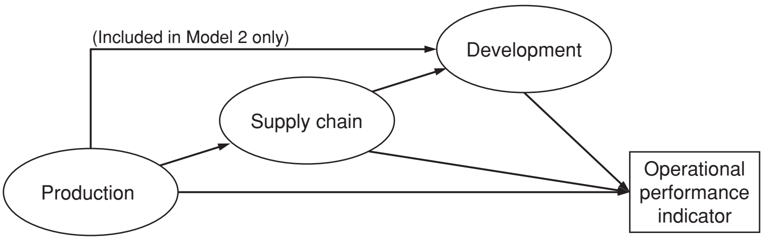

Fig. 5 Models that links competences to operational performance indicators

The second part of this paper focuses on the connection to operational performance that was reported by Feldmann and Olhager (2013). In order to test Hypothesis 2, indicators of operational performance were added to models 1 and 2 one at a time. The general corresponding structural equations model is shown in Fig. 5. These models allow us to differentiate between which competences have an impact on which performance indicators.

4 Survey and Sample

The study is based on a mail questionnaire survey. The questionnaire was designed and processed with respect to the guidelines and recommendations presented in Dillman (2000) and Forza (2002). The questionnaire was sent to members of PLAN (the Swedish Society for Supply Chain Management) affiliated with a manufacturing company. We complemented this sample with addresses from the Swedish Bureau of Statistics in order to reach all other manufacturing plants with more than 200 employees. In other words, managers at all Swedish manufacturing plants with more than 200 employees were contacted, with an addition of smaller firms with PLAN members. All in all, 563 Swedish manufacturing firms were contacted. After two reminders we received 109 responses, i.e. a response rate of 19.4 %. Six of these had missing data points on plant competence or location, wherefore this research is based on 103 responses. The survey is carried out at the plant level, providing the plant perspective of the manufacturing network. The unit of analysis in this study is the main product line at the manufacturing plant, and its corresponding network.

The data were checked for bias using correlations between early and late respondents based on company characteristics, e.g. number of employees and turnover. Neither tests indicated any significant difference between the two groups of respondents. We also tested all questionnaire items for size effects and found no effect for the factors that were retained in the study.

The respondents were all upper level managers related to production or logistics, and thus expectedly knowledgeable about the survey questions. The largest group of respondents was logistics/supply chain managers followed by production managers, operations development managers, plant managers, and presidents or vice presidents. The sample included smaller, medium-sized as well as larger manufacturing plants, based on number of employees and sales turnover; see Table 3. All types of customer order decoupling point positions were included in the sample: engineer-to-order, make-to-order, assemble-to-order, make-to-stock, and finally make and distribute to stock. The last position refers to holding finished goods inventory in the distribution system, beyond the plant inventory. Also, all kinds of process choices were represented in the sample: project manufacturing, job shop, flow shop, line, and continuous processing. Thus, a wide range of plants was included in the sample.

5 Results

5.1 Cumulative Nature of Production, Supply Chain, and Development Competences

All analyses were made using AMOS 19.0 within SPSS 19.0. Prior to analysis we verified normality, skewness and kurtosis; none of which showed to be a significant problem. Throughout this section we are simultaneously analyzing

Table 3 Respondent characteristics

Characteristic	Distribution (%)
Number of employees	
–199	32.1
200–499	26.4
500–999	13.8
1,000–	25.7
Sales turnover (M€; 1€ ≈ 1.4$)	
–10	6.1
10–50	34.3
50–100	19.2
100–	40.4
Customer order decoupling point	
Engineer to order	14.8
Make to order	35.2
Assemble to order	23.9
Make to stock	16.1
Make and distribute to stock	10.1
Process choice	
Project manufacturing	4.3
Job shop	22.7
Flow shop	29.2
Line	27.2
Continuous processing	16.5
Respondents position	
Logistics/supply chain manager	32.4
Production manager	32.4
Operations development manager	10.2
Plant manager	5.6
President/vice president	5.6
Other	13.8

and comparing the results for the two models (Model 1 and Model 2) in order to make a full comparison between them. Doing so will give additional insights in the nature of plant competences. Table 4 shows the measurement model of items and constructs. All individual items load significantly on the respective construct. To test the reliability of each construct a Cronbach's alpha is calculated. Since all alphas are above 0.7 the constructs can be regarded as reliable (Hair et al. 2010).

When calculating the estimates for Model 1, we received highly significant path coefficients for the link between Production and Supply Chain, as well as for the link between Supply Chain and Development, indicating a strong relationship between the three constructs; cf. Fig. 6. This result provides a strong support for a cumulative relationship in accordance with Model 1.

Also for Model 2, all links are significant; cf. Fig. 6. The link between Production and Development indicates a direct effect, which implies that Supply Chain does not fully mediate the impact of Production on Development. Thus, the results indicate that Development competences are both directly and indirectly

Table 4 Measurement model of constructs and items

Construct (bundle)	Items	Cronbach's alpha	Loading	Significance
Production	Manufacturing	0.709	0.503	($p < 0.001$)
	Technical maintenance		0.608	($p < 0.001$)
	Process development		0.895	($p < 0.001$)
Supply chain	Procurement	0.870	0.855	($p < 0.001$)
	Logistics		0.759	($p < 0.001$)
	Supplier development		0.888	($p < 0.001$)
Development	Product development	0.817	0.734	($p < 0.001$)
	Introduction of new process technologies		0.885	($p < 0.001$)
	Introduction of new product technologies		0.740	($p < 0.001$)

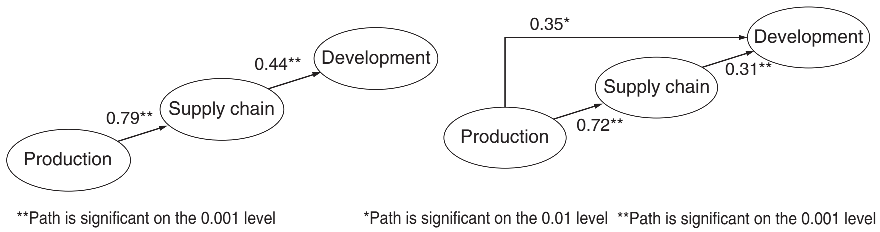

Fig. 6 Results for the two structural equations models

influenced by production competences. Still, Supply Chain partially mediates the impact of Production on Development, indicating that Supply Chain competences are vital for building Development competences.

5.2 Impact on Operational Performance

Nine different measures of operational performance were tested; cf. Table 2. Out of the nine, five proved to have a significant relationship to the plant competence constructs: Cost efficiency, quality, delivery speed, volume flexibility, and the rate of new product introductions, which are included in Table 5. The remaining indicators for operational performance had no significant links to plant competence and are therefore not listed in Table 5, which presents the path coefficients and levels of significance for each combination of construct and performance indicator.

Starting from the bottom of the cumulative model, we first note that production competences per se have no significant impact on any of the operational performance indicators. Second, adding supply chain competences has a significant positive impact on the rate of new product introductions. Third, by adding

Table 5 Effect on operational performance, in terms of level of significance

	Cost efficiency	Quality	Delivery speed	Volume flexibility	Rate of new product introduction
Model 1					
Production	0.229	0.800	0.450	0.522	0.744
Supply chain	0.572	0.845	0.871	0.400	0.054*
Development	0.055*	0.081*	0.108	0.021**	0.548
Model 2					
Production	0.207	0.922	0.382	0.482	0.690
Supply chain	0.592	0.838	0.771	0.297	0.028**
Development	0.057*	0.090*	0.097*	0.026**	0.557

*Link significant on the 0.1 level
**Link significant on the 0.05 level

Table 6 Comparison of model fit

Model	Chi^2	df	Chi^2/df	CFI
*Model*1	73.8	25	2.95	0.889
→ Cost	76.8	31	2.48	0.895
→ Quality	75.6	31	2.44	0.898
→ Delivery speed	77.8	31	2.51	0.893
→ Volume flexibility	82.0	31	2.65	0.885
→ Rate of NPI	77.1	31	2.49	0.896
Model 2	65.9	24	2.75	0.905
→ Cost	74.0	30	2.47	0.901
→ Quality	67.5	30	2.25	0.914
→ Delivery speed	69.7	30	2.32	0.909
→ Volume flexibility	74.0	30	2.47	0.900
→ Rate of NPI	69.2	30	2.31	0.911

development competences, positive and significant effects are obtained on cost efficiency, quality, and volume flexibility. Furthermore, a significant impact on delivery speed can be noted in Model 2, but not in Model 1. Since the significance of delivery speed changes from non-significant to significant at the 0.10-level between the models, it is highly questionable whether plant competences actually have an impact or not on delivery speed.

The overall fit of the model is determined by a combination of different goodness of fit indicators. The first is the ratio between Chi^2 and the degrees of freedom in the model (df), i.e. Chi^2/df. This ratio should be as low as possible but values under 3 are generally considered acceptable (Hair et al. 2010). We also checked the comparative fit index (CFI), which should be above 0.90. The ratio Chi^2/df and CFI are both acceptable. A comparison between the two models reveals that Model 2, with Production affecting Development both directly and indirectly, has an overall better fit (Table 6). The difference is very slight, but all indicators of good fit point slightly in favor of Model 2. It is a known fact that many indicators of good fit favor complex model (Hair et al. 2010), which could account for the slight increase in model fit for Model 2 compared to Model 1.

6 Discussion

The results provide empirical support for the hypothesis of cumulatively added plant competences (Hypothesis 1). Although there is support for that supply chain responsibilities mediate development competences, there is also a significant direct link between production and development responsibilities. This means that both Production and Supply Chain are predecessors of Development responsibilities. The increased measures of fit for Model 2 indicate that it is a better description of the sample. On the other hand the difference in fit is not particularly large, given that there is an additional connection to explain the variance. When comparing the loadings for the links from Production to Supply Chain and Development, the link to Supply Chain is the dominant one. This would indicate that the dominant path is Production → Supply Chain → Development, thereby supporting Hypothesis 1. Both models show that supply chain competences are built upon production competences as a first step. Then, development competences are built upon both production and supply chain competences. From production there are both direct and indirect relationships via supply chain competences, and from supply chain there is a direct relationship.

The results show that having supply chain competences has a positive effect on the rate of new product introductions. The rationale behind this could be that frequent introductions of new products implies that new supply chains need to be built more or less continuously, which is likely easier if the production plant has local supply chain competences. The analyses further support that having development responsibilities leads to better performance in cost efficiency, quality and volume flexibility. Thus, Hypothesis 2 is partially supported by this research.

In terms of managerial implications, these results support the importance of co-location of production and product development, since plants with responsibilities for all areas outperform those with only production competences on quality, cost efficiency, volume flexibility, and rate of new product introductions. By adding new areas of competences, higher levels of performance are attainable. Thus, from the plant perspective it is natural to strive for more competence areas which also give the plant a more strategic role. The logical sequence of building competences at a plant is to start with production competences, then add supply chain competences, and finally add development competences. However, the accumulation of competences is not a plant decision alone. The building of new competences should be matched by new responsibilities within the entire manufacturing network.

7 Limitations and Further Research

Considering the nature of the issues under study, it is reasonable to assume that there might be other factors that are involved in determining the paths of evolution for plant competences. Industry, country/region of the plant and type of coordination within the manufacturing network are examples of contingency factors that may influence how plant competences are built at a plant. The same can be said about the impact on operational performance. Another limitation is that this study is based on data from a single country. Although the majority of the companies that participated in the survey act on a global market, all plants are located in Sweden. Further in-depth case research is needed to understand in more detail how plants build competences.

8 Conclusions

The main findings of this paper are twofold. First, we find empirical support for that plant competences are added sequentially in bundles such that a new plant starts with production competences, followed by supply chain responsibilities, and then by development competences. Second, we find that there is a positive effect on cost efficiency, quality, volume flexibility, and rate of new production introductions from having supply chain and development responsibilities. These findings have clear implications for managers in that there are gains to be achieved by proper consideration of the distribution of competences among the plants in the manufacturing network.

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Exploring the Changing Roles of Western Subsidiaries in China: Balancing Global Priorities with Local Demands

Oluseyi Adeyemi, Dmitrij Slepniov, Brian Vejrum Wæhrens, Harry Boer and Xiaobo Wu

Abstract Over the past 30 years of economic development, the role of subsidiaries in China has changed. China has become an important host country for subsidiaries of western multinational companies seeking cost advantages and/or access to the emerging market potential. The objective of this paper is to explore the effects of the emerging strategic mandate of subsidiaries to serve local demands while meeting global corporate standards and operations priorities. We confirm well established dimensions such as strategic importance and operations capabilities while embeddedness into local business networks and level of process optimization are suggested as other dimensions determining the roles of subsidiaries and consequently their capabilities in an emerging market. These dimensions are established through literature review and validated by case studies of four Chinese subsidiaries of Danish industrial companies.

Keywords Server capabilities · MNC · Subsidiary roles

1 Introduction

The workings of global operations has been a key concern for practice as well as research over the past two decades—the dramatic upsurge of the cost seeking motive for offshore operations experienced were initiated in most western counties in the 90'ties and although survey results still support the cost seeking motive as the key motive for offshoring, it has more recently been followed by an increased

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intention to capture the potentials opening-up in emerging economies such as the Chinese. This trend also indicates a transition from cost to market seeking operations. As China is attracting a growing number of investments from multinational companies (MNCs), which are not only oriented towards utilizing operations cost gaps, it becomes increasingly important to understand the indigenous resources and capabilities of these offshore subsidiaries, effects of subsidiary changing roles and thus to understand the build-up of server capabilities. Therefore, the development of MNC subsidiaries in emerging markets has gained more attention from practice as well as research. To many companies it becomes clear that serving an emerging market is not the same as serving western markets and serving, therefore, requires the build-up of local capabilities to qualify the company for local orders. Hence in broad terms it may be said that while global capabilities may still act as order winning criteria that overcome liabilities of foreignness (Zaheer 1995), local capabilities ensure that the company is considered for the order.

From an operations process perspective capabilities represent a firm's ability to deploy its resources so as to achieve specific results. They are tangible or intangible processes that are firm-specific and are developed over time through complex interactions among the firm's resources (Amit and Schoemaker 1993). Capabilities may also be regarded as complex bundles of resources, skills and collective learning, exercised through organizational processes that ensure superior coordination of functional activities (Day 1994). Capabilities represent the means for acting-out a particular strategic role, and as such they are shaped by the strategic role of a subsidiary, but the two are not necessarily aligned. Capabilities—due to their experience based nature are always likely to lack behind the strategic role of a subsidiary. Understanding the dimensions of subsidiary roles are important in order to ascertain the attributes leading to the transformation and development of the local subsidiaries and its capabilities. In terms of practical implications, this perspective is important because subsidiary role change influences capability development which is recognized as one of the most sensitive business parameters as MNCs engage in different market contexts, where they are likely to be met with liabilities related to their foreignness (Zaheer 1995).

The next section introduces the theoretical background of the study, which concludes with the research question of the study. Followed by a description of the research design, four case studies serve to illustrate the trajectories shaping subsidiary roles and consequently their capabilities. Then the case results are discussed against extant literature and the paper is concluded by a discussion of the limitations of the study and directions for further research.

2 Theoretical Background

A subsidiary i.e. operational unit controlled by the multinational company (MNC) and situated outside the home country (Birkinshaw et al. 1998, p. 224). The term may refer to the totality of an MNC's holdings in a host country or to a single entity (such as a sales operation), and there may be one or many subsidiaries within a host country (Birkinshaw and Hood 1998). Recent work (e.g. Ambos et al. 2006) considers subsidiaries as organizations with the potential to take initiatives, develop value-added activities and implement autonomous decision making. That objects to previously held beliefs in two important ways. First, recent work points to models that question the strong hierarchical relation between an MNC's HQ and its subsidiaries, where all decision making is controlled centrally, and present a rather lateral network where multiple centers of excellence exist for different aspects of an MNC's businesses as stated by Hedlund (1986). Second, and in effect, the role of subsidiaries as passive recipients of HQ's mandates is questioned. As multinationals are confronted with the simultaneous need for global standardization and local adaptation, subsidiaries may differ in their role in an MNC's strategy, the scope of their operations, their set of responsibilities, the importance of the markets they serve, their level of competence and their organizational characteristics (Taggart 1998; Jarillo and Martinez 1990; Bartlett and Ghoshal 1986; White and Poynter 1984) and, thus, the server capabilities required to alleviate the pressure to reduce time-to-market, increase customer service, improve or adapt products to local tastes, and collaborate with customers (Adeyemi et al. 2012).

However, despite many researchers' interest in subsidiary characteristics during the 2000s (e.g. Birkinshaw et al. 2005; Benito et al. 2003), "… *there has been very little research that looks explicitly at the role of foreign owned subsidiaries in a host country*" (Hogenbirk and van Kranenburg 2006) and the determinants of subsidiary roles (Manolopoulos 2010). In addition, subsidiaries in a local market (local subsidiaries) are changing roles autonomously due to the strategic importance of the local environment, leading to the development of activities according to subsidiary's transformed roles. The transformed roles lead to an aftermath such as developing the subsidiary which entails developing the capabilities required to function properly in the subsidiary's new roles. The transformation demands new operational configurations, proper management of existing capabilities and building of new capabilities so as to cater for arising challenges and to achieve desired operations. Taking a broad perspective a server can be regarded as an operational configuration that develop, improve, adapt, produce, distribute, market and sell products in a local market, specific region or host country only. As such, a server subsidiary is a local subsidiary with a server role that is supplying specific national or regional market. It has autonomy to adapt products and production methods suitable for local markets though, it has relatively developed capabilities. And, server capabilities are the abilities to develop, improve, adapt, distribute, market and sell products based on learning, knowledge accumulation and competence development. Server capabilities are relevant so as to penetrate and serve local markets and to ensure that a local subsidiary is specifically fulfilling its role as a server. These server capabilities could help managers to gain acumen in resources allocation to a local subsidiary towards enhancing a subsidiary's server role throughout its international operations networks.

2.1 Subsidiary's Role Typology

Barnevik (1994) and Porter (1990) proposed a set of motivations such as: advantages of competitive positioning and informational advantage, economies of scale and scope and shortening product lifecycle among others, for firms to formulate their global strategies. Thus, the key decision making for a MNC has been centered on how to configure foreign subsidiaries to take advantage of the potential benefits of global operations: namely, gaining access to new markets, acquiring essential supplies, utilizing local skilled and talented labor, gaining access to knowledge spillovers, and taking advantage of multinational market positions. Although the selection of the location of a foreign subsidiary defines its initial role in the MNC's global network, new roles evolution of a subsidiary is influenced by the level of its capabilities (Kim et al. 2011). But, the studies of subsidiary management have focused on what strategic roles should be taken by subsidiaries from the perspective of global network optimization (Meijboom and Vos 1997).

Accordingly, literature also suggests a multitude of ways to classify the strategic roles of subsidiaries: Enright and Subramanian (2007) propose a four-dimensional approach based on characteristics such as: geographical scope, product scope and capabilities; White and Poynter (1984) classify subsidiary roles with dimensions like market scope, the types of product and the range of value-adding activities; Bartlett and Ghoshal (1989) describe subsidiary types using attributes like competence in the subsidiary and the importance to the company's global strategy. Jarillo and Martinez (1990) suggest attributes like the localization of functional activities and the degree of the integrations of the activities to provide a classification of subsidiary roles. Gupta and Govindarajan (1991) characterize subsidiary's roles from the perspective of knowledge flows within the MNC across countries. Ferdows (1997) also contributed to the understanding of MNC's global operations by suggesting a framework of foreign plant (subsidiaries) that are: offshore, source, server, contributor, outpost and lead factories. Furthermore, Ferdows' framework has been tested extensively, its validity has largely been confirmed (e.g. Vereecke and Van Dierdonck 2002, Maritan et al. 2004) and it has gained recognition (Meijboom and Vos 2004; Vereecke et al. 2006; Feldmann and Olhager 2013). But, we propose that the above dimensions are not fixed and could change along the path of subsidiary role transformation (e.g. transformation from an offshore to a server) in a local market. Hence, the relevance of exploring dimensions determining subsidiaries roles and consequent capabilities in a local market.

2.2 The Role Change of Subsidiaries

A subsidiary changes its role through an incremental process of integrating the various activities of the company (Malnight 1995). The different roles that each subsidiary plays could be assigned to it by the MNC HQ or assumed by the subsidiary in an attempt to gain higher degree of autonomy. In a MNC network, some specific units are granted more autonomy, either because they have made their own strong strategic choices (Ghoshal and Nohria 1989) or because they are perceived by a MNC as strategic. More autonomy is demanded by subsidiaries that face a local environment which is complicated and volatile, or in which consumers' demands for localization is strong, so that local managers can bring their crucial local knowledge into play (Ghoshal and Nohria 1989; Gates and Egelhoff 1986). Therefore, the role of a subsidiary, shaped mainly by the factors of integration and local responsiveness, may be a key determinant of its level of autonomy. Hood and Taggart (1999) suggest three major factors in changing a subsidiary's role, that is, the task assigned by HQ, the subsidiary's choices, and local market forces. Strategic role changes demonstrate noticeable patterns of competence building that could later become a key capability.

Westney and Zaheer (2001) maintain that a subsidiary's role is formed through a combination of its own capabilities, the decision-making processes of the MNC and the resources that are available in the local environment. Similarly, Birkinshaw and Hood (2000) in their later work present that the parents and local environment influences the determination of subsidiary roles and the added influence of subsidiary management cannot be neglected. As such, a subsidiary increasingly builds up its position in the local environment by acquiring alternative value-added resources with the help of external network partners (Schmid and Schurig 2003) and that could influence the determination of subsidiary roles as an effort towards subsidiary development.

Following Hogenbirk and van Kranenburg's (2006) observation of the roles of foreign- owned subsidiaries in emerging markets and Manolopoulos (2010) suggestion to further explore the dynamics of these role sets, the research question of this study is: *how does the shift of primary strategic motive from serving global to local demands influence the capabilities and roles of local subsidiaries?* The answer to that question is a step in understanding the development trajectories of subsidiaries working under the diverging formative pressures of HQ and local market influences.

3 Research Design

The present study is of an exploratory nature which is for furthering understanding of particular issues or concepts which have not been deeply investigated so far (Eisenhardt 1989; Voss et al. 2002; Yin 2009). Following Tranfield et al. (2003) recommendations, a review was conducted of relevant operations management, strategy management and international business publications, found using title, keyword and abstract content. This approach was supplemented by a citation review of the key literature. EBSCO, ProQuest and Scopus were searched with Google Scholar used for triangulation purposes. As a result, a range of dimensions as trajectories shaping the roles of subsidiaries and consequently their capabilities in a local market are suggested. In order to validate and, if necessary, extend this set of dimensions, a qualitative approach, i.e. case studies of four Chinese plants of Danish-based industrial companies was adopted. Interviews with key informants, annual reports, press releases, media materials, presentation material to customers and stakeholders, and other company documents were used as data sources. The interviewees were contacted by emails and telephone calls were used to follow-up in scheduling a convenient time and place for interviews. The interviews mostly lasted 2 hours and were complemented by plant tours.

A case study protocol was developed to guide the data collection, validation and analysis. An analysis of the case studies, particularly a confrontation of the cases with existing literature, aided the suggested dimensions determining subsidiaries roles and their capabilities in a local market context and that was validated by peer researchers.

4 Case Description

4.1 Subsidiary A

The company is a subsidiary of a western MNC with expertise in advanced compressor technologies. All its sales were focused on the Asian market, where the company sold a major part of its products and solutions through its sales offices, authorized distribution channels and another big brand group. In 2008 the company decided to move production and product development to China in order to provide better support for the local market, to facilitate production process and to avoid fluctuations in exchange rates. This meant that an entirely new capability would be required in China to fulfill local market demands. Subsidiary A already sold its products for light commercial and mobile applications in China. To serve the Chinese market better and since it is autonomous from HQ operations; the company expanded its business focus by introducing household applications. Based on a new platform, the new series of household products were a significant upgrade to a range that covers the entire field of household appliances.

The manufacturers of household appliances can also save considerable R&D and production resources when optimization was needed by utilizing the efficiency of the products and the production process. Furthermore, the ratio between outsourced units and in-house production of the product have increased from 50/50 in the early 2000 to approximately 80/20 in 2011, requiring an augmented set of skills in the China office from purchasing to supply development. Through outsourcing, subsidiary A penetrate the local networks and exploits inherent benefits.

4.2 Subsidiary B

The company is a subsidiary of one of the world's leading pump manufacturers. It later grew to have sales offices in each region of China to support its customers. Most of the products and solutions sales in China were project related, and some through licensed dealers. The company moved production to China in 1997 in order to be present in a market that represents 25 % of the company's global sales. Establishing operations in China brought with it the need to establish R&D there, too, to support global product development and to develop local products. However, the company's R&D was set up in China by employees without formal training or experience in R&D. Therefore, it took a lot of time to build R&D and production capabilities suitable for local operations.

Entering the local business networks is important so as to focus on the appropriate niche market because the Chinese market for pump manufacturers is strategically divided into three levels. Level A concerns strategic products that are sold to environmental treatment plants, governmental and world financed projects. Level B is where the company competes with local brands under another name which cannot be traced to it. The purpose is to prevent the local competitors from graduating into level A where the company is having a strong competitive edge. Competing on level B also gives subsidiary B the opportunity to develop new product variants with local customers to achieve performance levels that no other company could promise. Targeting local customers, level C is where the company competes under an entirely different name as well, with lower-quality products, which cannot be traced to it. These products are adapted to local customers' requirement in order to aid the customer's business.

In order to adapt to local market conditions and so as to enhance the operation process, subsidiary B also gives aftersales licenses to some accredited companies to coordinate their services. Likewise, it has reduced the number of its dealerships by upgrading some of the previous dealers to licensed dealers. Those upgraded as licensed dealers are the dealers who are big enough in terms of annual turnover or those that have shown a steady growth in their business with a close relationship with subsidiary B. Subsidiary B is autonomous from HQ operations.

4.3 Subsidiary C

The company is a logistics, sales and service support unit for a manufacturer of televisions, music systems, loudspeakers, telephones, and multimedia products that combine technological excellence with emotional appeal. Its basic strategy is to replicate key functions from HQ to China but the local knowledge, marketing and sales resources and proper product introduction skills are still not fully operational in China. It has fifty-two (52) stores across the whole Greater China region to achieve its basic strategy, support growth ambitions, to be closer to the customers and to reinforce the brand awareness. Based on its growth initiative, subsidiary C has a new business area and partners with four orient state-of-art OEMs having huge market share in China. To import products to China, it uses contract import licensees before it got its importation license and it sells products through key account customers and master dealers. Because of business-to-business relationship, the products are sent to the Chinese facilities of all the partners except one of them. It also built relationships with non-conventional partners in order to be locally embedded. Subsidiary C shares knowledge with its business partners in a range of areas with strong partnership focus.

Due to poor management of some of its dealership outlets, subsidiary C acquired some stores in China to initiate further growth and to set best-practice example of managing a dealership outlet. Although the corporate brand is well-established internationally, awareness in the Chinese market remains low and the companies' marketing budget has to be doubled to accommodate product launching at clubs and accessing local consumers on social media. Subsidiary C has partial autonomy from HQ operations.

4.4 Subsidiary D

The company produces and sells wood and steel-based staircase solutions. Raw materials are sourced mainly from China and Eastern Europe while the remaining supplies come from France and Germany. The raw material is supplied as semi-processed materials, and the subsidiary's main task is to finish the processing and assembling the final products and performing quality control inspection. Steel is sourced from two distributors from a big steel company in China. And it is better to produce steel related than wooden related products in China owing to its low cost and ample supply. Consequently, more than 90 % of steel based products are manufactured in the Chinese factory and most of them are exported to the Danish site but, approximately 5 % of the volume is dedicated to sub-supplier work for local customers. The Danish site takes charge of R&D, product design, production, marketing, and sales activities. But, a local Chinese company has been hired to work with the adaptation of product designs to match local demands and standards. To sell products in China, subsidiary D has difficulty in dealing with just one distributor to a city unlike other countries where they operate through chain stores with products availability. But, it built relationships with non-conventional partners so as to access local business networks and to be locally embedded. Subsidiary D has limited local autonomy and it serves the markets exclusively through retailers (chain stores) relationship, which is managed from the HQ primarily. Attempts to penetrate the Chinese construction market pose difficult in terms of acceptable price/quality mix.

5 Analysis

The four subsidiaries serve the Chinese market and Table 1 presents a summary of important findings or strategies of the subsidiaries and main reasons. In the early stages, essential resources and capabilities necessary to perform a server role were transferred to the subsidiaries from their internal network members, HQs, and sister subsidiaries, and worked under a strong formative pressure from these, a transfer strategy which is well-known in the literature (Florida and Kenney 2000).

Table 1 Critical findings/strategies and main reasons

Subsidiary	Critical findings/strategies	Main reasons
A	Proximity of production and product development in China	Subsidiary facilitate production process
		Support local market
	Outsourcing in China	Diversification of product application
		Autonomous from HQ operations
		Scarcity of capabilities for internal operations
B	Local production in China	Excess time in building capabilities
	Market segmentation	Penetration into local business networks
	Localizing through aftersales licenses and dealerships	Development of the operations process
		Autonomous from HQ operations
		Lack of R & D capabilities
C	Diversification into new business area	Leading by example
	Wide coverage of customers	Contract licensees to enhance operations process
	Replicate key HQ functions	Budget increase in order to get into local business networks
		Partnership to leverage capability
		Partial autonomy from HQ operations
D	Access specific markets	Chain stores to optimize operations process
	Offshore production site	Skill upgrade so as to adapt products locally
		Not autonomous from HQ operations

As a result of that, the subsidiaries could tap into headquarter resources, established global customers relationships, knowledge or competencies to ensure smooth operation while developing operational experience. Due to the growth of the subsidiaries and their ability to sense and explore local opportunities; it became important to interact with local suppliers, more local customers and to gather information for the development of products towards satisfying local customer's requirements. Therefore, subsidiaries seek autonomy to reduce the control of headquarter in its operations. A transformation from subsidiary's initial basic responsibilities and standard products supply to an independent operational entity has both benefits and challenges. To turn the challenges of operating in a local market into benefits require the ability to leverage headquarter competences (Bartlett and Ghoshal 2002) and to build new capabilities. These capabilities could enable subsidiaries to fully explore, respond to local market opportunities and to cope with operational difficulties in order to satisfy local customers. All the subsidiaries except for subsidiary C have plants in China so as to be closer to the market they serve and to reduce operational complexity while adapting and developing products for the Chinese customers.

Furthermore, Subsidiary C initiated a new business area and partner with other companies to reinforce its brand awareness and to share knowledge and site resources. Subsidiaries A and B have promoted the development of their initial outsourcing partners through training and effective collaboration procedures. More involvement of the outsourcing partners' right from the early stages of product development and introduction has helped them to develop capabilities for process integration and local responsiveness. On the other hand, subsidiary C is relying on its importation of components and products, and therefore depends on the effective performance of its insourcing agents (e.g. UPS) in order to optimize its processes and to reduce lead time delivery of products to customers. Subsidiaries A and B enjoy extensive autonomy from HQ in their operations which enables quick decision making in connection with the exploration and exploitation of local resources to meet local customers' demand. Subsidiary C has partial autonomy from HQ in its operations, while subsidiary D is still dependent on HQ in decision making and operations processes, though it is coping well due to its possession of some server capabilities to optimize its processes and for integration in its internal network. Subsidiary A outsources about 80 % of its operations due to lack of technical competences while subsidiary D produces more than 90 % of its products due to availability of raw materials and production competences. Subsidiaries B and C also used aftersales support as a way of relating to customers, accessing local social networks and for information gathering purposes. Subsidiary D also sells its products exclusively through retailers (i.e. chain stores) in the European market but the approach is difficult to adopt in China due to difference in mindset and buying culture. Master and licensed dealers (subsidiary C), authorized distribution channel and local sales offices (subsidiaries A and B) are used for product sales and to penetrate local business networks.

6 Discussion

Subsidiary role may be drawn from its mode of entry into a geographic market, the strategy of HQ/subsidiary, local innovation, customer relationships or supplier relationships. Relationships between HQ and subsidiaries led to the transfer of capabilities in the early stages based on fixed templates detailing the mode of operation. However, as the particular conditions of the subsidiary are surfaced the standard practices from the HQ should be open for adaptation as illustrated in the cases. Subsidiaries A–D demonstrate the strategic importance of the local opportunities by establishing a significant operations footprint and slowly redirecting capacity from export to serving local demand as well as by diversifying into new business area (subsidiary C). This capacity redirection is required to cope with the shift in the original motive (offshore) of the subsidiaries towards fulfilling a new role (server) which demands a mix of some existing and new capabilities to match the server role. Subsidiaries A, B, and C specifically exhibit that strategic importance as a result of their proximity to the Chinese market while subsidiary D reflects its relevance due to low-cost production. The scope of all the subsidiaries current activities is increased in China compared to when their primary motive was mainly to access low cost production (offshore role). The increased local operations as a consequence of the strategic importance of the local opportunities is in line with the suggestion of Bartlett and Ghoshal (2002) that strategic importance encourages local subsidiaries efforts to adapt and leverage parent company competences, knowledge developed for foreign operations, their marketing and sales culture and established local customers' relationship. As a result of that, the dimension—strategic importance of local opportunities supports the findings of Bartlett and Ghoshal (1986) in the dimensions of their original subsidiary typology and the framework of roles of foreign factories (Ferdows 1997 and Kim et al. 2011). Hence *strategic importance* is affirmed as a key determinant of a subsidiary role.

Following Bartlett and Ghoshal (1986) the relevance of capabilities required to serve a local market was evident in the analysis of the four subsidiaries. Diversifying or adapting product applications to local conditions demands new sets of operations capabilities different from that used for former products applications. Leveraging and upgrading of operations capabilities were evident across subsidiaries C and D in order to match desired operations level of internal processes within the subsidiaries. So as to cater for the demand of new capabilities as the strategic motive is changing from serving global to local demands. This argument is in line with the transfer strategy suggested by Florida and Kenney (2000) whereby resources and capabilities required to fulfil a server role are transferred from internal networks, HQ or sister subsidiaries to the necessary subsidiary. The competences and experience dominant in the four subsidiaries are expressed as knowledge based resources; market relationship and managerial skills/authority and that could be linked to the resources enhancing internal operations and those resources could influence the strategic role of a subsidiary according to the framework of Bartlett and Ghoshal (1986), Ferdows (1997) and Kim et al. (2011) and consequently the capabilities to match such roles. The devotion of time used by subsidiary B in building R&D and production capabilities depicts the necessity of operations capabilities in adapting products to local market requirements. As such the product requirement of a local market influences the capabilities required by the subsidiary serving that market. Subsidiary A's expansion of business focuses by introducing household products in order to serve the local market places a demand on operations capabilities to accomplish the production process in China. Thus, capabilities and in particular, *operations capabilities* is another dimension of a subsidiary role.

Subsidiaries A and B could develop higher levels of management skills than the others, as a result of their concerted efforts to explore the local markets and to increase local R&D activities aimed at reducing production costs and to serve the demand of the Chinese market. The development of higher levels of management skills builds on Birkinshaw and Hood (2000) that the influence of subsidiary management cannot be neglected in the determination of subsidiary roles. Meanwhile, subsidiary D has been delivering products based on acceptable quality standards in export markets and its distribution network through its embeddedness in the business network of the local market is improving. Subsidiary C is exploiting and developing its local business networks in China through access into social media. As such, some of the subsidiaries used local sales offices, authorized distribution channels, outsourcing (subsidiary A) and market segmentation (subsidiary B) to get into local business networks. On the other hand, subsidiary C used diversification into new business area and partnerships (subsidiaries C and D) to get more involved in the local business networks in order to serve local markets.

The new business area that subsidiary C has developed is an attempt to develop its domain while managing its customer relationships and gathering information for innovation. The domain development initiative is supported by Delany (2000) as a pursuance of new business opportunity in a local market. As earlier mentioned, involvement in local business networks found support in the work of Birkinshaw and Hood (2000) where it is stated that local environment influences the determination of subsidiary roles. Likewise, it builds on the suggestion of Hood and Taggart (1999) that local market forces (as experienced through diversification and partnerships by subsidiaries C and D) is one of the major factors in changing a subsidiary's role. Similarly, embeddedness of subsidiaries in local business networks builds on the work of London and Hart (2004) that local business networks and partnership with local actors is strongly related to subsidiary's performance and the responsiveness of a subsidiary to local market as revealed by Jarillo and Martinez (1990). Considering the four subsidiaries initiatives to get involved with local actors so as to serve local market demands hence, *embeddedness into local business networks* is another dimension of a subsidiary role.

In terms of the level of process optimization, subsidiaries A, B and D must have benefited from high degree of market relationship and accumulated experience of HQ, which had first entered China through the operations of local sales agents. The benefits reflect in the high level of their production process optimization and responsiveness to local requirements. In addition, licensed dealers (subsidiary B), contract import licensees (subsidiary C) and low cost production of steel compared to its other sites (subsidiary D) was adopted to eliminate sloppy activities and to increase the efficiency of their operations process. Subsidiary C used insourcing agents to improve and further optimize its processes while it increased efforts at sensing and orientating towards local market requirements. The respective optimization activities of all the subsidiaries such as leveraging on existing business relationships, experiences and local market accumulated knowledge to increase operational performance are relevant as the local subsidiaries shift motive from serving global to local demands. Therefore, another dimension determining the role of a subsidiary in a local market is the *level of its process optimization*.

The role of headquarter depicted by the level of autonomy of local subsidiaries operations was also evident as dimension of subsidiary role in subsidiaries A and B but lacks strong support in subsidiaries C and D perhaps due to their dependence on HQ operations. Hood and Taggart (1999) builds on the role of HQ by stating that the task assigned by HQ is one of the major factors in changing a subsidiary's role.

7 Conclusions, Limitations and Further Research

Based on a review of the literature and supported by qualitative data collected, the contribution of this paper is to increase our understanding on the processes of subsidiary localization by introducing a set of dimensions as the trajectories shaping subsidiary roles and capabilities in emerging markets namely; strategic importance, operations capabilities, embeddedness into local business networks and level of process optimization that capture subsidiaries' development in their localization processes. The contribution is relevant on how to determine a subsidiary's role and/or capabilities and could add to theory on capability development. As a managerial implication, the dimensions could guide managers to ascertain the role of a local subsidiary, the capabilities required to match such role and to exploit such capabilities for the benefit of that subsidiary or other subsidiaries in the operations network. Similarly, managers' understanding of the significance of embeddedness in local business networks for growth and expansion could be improved.

The study suffers from the usual limitations associated with the use of qualitative methodology. While it aims to provide an essential platform, further, larger-scale, research will be needed to test, and generalize beyond the Sino-Danish context, a set of dimensions determining a subsidiary role that is proposed in this study. The authors wish to express their appreciation to the Sino-Danish Center for Education and Research (SDC) for funding this study.

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Design and Management of (Multi-site) Global Operations Networks by Using Ferdows' Factory Role Model

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Abstract In the current global economy, with an increased international presence of all type of organisations, the design and management of global operations networks (GON) plays a vital role in organisational competitiveness. Whilst all type of organisations are facing significant challenges for managing increasingly complex global operation, current literature on global operation networks is still limited in its scope. The aim of this chapter is to discuss the development and evaluation of a construct for assessing the strategic plant role and developing of an improvement roadmap in GONs. This research makes a contribution to current knowledge on global operations by extending the model proposed by Ferdows (Harvard Bus Rev 75:73–88, 1997a) and operationalising it to enable its application for the design and optimisation of global operations networks.

Keywords Akondia framework · Strategic plant role · Value chain · Global operations network

1 Introduction

As a result of the internationalisation trend and in order to take the opportunities that exist in markets worldwide, companies of all types have now a global presence (Vereecke 2007). This has created a new set of organisational challenges that

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require attention and answers from the academic community. As a consequence of the economic globalisation the design of global operations networks (GON) will increasingly need to cover multiple regions and cope with higher network complexity (Shi and Gregory 1998; Ernst and Kim 2002), connecting markets to global supply and manufacturing sources beyond any geographical border. However, the literature on global operations network design and management is still scarce and fragmented (Corti et al. 2009; Laiho and Blomqvist 2010).

An interesting proposal was presented by Ferdows (1997a), who stated that the management of GON could be carried out based on the strategic plant role concept. However, there are few evidences of empirical testing of Ferdows' model and the deployment of the strategic plant role concept to an operational level (Vereecke and Van Dierdonck 2002; Mediavilla and Errasti 2010). As a result, any attempt to design and/or restructure a GON is difficult to put into practice, as the plant role concept is complex to formulate, deploy and prioritise. This is paradoxical as the higher the role the lower chance for a plant to disappear from the GON (Vereecke 2007). With the current degree of globalisation inefficient plants can no longer survive even in distant local markets (Mefford and Bruun 1998).

In this chapter it will be discussed the application of Ferdows's model for the analysis of strategic plant roles in a GON and extends the scope of this model by discussing a framework for deploying an improvement roadmap, which facilitates the strengthening of capabilities of individual plants and a gradual upgrade of their strategic role within a GON.

2 The Importance of (Multi-site) GON Design and Management

In recent years the competitive environment has been characterized by a highly dynamic macro economical context and a global competitive landscape. In this environment, the internationalisation of operations has become a common trend for companies and this has further confirmed the necessity for strategies that continuously enable the renewal of organisational capabilities to adapt to this global competitive environment.

In this context, designing and managing a GON is widely recognised as one of the most important challenges within international operations management (Ferdows 1997a, b; De Toni and Parussini 2010; Netland 2011). Evolving from an independently managed (or with lower interaction) plant network to a coordinated manufacturing network allows benefiting from the synergy among the plants (Dubois et al. 1993; Shi and Gregory 2005) by improving cost and delivery performance and enhancing the learning curve from the experiences of partners in the network (Flaherty 1986). However, the process and practice to optimise the overall performance of the operations network is still not well understood (Rudberg 2004).

Defining and managing the roles of individual plants is a critical component for optimising the performance of GONs because this enables the alignment of the business strategy with operations across the network (Shi and Gregory 2005). The optimisation of a GON is dependent on the specialisation of activities and capabilities that individual plants within the network develop (Ferdows 1997b; Maritan et al. 2004). It is therefore important to align the way in which each plant is managed with the requirements of the entire network. In the past, a common internationalization approach was to look for short-term cost reduction and competitiveness and resulted in the establishment of foreign plants to benefit from the cost advantages of a particular location (e.g. tariff and trade concessions, labour cost, subsidies, etc.). As a consequence, these plants had a limited range of responsibilities, autonomy, network participation and resources assigned to them (Ferdows 1997a). However, many organisations expect the benefits of individual plants within the network to go beyond the cost orientated incentives, including access to markets, customers and suppliers or specifically skilled, talented and motivated workforce. These factories will have a wider range of responsibilities in addition to production work including product or process engineering, purchasing decisions, after-sales service, etc. (Ferdows 1997a).

3 Existing Models on (Multi-site) GON Design and Management

Several authors have proposed classifications for defining the strategic roles of plants within a GON (Bartlett and Ghoshal 1989; Jarrillo and Martinez 1990; Ferdows 1997a; Vereecke et al. 2006) (Table 1). The classifications by Bartlett and Ghoshal (1989) and Jarrillo and Martinez (1990) provide useful insight into strategic roles of different type of subsidiaries within multinational organisations but it is Ferdows's work that specifically focuses on roles for manufacturing plants with a global network, which is the focus of the study presented in this paper.

Ferdows stated that "superior manufacturers gain a competitive advantage by methodically upgrading the strategic role of their plants abroad" (Ferdows 1997a, p. 73). He proposed a model that identifies different strategic roles that plants within a GON can fulfil and provided a development path to increase the competencies of individual plants in pursuit of higher strategic roles. Ferdows's strategic roles are based on two dimensions: location advantage and competence level. In terms of location advantage Ferdows identifies the following factors: access to low cost production, access to skills and knowledge, proximity to market. The competence level (i.e. high or low) of the plant is the second dimension that Ferdows uses to identify the strategic roles. Competences that Ferdows refers to include production, procurement, supply, logistics, supplier development, product and process development/improvement and product/process innovation. Based on these two dimensions he identified the following strategic roles: outpost, offshore, server, source, contributor and lead (Table 2 provides a description of each strategic role). In a recent publication, Feldmann (2011) suggest dividing the competencies into three levels instead of the two levels proposed by Ferdows. These authors

Table 1 Classifications of strategic roles for multinational network plants

	Bartlett and Ghoshal (1989)	Jarrillo and Martinez (1990)	Ferdows (1997a)	Vereecke et al. (2006)
Key dimensions for considerations	• Competence • Strategic alignment with national environment	• Competence • Integration level	• Competence • Location	• Knowledge flow
Strategic roles	• Implementer • Black hole • Contributor • Strategic leader	• Receptive • Active • Autonomous	• Off-shore • Source • Server • Contributor • Outpost • Lead plant	• Isolated • Receiver • Hosting network player • Active network player

state that 3 types of plants can be identified based on the level of competence. These include: Type 1—plants that have only competence of production related matters; Type 2—plants that have competences for production and supply chain activities; Type 3—plants that have competencies for a whole range of technical activities related to production, supply chain and product/process development.

4 Key Challenges on (Multi-site) GON Design and Management

The question that still remains unanswered is how to deploy the operations strategy in a multi-location GON and, in particular, how to balance the different competences and responsibilities of individual plants within the network, taking into account that the each plant could develop capabilities specific for that plant or used by the whole GON. Cheng et al. (2011) state that most of the debate around plant roles has been focused on the advantages of location and competencies of individual plants without understanding its influence on the entire GON. It is therefore necessary to study the development of individual plant roles and the interactions with the evolution of the wider network.

Slack and Lewis (2002) define operations strategy as the total standard of decisions that mould the long term capacities of any kind of operation and their contribution for the general strategy through the reconciliation of the market requirements with the operations resources. The operations strategy should be reflected in the operations network design, which basically is about where to locate your sources of supply and manufacturing and distribution operations, as well as the deployment of such operations. Operations strategy also plays a vital role when going through the rationalisation or restructuring process of an existing network (Vereecke and Van Dierdonck 2002; Mediavilla and Errasti 2010). The strategy formulation and deployment process is in fact a changing and adaptive exercise for a GON and each individual plant within it. Therefore the operations

Table 2 Strategic plant roles in global operation networks (Ferdows 1997a)

High	**Source**	**Lead**	**Contributor**
Site competence	Low cost production	Creates new products, processes and technologies for the entire company	Supplies national/regional market
		Taps into local skills and technological resources to develop transform technology into new products and processes	Autonomy for product/process engineering, procurement, development of suppliers
	Autonomy for procurement, supplier selection, production planning, outbound logistics, process changes and product customisation	Autonomy for supplier selections, customer communication, procurement of machinery, management of research and innovation activities	Competes to be testing ground for new process technologies, and products
	Same production capability as best plant in the network		Includes development, engineering and production capabilities
	Location requires developed infrastructure and availability of skilled workforce		
Low	**Offshore**	**Outpost**	**Server**
	Low cost production	Primary role is to collect information about suppliers, customers, competitors and research expertise	Supplies national/regional markets
	Minimal investment in technical and managerial resources	Usually has secondary strategic role as a server or offshore	Overcome tariff barriers, reduce taxes, logistic costs and exposure to currency fluctuations
	Little engineering development work		Limited autonomy (only for decision to fit local conditions)
	Access to low cost production *Location advantage*	*Access to skills and knowledge*	*Proximity to market*

strategy and, by extension, the GON design process should include the evaluation of dynamic capabilities (Sweeney et al. 2007).

These dynamic capabilities are defined by Teece et al. (1997) as "the ability to achieve new forms of competitive advantage" to emphasise two key aspects that were not the main focus of attention in previous strategy perspectives. The term "dynamic" refers to the capacity to renew competences so as to achieve congruence with the changing business environment. The term "capabilities" emphasises the key role of strategic management in appropriately adapting, integrating and reconfiguring internal and external organisational skills, resources and functional competences to match the requirements of a changing environment. Dynamic capabilities have a significant impact on how quickly and effectively an organisation reconfigures its resources in line with changing market conditions (Eisenhardt and Martin 2000; Helfat 2007). These capabilities will therefore play an important role not only in the design of a GON but also in the development of the capabilities of individual plants within the network. Literature on dynamic capabilities states that these are realised through organisational processes that contribute to the reconfiguration of resources and that they act on lower order organisational routines (Eisenhardt and Martin 2000; Helfat 2007; Ambrosini et al. 2009), suggesting that dynamic capabilities are closely related to the formulation and implementation of the operations strategy.

Ferdows and Fritz Thurnheer (2011) refer to the concept of production fitness as a way of "developing [a firm's] cumulative capabilities and improving its ability to respond to changing market and business conditions". The authors suggest that fitness in production is different from leanness and that manufacturing firms need to continuously deploy a fitness programme to ensure long term sustainability. Furthermore, this paper suggests the use of the 'Sandcone' model (Ferdows and De Meyer 1990) to develop and improve multiple capabilities simultaneously and continuously. This notion of production fitness plays an even more significant role in the context of global operations networks due to the fact that several plants require to simultaneously develop multiple capabilities in order to remain competitive and contribute to the overall business strategy. However, the work by Ferdows and Fritz Thurnheer (2011) and Ferdows and De Meyer (1990) has been carried out in the context of a single manufacturing plant, not a multi site manufacturing environment where all plants require a continuous development of their capabilities.

Whilst Ferdows' work provides a useful starting point for designing or re-structuring the operations of plants within a GON there is little evidence of the application of the model beyond the work by Vereecke and Van Dierdonck (2002). The Akondia model within this chapter discusses the application of Ferdows's model to the decision making process of establishing, redesigning and/or acquiring a new production unit. However, it does not look into how the competencies of the production units within the existing network can be developed to enable the adoption of a higher level strategic role. In order to generate new insights into the application of the model further empirical research is required (Chakravarty et al. 1997; Netland 2011). Furthermore, it is clear that more research is needed to understand the evolution and coordination of the operations of individual production units within a network of manufacturing facilities (Dubois et al. 1993; Shi and Gregory 1998, 2005; Cheng et al. 2011). Models and techniques to aid practitioners formulating and developing operations strategy when designing or restructuring a GON are lacking (Vereecke and Van Dierdonck 2002) and the study areas are dispersed (Corti et al. 2009; Laiho and Blomqvist 2010), which results in difficulties to renew competences and capabilities of individual facilities (Teece et al. 1997; Sweeney et al. 2007). Finally, there is limited research on the improvement programs and intra-firm practice transfer in multinational manufacturing enterprises with GONs (De Toni and Parussini 2010).

In summary, the new paradigm in multi-site global operations strategy is the need for continuous reconfiguration of the manufacturing systems and operations of a GON to adapt to a dynamic environment. The ability to quickly and effectively reconfigure the operations of the plants within the GON is then a key source of competitive advantage. The questions that still remain unanswered in this regards are (1) how to balance the strategic roles, competencies and responsibilities of multiple plants within a GON and (2) how to deploy the operations strategy within a GON where individual plants require to simultaneously and continuously develop their capabilities to remain competitive.

5 Akondia Framework for (Multi-site) GON Design and Management

This chapter proposes a framework for the empirical application of Ferdows' model and discusses its implementation within a multinational white goods manufacturer. The findings of the study extend the current knowledge in the area by defining how to upgrade a plant's strategic role within the framework of a GON, beyond the sole analysis of the current strategic role.

The proposed framework called 'Akondia' aims to facilitate the practical application of Ferdows's model and to extend its application by defining how to systematically upgrade the strategic role of a plant within a GON. Depending on the scope of analysis the 'Akondia' framework contributes to the continuous optimisation and sustainability of (1) the GON (by identifying strengths of each network unit and prioritising the development of competences from a network perspective) or (2) individual units (supporting plants to strengthen their capabilities and potentially upgrade to a higher value added plant role).

Prior to developing the 'Akondia' framework the authors had discussed in two previous papers the usefulness of the lean production based models for assessing the plant role suggested by Ferdows (Mediavilla and Errasti 2010; Mediavilla et al. 2011) This analysis showed that lean management models had significant limitations for operationalising Ferdows's strategic plants roles. Therefore the main research motivation for the 'Akondia' framework is to find a systematic method for assessing and improving the competencies of a plant or a GON based on the Ferdows' plant role model (Table 3).

Table 3 Stages of the 'Akondia' framework

Stage	Purpose	Who is involved	What to do	Support tools
Stage 1: Assess the competencies of the plant	To carry out an assessment of the plant's competencies based on Porter's value chain model	Researchers	1. Interview business unit management team	Structured questionnaire based on Porter's value chain model
		Business unit management team	2. Interview plant management team	
		Local Management of the plant	3. Plot results in appropriate graphical format	
Stage 2: Develop generic profiles for all strategic roles	To identify the required and recommended competencies for each strategic role as defined by Ferdows and define their maturity level	Researchers	1. Delphi panel	Delphi panel results
		Business unit management team	2. Plot generic profiles in appropriate graphical format	Competency assessment results
Stage 3: Define the plant role	To define the plant's role based on the analysis of the competency assessment	Researchers	1. Compare the generic plant role profiles with the results from the competency assessment	Generic plant role profiles
			2. Define plant role based on closest match to generic plant role profiles	Competency assessment results
Stage 4: Define an improvement roadmap	To define an improvement roadmap to strengthen the competitive position of the GON or individual plant	Researchers	1. Define improvement roadmap to strengthen current plant role	Graphical priorisation matrix (competence level and influence level)
		Business unit management team	2. Define improvement roadmap to adopt a new plant role	Relevant improvement models and tools to support specific competence development needs
		Plant management team		

The 'Akondia' framework is divided into four stages. The following table provides an overview of each stage of the process:

5.1 Stage 1: Assess the Competencies of the Plant

The first stage of the framework aims to provide a strategic plant profile or competitive position as an output, which later could be compared to the generic roles defined by Ferdows in the second stage of the framework—and finally provides the basis for the gap analysis and improvement plan. The plant role, as originally defined by Ferdows, implicitly covers functions beyond purely production and supply chain activities, i.e. aspects within a GON which are not only part of a supply chain but of the entire value chain. This is specially remarked when introducing the concept of "lead plant" (Ferdows 1997a), a plant contributing to the company's strategy by developing capabilities as new processes, products and technologies, and sharing these capabilities with other plants in the network. Therefore the value chain concept defined by Porter (1985) was adopted as the basis for the plant role assessment proposed by the 'Akondia' framework. Based on Porter's model the following six main fields of analysis were defined to carry out the plant role assessment: (1) Markets and customers, (2) Suppliers, (3) Internal Operations, (4) HR Management, (5) Technology Management and (6) Sociopolitical and regulatory. These six fields are mentioned by Ferdows in the description of the different generic plant roles.

In order to assess the competencies of the plant a questionnaire has been focusing on the six analysis fields mentioned above. The questionnaire includes 38 questions with each question focusing on a particular competence. Each competence is then evaluated under two dimensions: (1) level of influence of the plant to develop the competence using a 5-point Likert scale (e.g. is the plant able to select its strategic suppliers or is this centralised decision? Has the plant any influence in the new product technologies or is this carried out by other plant within the network?); (2) current competence level using a 9-point Likert scale.

The questionnaire is aimed to be used during structured interviews with individuals from the management team of the plant that is to be assessed and from the top management team of the corresponding business unit (or headquarters). The purpose of the latter is to provide an 'external' view of a given plant in order to gain a better overview of the different plants within the network and enable richer comparisons. Furthermore, the headquarters are usually the decision making agents for assigning, strengthening or denying the competences for each plant or the plants' influence level on each competence.

The next step is to graphically plot the data gathered through the questionnaires to show the strategic profile for any given factory. Figures 1 and 2 illustrate an example of the output from Stage 1 of the 'Akondia' framework. The figures below show a real case from the white goods sector, with the evaluation of 6 plants from the same business unit located in different countries. Figure 1 provides the detailed

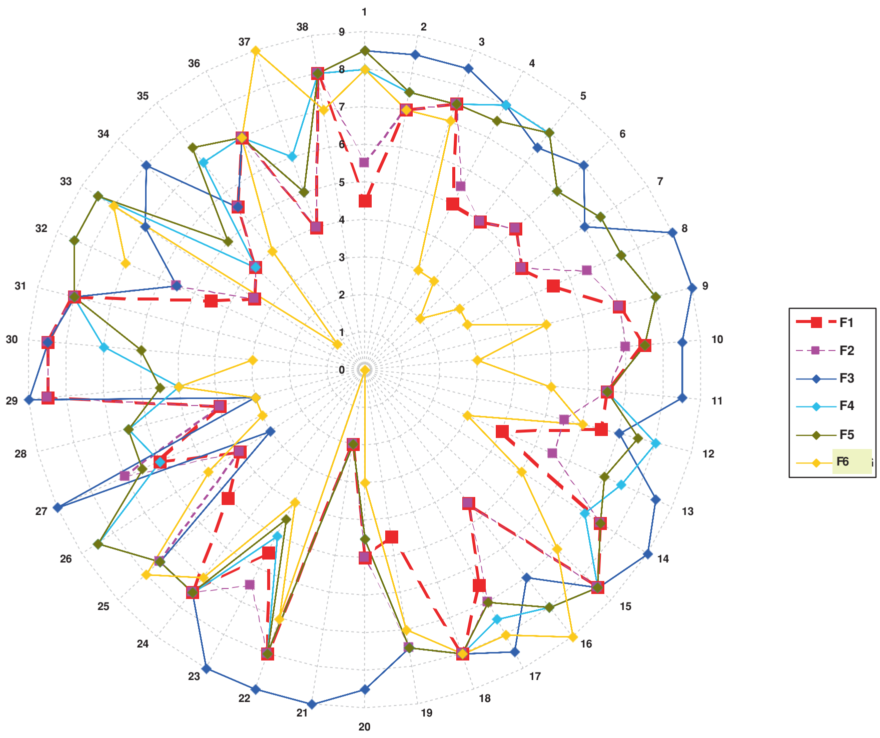

Fig. 1 Strategic profile of 6 factories acting in the same business unit

strategic profile showing the results of the 38 questions—the score for each question is plotted and the line linking all scores provides the strategic profile of the plant. Figure 2 shows a consolidated view of the results based on the 6 analysis fields.

The main output coming out from this stage is the strategic profile or competitive position of each plant. Apart from the overview of the strengths and weaknesses in each competence the first graphical comparison of different plants provides an overview of the competitive position of each plant within its GON.

A complementary graphical plot is the comparison between the assessments carried out by the managers from each plant (internal assessment) and the business unit/headquarters management team (external assessment). This comparison is critical as it enables checking variance in the understanding of the competitive position of a plant and correcting scaling differences in the answers given by different interviewees. Figure 3 illustrates a somewhat unusual example where the evaluation of the plant's management team has a much lower score than that carried out by the business unit's management team. Usually the business unit's management team tends to be more critical when doing the evaluation because the plant's management team will want to protect its own interests. Figure 3 shows 3 different views of the variance between the internal and external assessment for a specific plant.

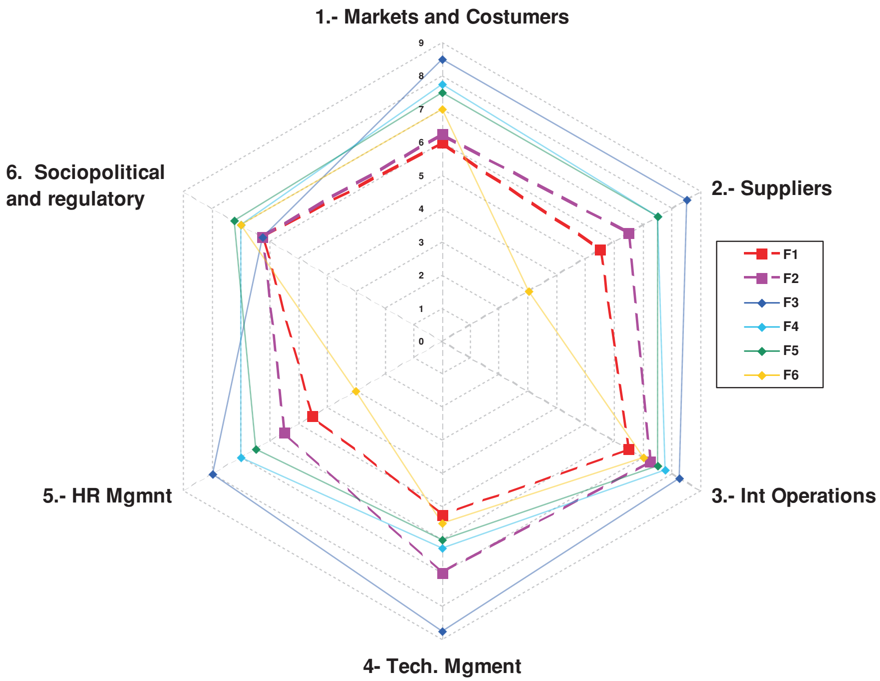

Fig. 2 Consolidated view (mean per analysis field) of the strategic profile

5.2 Stage 2: Develop Generic Profiles for the Strategic Roles

The second step of the 'Akondia' framework is to create generic profiles (specific to the GON under study) for each strategic plant role identified by Ferdows, i.e. "low cost production" roles (offshore, source), "Skills and knowledge" roles (outpost, lead) and "proximity to market" roles (server, contributor). The comparison of the analysis carried out in Stage 1 with these generic profiles will then enable the identification of a strategic role for each individual manufacturing plant (Stage 3).

The application of the framework demands to create generic profiles assigned to each of the Ferdows plant roles through the following steps:

- Delphi panel with the HQ/Business unit management team to relate each plant assessed with a particular strategic plant role;
- Group the plants with the same strategic plant role;
- Based on the evaluation done in the Stage 1, carry out a quantitative analysis and identification of the common competences that each plant of a given role shows;
- In a second Delphi panel session contrast the identified common competences and discuss/agree the "must" and "recommended" competences for each of the strategic plant roles.

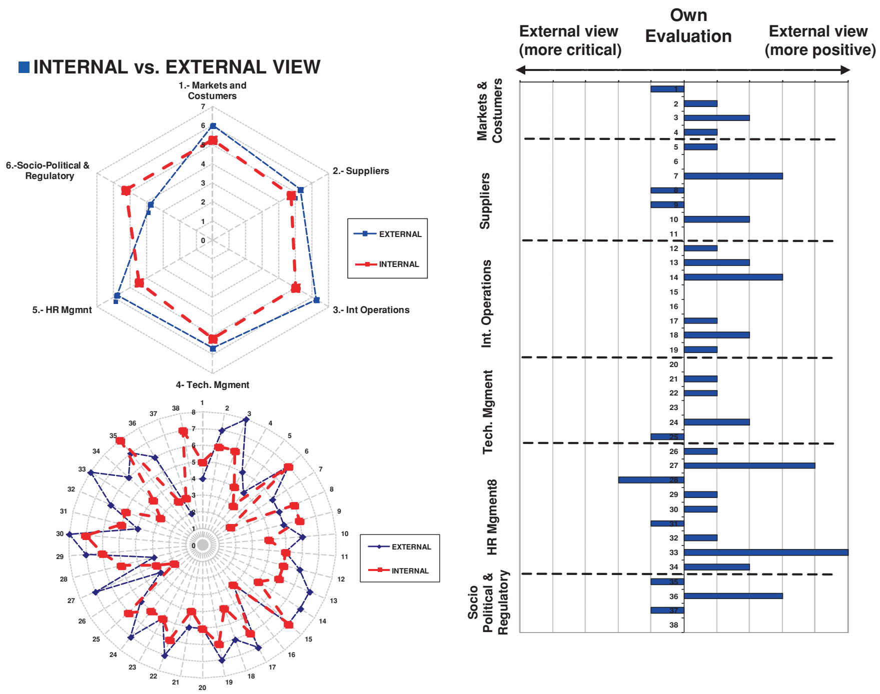

Fig. 3 Example of plant capability assessment (external vs. internal evaluation)

The outputs from the above process are the generic profiles for each strategic plant roles that included the required competencies ('must' and 'recommended') and their level. Table 4 shows the "must" and "recommended" competences for each strategic role. Note that a similar matrix can be shown for the influence level per competence. These choices are later discussed during the delphi panels in order to reinforce their validity.

These generic profiles would then be used to compare each plant with the competitive assessment carried out in the previous stage. It is important to note that depending on a number of variables (e.g. sector, company size, product range, business unit) these generic profiles for each strategic plant role could be different (i.e. include different 'must' and 'recommended' competencies). Figures 4 and 5 show two examples of generic strategic profiles developed for a case study carried out by the authors.

5.3 Stage 3: Define the Plant's Role

During Stage 3 each analysed factories are subjected to an affinity analysis (strategic competence assessment from Stage 1 versus generic profiles from Stage 2) executed by the research team. As a result of this a strategic plant role was

Table 4 "Must" and "recommended" competences for plant roles

Strategic site reason	"Must" competences	"Recommended" competences
Access to low cost production	Availability of low cost blue collar	Access to a cost-competitive network of suppliers
OFFSHORE	Availability of low cost engineers	Capacity of having a stable supply process from low cost-suppliers
		Efficiency of utilization of the work-force
		Efficiency of utilization of the machines/installations
Access to low cost production	Access to a cost-competitive network of suppliers	Integration/Response with customer service of main markets
SOURCE	Access to reliable and flexible "order-delivery" processes from the network of suppliers	"Purchasing productivity" (technical- material ratio)
		Capacity of successful collaboration/integration with suppliers
	Capacity of having a stable supply process from low cost-suppliers (LCC)	Capacity of robust supplier administration contract management (currencies, delivery terms, penalties, etc.), financial risks monitoring
	"Purchase productivity" (administrative-price ratio)	
		Efficiency of utilization of the work-force
		Efficiency of utilization of the machines/installations
		Capacity of maintaining a reliable delivery fulfilment
		Flexibility to adapt the production to changes in the demand and special occasions (seasonality, special promotions, etc.)
		Commitment/motivation of the employees
		Capacity of maintaining low absenteeism rate
		Attachment of the plant to complaint behaviour
Access to skills and knowledge	Proximity to a knowledge/technology networks-sources	Integration/Response with Customer Service of main markets
OUTPOST	Availability of high skilled blue collars	Capacity of innovating in utilization of new process technologies
	Availability of high skilled engineers	Capacity of improving existing manufacturing processes (labour rationalization, Q-improvement)
		Capacity of implementing existing tools/techniques/methods (best practice) or develop them
		Availability for developing other factories/subsidiaries

(continued)

Table 4 (continued)

Strategic site reason	"Must" competences	"Recommended" competences
Access to skills &knowledge	Integration/Response with Customer Service of main markets	Capacity of offering value added services to customers aligned with main subsidiaries of strategic markets
LEAD	"Purchase productivity" (administrative-price ratio)	Capacity of robust supplier administration → contract management, financial risks monitoring
	"Purchasing productivity" (technical- material ratio)	
	Capacity of successful collaboration/integration with suppliers	Efficiency of utilization of the work-force
		Capacity of maintaining low number of incidents and accidents
	Efficiency of utilization of the machines/installations	Attachment of the plant to complaint behaviour
	Efficient utilization of energy and appropriate waste management	
	Capacity of serving as a pilot for new introductions	
	Proximity to a knowledge/technology networks-sources	
	Capacity of innovating in product technologies	
	Capacity of minor adaptations/face lifting of existing products/platform	
	Capacity of innovating in utilization of new process technologies	
	Capacity of improving existing manufacturing processes	
	Capacity of implementing existing tools/techniques/methods (best practice) or develop them	
	Availability of highly skilled blue collars	
	Availability of highly skilled engineers	
	Availability for developing other factories/subsidiaries	
Proximity to market	Proximity to strategic markets	Integration/Response with Customer Service of main markets
SERVER	Robust phase-in/phase out fulfillment	Capacity of having a stable supply process from low cost-suppliers
	Access to a cost-competitive network of suppliers	Efficiency of utilization of the work-force
	Incentives for investments, innovation or keeping the operations	Efficiency of utilization of the machines/installations
		Flexibility to adapt the production to changes in the demand and special occasions
		Stability in the macro economical situation

(continued)

Table 4 (continued)

Strategic site reason	"Must" competences	"Recommended" competences
Proximity to market CONTRIBUTOR	Proximity to strategic markets	Capacity of offering value added services to customers aligned with main subsidiaries of strategic markets
	Robust phase-in/phase out fulfilment	
	Integration/Response with Customer Service of main markets	Capacity of having a stable supply process form low cost-suppliers
	Access to a cost-competitive network of suppliers	Capacity of robust supplier administration contract management, financial risks monitoring
	Access to reliable and flexible "order-delivery" processes from the network of suppliers	Efficiency of utilization of the work-force
		Efficiency of utilization of the machines/installations
	"Purchase productivity" (administrative-price ratio)	Efficiency utilization of energy and appropriate waste management
	"Purchasing productivity" (technical – material ratio)	Capacity of serving as a pilot for new introductions
	Capacity of successful collaboration/integration with suppliers	Capacity of minor adaptations/face lifting of existing products/platform (extend/reduce features)
	Capacity of managing a reliable delivery fulfilment	Capacity of maintaining low absenteeism rate
	Flexibility to adapt the production to changes in the demand and special occasions	Availability for developing other factories/subsidiaries
		Stability in the macro economical situation
		Stability of the labour law framework
	Capacity of innovating in utilization of new process technologies	Attachment of the plant to complaint behaviour
	Capacity of improving existing manufacturing processes	
	Capacity of implementing existing tools/techniques/methods (best-practice) or develop them	
	Availability of highly skilled blue collars	
	Availability of highly skilled engineers	
	Incentives for investments, innovation or keeping the operations	

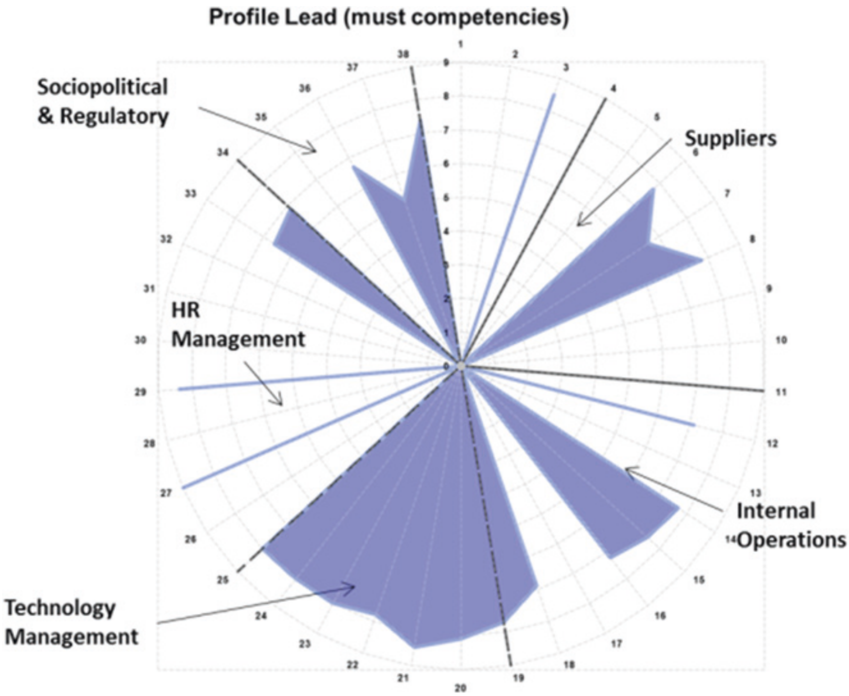

Fig. 4 Example of a generic strategic profile for an "lead" role—showing the "must" competences

assigned to each plant. The comparison of the strategic plant profile (outcome of Stage1) against the generic strategic profiles (Stage 2) provides a quantitative and structured approach for defining the current plant role.

As explained in stage 2, there are "must" and "recommended" competences for each generic strategic profile assigned to each of the Ferdows's plant roles. These competences are then used to get the affinity level of a plant to a particular plant role by quantitatively comparing the current competence level to the required level for a generic strategic role. This quantitative analysis provides an affinity level to each of the Ferdows's plant roles.

In Fig. 6 the reader can observe the affinity level of 6 factories to Ferdows's model included in a real case developed by the authors. Note that in these cases the initial affinity analysis has been done in relation to the three types of strategic location advantage rather than the six generic plant roles. A similar affinity analysis can be carried out clustering the framework in the six generic plant roles.

All plants showed a certain affinity grade to each strategic plant role but with a clearly dominant role. Figure 8 illustrates examples from two of the plants evaluated, in both cases indicating the dominant plant role ('lead' in the first case, 'offshore' in the second). The fact that a clearly dominant plant role emerged in all cases increases the validity of the generic profiles generated and the comparative analysis carried out during Stage 3 (Fig. 7).

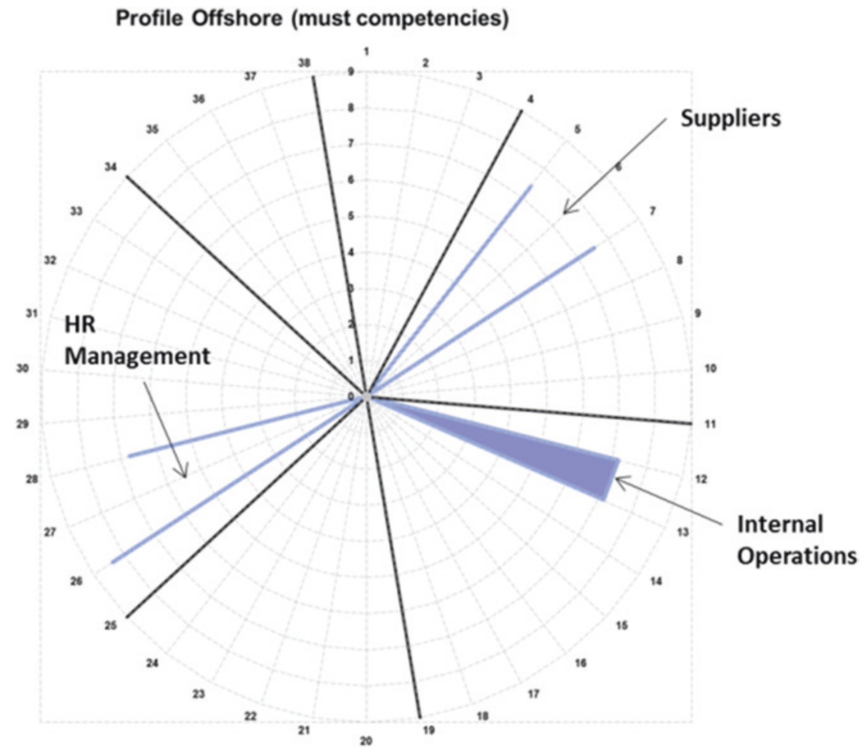

Fig. 5 Example of a generic strategic profile for an "off-shore" role—showing the "must" competences

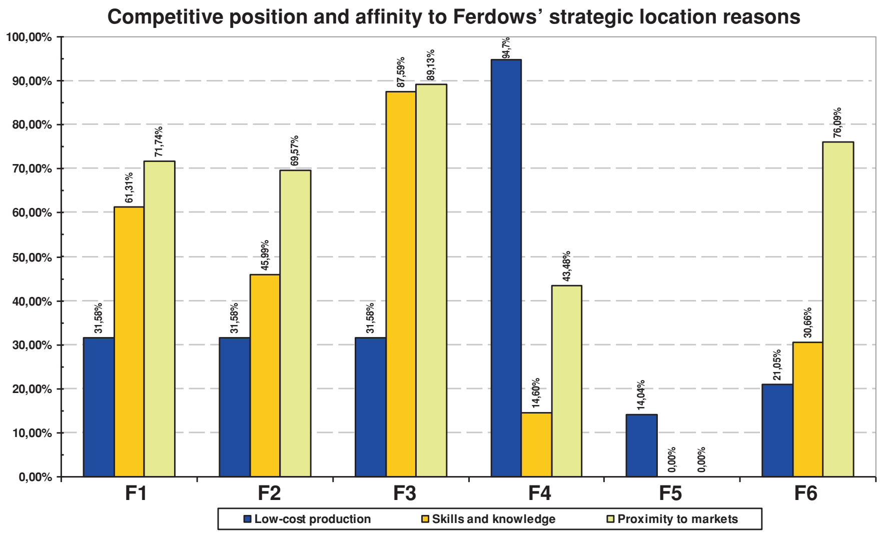

Fig. 6 Affinity to Ferdows's model for 6 factories (each bar shows affinity in % in relation to a type of strategic location advantage)

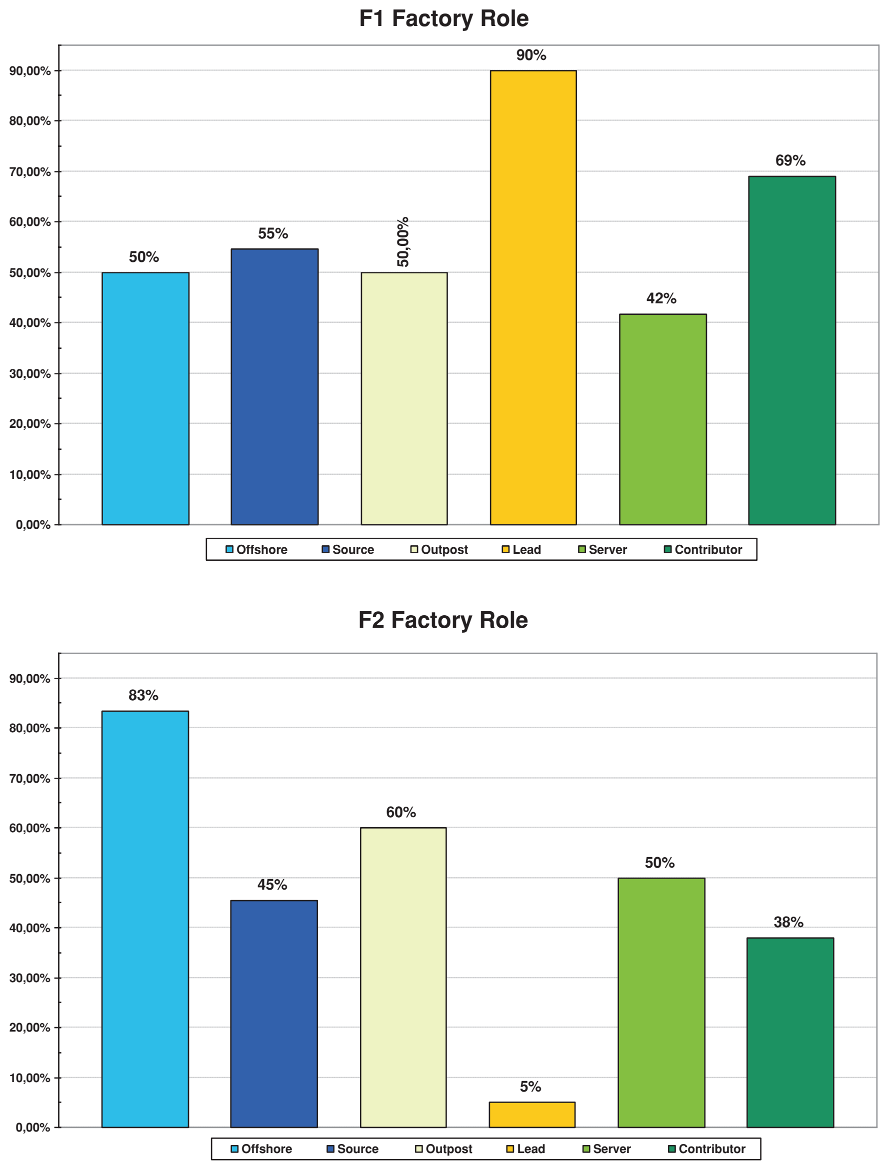

Fig. 7 Examples of two assessed plant with clear dominant plant role (“lead” and “off-shore”)

In order to finalise the third stage, the most suitable graphical presentation is to summarise the whole affinity analysis by mapping each of the analysed plants on Ferdows’s model (Fig. 8).

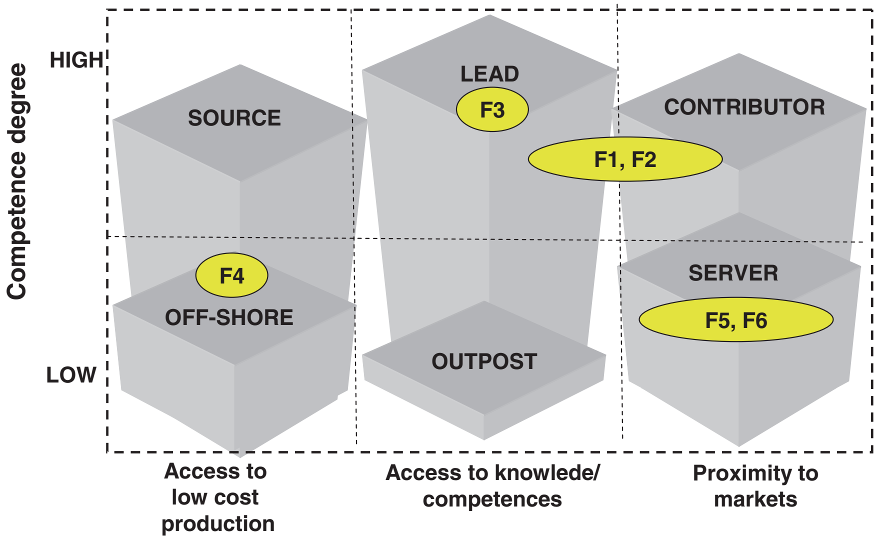

Fig. 8 Plants and their strategic role

5.4 *Stage 4: Define an Improvement Roadmap for the Plant*

The last step of the ‘Akondia’ framework is focused on the process to develop an improvement roadmap for each plant. The aim is to first improve the capabilities to strengthen the current factory role and later enable the plant to adopt a higher value added role within the GON (in line with the overall strategy of the GON). As a result, and to make this process systematic, two improvements roadmaps are developed at this stage: one to strengthen the current plant role and the other to enable the transfer to a higher added value role. This two-phase approach aims to support the optimisation of the entire GON rather than to maximise the capabilities of each individual plant. Only by clustering the improvement areas around the 6 fields of analysis and defining improvement paths for given competences will the plants be able to move into higher value added roles. From a network perspective the roles assigned to each plant could be upgraded, downgraded, maintained or changed horizontally, and this will have an impact on the improvement roadmap defined for each particular plant. Logically, individual plants will always try to improve their current roles as the “less successful plants may disappear from the map” (Vereecke and Van Dierdonck 2002).

To enable the definition of the improvement roadmap the ‘Akondia’ framework has been developed in two levels of analysis. The first level is a “macro” perspective along the 6 main analysis fields executed in the stages 1 and 2 of the framework. A second detailed and separated “micro” level analysis is then utilised

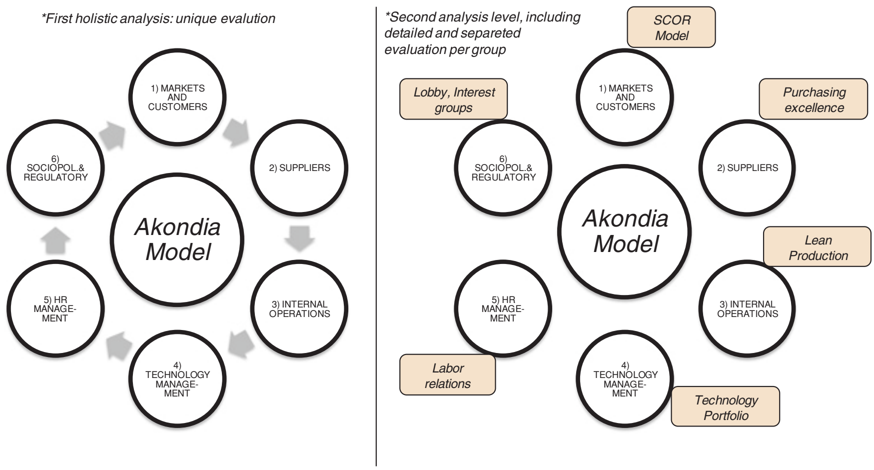

Fig. 9 Levels of analysis of the 'Akondia' framework

for the development and implementation of the improvement roadmap by adopting existing models, frameworks and techniques related to each analysis field. The choice of these models and techniques will be context/company specific and dependent on a number of variables including company type, sector, organisational culture, skills, etc. For example, the company in this study adopted the principles of Lean Production as the main methodology to improve the capabilities related to Internal Operations while the SCOR reference model was adopted to develop the capabilities for Markets and Customers. This choice was mainly based on the relevance and the already existing level of acceptance of these models across the organisation (Fig. 9).

To strengthen the current plant role, it is necessary to identify the weakest competences. However it is important to remember that the questionnaire allowed assessing two aspects of each plant: the competence level and the influence level of the plant in that competence. It is logical to assume that the higher the influence level on a given competence, the easier to improve its level. The 'Akondia' framework proposes first strengthening of the current strategic role by analysing the following priorisation matrix.

The priorisation matrix shows graphically each of the 38 competences assessed in the questionnaire. The Y-Axis shows the level of each competence, while the X-Axis provides the influence of a given plant on the development of that particular competence. Another graphical alternative for a quick identification of the fields requiring improvement is shown in Fig. 11. Note that the highest influence level is scored as 5 while the scale for the competences level goes up to 9 (Fig. 10).

After strengthening the current competitive position with a focused improvement on the competences where the influence is high, any plant could be suitable to develop a strategic role roadmap. Using the generic competitive positions (or

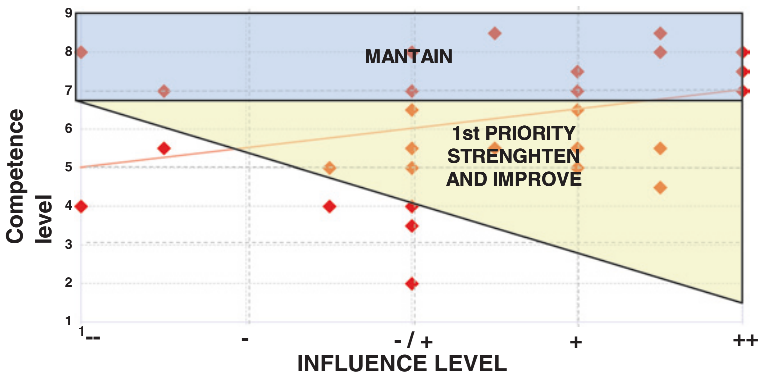

Fig. 10 Priorisation matrix based on questionnaire scoring

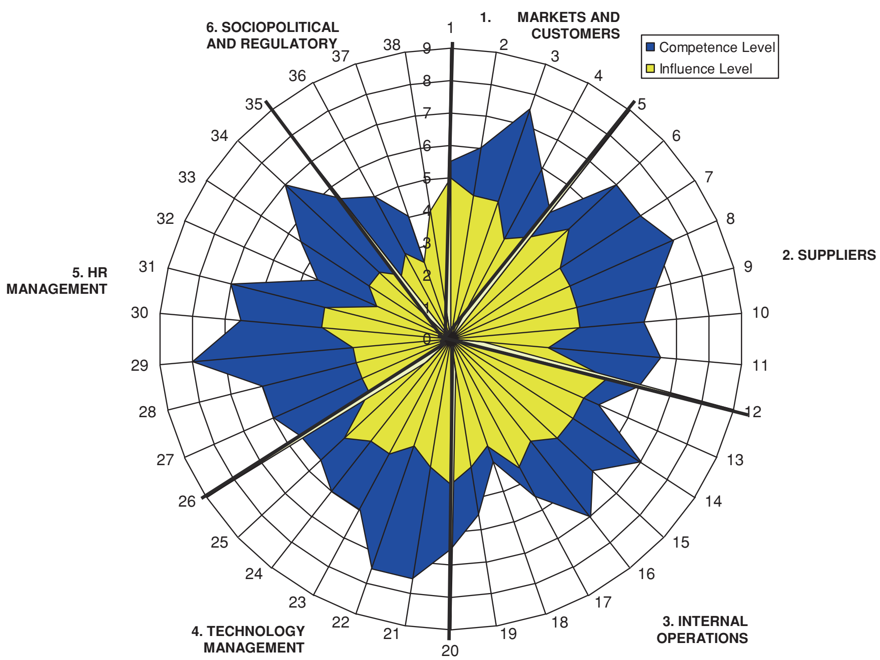

Fig. 11 Competence level and influence level for a plant

strategic profile) for the strategic roles of Ferdows, a step by step middle to long-term roadmap can be deployed.

The authors recommend a deployment roadmap based on the 6 analysis field, balancing the current competence level, the influence level and the effort required (e.g. providing more influence to a facility by giving new responsibilities). These role changes could in fact imply organizational decisions or re-assignment of

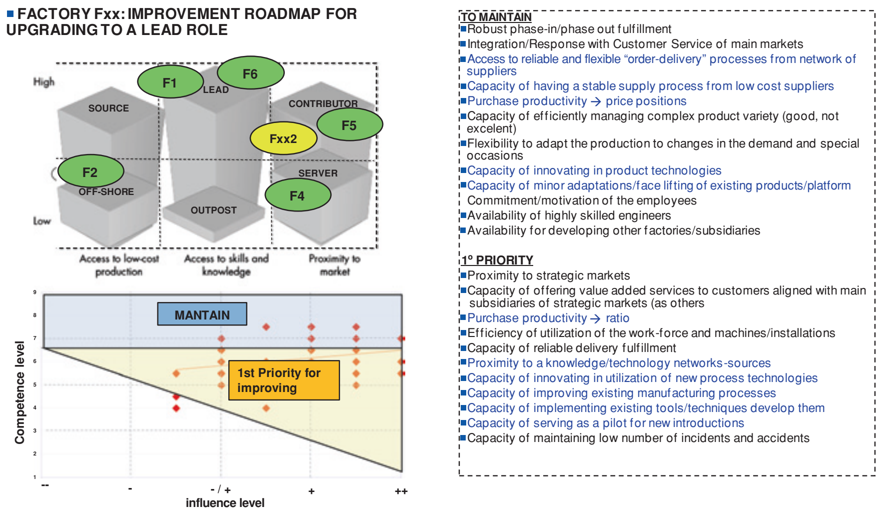

Fig. 12 Priorisation matrix and improvement roadmap for plant Fxx

responsibilities. Any improvement roadmap per field should have a second level analysis and detailed deployment at the operational level. Figure 12 shows a summarised analysis of factory roles, priorisation matrix and improvement roadmap for one of the plants studied.

6 Conclusions and Discussion

During the application of the Akondia framework to real projects in the industry (e.g. White-goods, Automotive, Wind-energy, etc.), the authors have tested its validity. The main conclusions are as follows:

- The 'Akondia' framework enables making Ferdows's strategic roles operational by focusing on the competencies of different areas of the value chain. Only assessing supply chain and production related aspects would lead to an incomplete plant role analysis.
- Each of the strategic plant roles defined by Ferdows contains a clearly identifiable set of 'must' and 'recommended' competencies for different aspects of the value chain. Whilst there might be commonalities when developing generic profiles for each strategic role these competencies are specific to the context of application (e.g. company, business unit).
- All the assessed plants have a clearly dominant affinity to one of the Ferdows strategic location advantage types ("low cost production", "Skills and knowledge" and "proximity to market") and therefore to a certain plant role. However, all plants have a certain grade of affinity to most of the other plant roles, which indicates a certain hierarchical order within the plant roles.

- The assignment of competences within a GON has a systemic nature, which does not allow the plants to decide independently. The influence grade per competence shown in the 'Akondia' framework could provide an interesting point for joining corporate and operations strategies to operational decisions regarding competence assignment.
- The 'Akondia' framework provides a structured improvement path for each plant that wants to reinforce its role within a GON, first by stabilising the current assigned role followed by gaining additional competences.
- The contribution that this research makes stems from defining a process for GON optimisation by assessing the strategic role and improving the competencies of individual plants within a GON. This is achieved by enabling the integration of existing GON and value chain models (i.e. Ferdows, Porter) with relevant operational improvement methodologies (e.g. Lean, SCOR, Innovation models).

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Knowledge Transfer and Manufacturing Relocation in International Manufacturing Networks

Erik Skov Madsen

Abstract This paper is built on six longitudinal case studies of knowledge transfer in manufacturing relocation. By focusing on tacit and explicit knowledge the paper introduces a model for identification of knowledge in relation to four task situations on the shop floor in a manufacturing environment. The paper discusses and suggests how the transfer of tacit and explicit knowledge can be improved. Further the paper discusses two dramatic shifts in organizational settings i.e. from operations management and to project management in the sending unit before a transfer and reverses in the receiving unit after relocation. Finally the paper discusses how "dispatching capacity" and "absorptive capacity" can improve the process.

Keywords Knowledge transfer · Manufacturing relocation · Manufacturing networks · Dispatching capacity · Organizational change

1 Introduction

Knowledge transfer and knowledge sharing constitute a major challenge when different companies and organizations are working together within International Manufacturing Networks or in International Operations Network (IMNs/IONs). Knowledge may for instance be generated in an R&D department at one plant and then later this knowledge shall be shared and transferred into operational knowledge when ramping-up production in another manufacturing plant. Even though several studies (e.g. Polanyi 1962; Teece 1977; Zander and Kogut 1995; Dyer and Nobeoka

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2000; Kohlbacher and Krähe 2007; Madsen 2009) have studied manufacturing and production knowledge this field appears to be immature because as stated by Ferdows (2006) "*…scholars in the field of operations management are almost absent in the knowledge management literature and our practitioners are often relegated to the back seat in their companies' knowledge management campaigns*".

There may be a number of reasons why scholars and practitioners within the field of operations management (OM) are focusing very little on knowledge transfer and knowledge sharing. First of all it is difficult to work with knowledge. Knowledge can for instance be tacit and therefore knowledge transfer most often involves organizational changes and even unlearning may be needed among individuals and on the organizational level. Profound learning programs will be needed particularly when new competences, new habits and new attitudes have to be transferred. The purpose of this chapter is therefore to give an introduction to knowledge management in IMNs/IONs. First different types of knowledge in a manufacturing environment will be considered in relation to different task situations. Second, explicit knowledge, non-normal operations and tacit knowledge will be discussed. Finally, the influence from the changes in organizational settings when transferring manufacturing facilities and knowledge from one location to another will be discussed.

2 Methodology and Case Context

This chapter is based on longitudinal studies in three large Danish manufacturing companies and in one German company. The three Danish companies are operating on a global scale and employing more than 10,000 each, whereas the German company globally employee above 2,500. Five of the cases are studies of knowledge transfer when moving manufacturing facilities and case E is concerning internal knowledge sharing within company 1.

The main methods that have been used throughout this study is the case study method (Eisenhardt 1989; Voss et al. 2002; Yin 2003; Swanborn 2010). In addition action research (Westlander 2006; Thorsrud and Emery 1969) has been used in four cases when developing and testing new models for knowledge sharing and knowledge transfer. Nearly 100 semi-structured interviews and 20 focus group interviews have been conducted at all levels in the companies. In addition a number of talks, observations and survey of documents have been made. The main focus has been on knowledge in relation to tasks on the shop floor in a manufacturing environment but the study has involved all levels in the organization i.e. from the unskilled worker to the responsible general manager. The studies have been conducted in manufacturing plants in Denmark, Mexico, The Czech Republic, China and Germany (Table 1).

In this section methodology and cases have only very briefly been introduces. More information of methodology and cases and a profound description of methodology can be found in earlier work (i.e. Madsen et al. 2008, 2010; Madsen 2009).

Table 1 Main features of transfer processes

Case/company	A/1	B/2	C/3	D/1	E/1	F/4
Manufactured products/tasks	Valves	Electric machines	Electronics	Valves	Production Planning	Compressors
Duration of research	2½ years	2½ years	2 years	1½ years	1 year	2½ years
Employees involved	120	150	20–25	20–25	18	100+
Nature of manufacturing system and equipment	Manual assembly on workbenches and semi-automatic manufacturing equipment	Automated and semi-automated manufacturing, not standard equipment,	Automated manufacturing, high tech standard equipment	Semi-automatic manufacturing equipment not standard equipment	Development of knowledge sharing among planners in factory for manufacturing	China: Manual assembly. Germany and Mexico: semi-automated
Manufacturing relocations	Within Denmark	Denmark–Mexico	Denmark–the Czech Republic	Denmark–China	No relocation	1. German–Mexico and back 2. Germany–China
Characteristics of transfer process	Gradual transfer, sending plant closed down	"Big bang" transfer in one go	Establishment of parallel production	Establishment of parallel production	No transfer	1. First transfer failed 2. Second transfer successful

3 Identification of Knowledge Task Situations in a Manufacturing Environment

As a first step in knowledge transfer within IMNs/IONS; the different categories of knowledge first need to be structured e.g. by the use of the model illustrated in Fig. 1. The model illustrates how different dimensions of tasks are related to uncertainty and complexity and how these tasks make up four distinct work situations. These different task situations require different competencies, means and organizational support. They also depend on different representations of knowledge. On the complexity dimension a less complex task is expected to be carried out by a single operator whereas more complex tasks usually require the involvement of several operators and specialists with different kinds of knowledge and experience. The uncertainty axis may similarly be divided into a less uncertain and a more uncertain task situation; the former characterized by a high degree of predictability and regularity, and the latter dominated by a lack of knowledge of what incidents may happen and when.

First the model will roughly be illustrated through case C and then later discussed in relation to knowledge sharing and knowledge transfer in IMNs/IONs.

> A new operator is operating and monitoring a high tech production line where electronics components are placed on printed circuit boards by the use of Surface Mounted Technology (SMT). The technology is rather advanced and a key machine picks and places up to 20 components per second on a circuit board. The operator has been externally educated and been trained for almost half a year in performing the job. In "Normal Operation" the operator is checking quality, adding components by splicing rolls of components to empty roles, operating and monitoring the high tech line by the use of nearly 17 monitoring screens. "Operations with Disturbances" shows up from time to time and the new operator have to call for help from a more experienced operator. Particularly the dispensing of paste for soldering sometimes call for extra attention. Even though a number of measurements and control systems handle this process "*the dispensing of paste is sometimes like pulling a rubber boot out of the mud or like having dough to leave a tin and this is hard to describe*" is the comment from the operators. The technology is rather robust but particularly in case of "Systemic Breakdowns" management has made access to expertise knowledge outside the company available.

Normal operation constitutes a situation where everything functions as planned and prescribed. As illustrated in the case above operators are normally relaxed while they carry out their normal job and routines. In this situation the tasks in "Normal Operation" are typical like starting up manufacturing equipment, filling up magazines with component and monitoring automatic equipment, which work as intended. Kusterer (1978) defines knowledge related to this kind of work as "*basic knowledge*" and through the field studies it was experienced how the less-experienced operators to some extend used drawings, Standard Operational Procedures (SOPs), maintenance instruction, quality instruction and manuals. In the development of the model (Fig. 1) the field studies revealed how employees on the shop floor used these documents especially to train new members of staff by using them as a vehicle for discussions between the experienced operator and the new operator. When sharing knowledge or transferring knowledge of "Normal

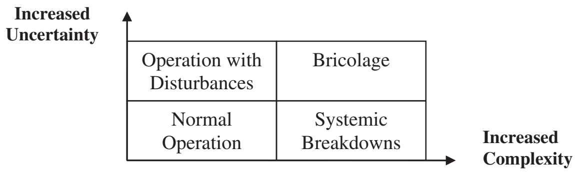

Fig. 1 Dimensions of task situations on the shop floor Madsen et al. (2008)

Operation" in IMNs/IONs this situation has therefore been identified to call for well-arranged documentations that are easy to understand and these documents are needed for training in executing tasks of normal operation at a work station.

Operations with Disturbances denote that operators on the individual level experience incidents that occur randomly and call for an extra effort what may be referred to as "*supplementary knowledge*" (Kusterer 1978). In case A, D and F it could be a spot of rust or a burr on the component to be assembled, which the operator had to let pass, remove or decide if he had to scrap the component. It could also be unplanned stops of a machine due to wear of tooling, or it could like in case C be stops or disturbances of dispensing paste for soldering. Our field studies have illustrated how know-how about how to handle these disturbances was possessed by experienced individuals when operating equipment and the know-how about how to solve this kind of disturbances was far beyond what could be described in Work Instructions. When transferring manufacturing facilities from one location to another management realized that much more internal and even additional external education and training was needed for each employee to develop a broader understanding in order to be able to discover and to act in case of disturbances.

As different plants in IMNs/IONs most often depend on each other a focus on how to reduce "Operations with Disturbances" will often take place and internal and external training and learning programs will therefore become important.

Systemic Breakdowns. In this situation incidents do not readily point to a solution; rather they require a great effort of diagnosis, mainly due to a complex set of interaction between technologies and people. Manufacturing equipment normally combine a large number of different sophisticated technologies e.g. robots, PLC-controls, computer-control, pneumatics, hydraulics, electronics, mechanics, CNC-tooling machinery with a high complexity. Our field studies identified how unskilled operators found it difficult to cope with this situation, and the complexity called upon a diverse set of skills, know-how, and a social dimension embedded in the informal task environment of the work place. The description from case C above illustrates how access to know-how from experts outside the company was important. The access to other experts could also be made internally in the company (experienced in case A and B).

Our field studies also revealed how this kind of work situations call for more holistic knowledge, skills and competences among employees within a manufacturing environment to avoid that a problem from one place on the line result in more problems at other places on the line. Therefore our studies illustrate how management in IMNs/IONs needs to support systematic problem solving.

Bricolage. The term bricolage (Lévi-Strauss 1966) is used for incidents where situations are dominated by a high degree of complexity and therefore call for profound knowledge, know-how and experience of each individual within a whole group of employees. Because of the mutual interplay of different technologies, skills, and organizational units, this situation requires a combined effort of several persons in making creative and resourceful use of whatever materials are at hand. The more uncertain and ambiguous the situation is, the more it relies on situated knowledge tied to the relational practices on the shop floor. The example from case B below illustrates a situation of "Bricolage" where a whole group of people having different educations, skills, knowledge and competences were trying to solve a complex problem:

> While a thin stainless steel pipe was pressed into a component, dents were formed on the pipe, and all components had to be scrapped. To solve the problem all trades and professions, i.e. operators, skilled set-up fitters, technicians, quality department and engineers from different departments, were working together to find out what caused the problem and how to solve it. An operator explained that "*sometimes we say that there are ghosts on the line, and everything goes wrong on the line*".

As argued in the introductory section, "Bricolage" calls for intuition, improvisation competencies and training of a group of people representing different skills, disciplines and experiences. Therefore, task situations related to "Bricolage" are far from what can be described in a work instruction, and remains difficult to document or to express and therefore even difficult to talk about. In the IMNs/IONs the situations of "Bricolage" are therefore the most challenging to handle while it is difficult to set up mundane solutions to this kind of complex problems, thus, adding a dimension dealing with resource-fullness and improvisation to understand the manufacturing process.

4 Management of Explicit Knowledge in IMNs/IONs

Within the knowledge management literature there is mainly two different approaches i.e. the objectivist perspective on knowledge focusing on explicit knowledge and the practice-based perspective of knowledge focusing on tacit knowledge (Hislop 2013).

Davenport and Prusak (1998) define explicit knowledge to be "thin knowledge" of "low viscosity" and in line (Johnson et al. 2002) find that explicit knowledge holds a focus on data i.e. the "know-what" or the more scientific knowledge "know-why". Within IMNs/IONs the explicit knowledge like data and information can be relatively easy to share. Our studies of knowledge transfer in manufacturing relocation showed how managers most often tend to focus on explicit knowledge transfer like preparation of drawings, work instruction and a number of other documents but neglecting the tacit side of knowledge among individuals and groups of employees. Several studies (e.g. Zander and Kogut 1995; Kohlbacher and Krähe 2007) have illustrated how a good foundation of explicit knowledge is important and may form the basis for knowledge sharing and knowledge transfer. However, our studies of different task situations (Fig. 1) illustrated that a focus on explicit knowledge was mainly supporting “Normal Operation” whereas more complicated tasks where employees become able to handle tasks like “Operations with Disturbances”, “Systemic Breakdowns” and “Bricolage” call for much more time and learning programs.

A sharing and transfer of explicit knowledge within IMNs/IONs may appear to be relatively simple to carry out through a strong internet connections. However, our studies in the field have revealed that a conversion of explicit knowledge is necessary. In line with other studies (e.g. Zander and Kogut 1995; Kohlbacher and Krähe 2007) our field studies identified how a “Combination” process (Nonaka and Takeuchi 1995) including conversion of explicit knowledge to new explicit knowledge is important to make the receiver able to understand instructions, drawings etc. in relation to his background and experiences.

5 Tacit Knowledge and Non-Normal Work Situations in IMNs/IONs

The quotation from Polanyi (1966) “*we know more than we can tell*” is often used to explain the difficulties of how to identify, how to transfer and how to share tacit knowledge. In this section the focus will therefore be on tacit knowledge i.e. the practice-based perspective on knowledge (Hislop 2013).

Davenport and Prusak (1998) define tacit knowledge as skills and competences to be “thick knowledge” of “high viscosity” which therefore is difficult to identify and difficult to disseminate to others. Johnson et al. (2002) use the term “know-how” in relation to tacit knowledge like skills and experiences and expand the concept of tacit knowledge by also introducing the notion of “know-who”. In IMNs/IOMs the “know-who” is particular relevant because in large global network it is no longer a question of “know-who” within the local organization but globally.

In Fig. 1 the 2 by 2 model was introduced and explained through two case situations. As may be noted from the case stories, much of the knowledge associated with “Normal Operation” may be expressed in explicit forms. If not available, an effort to up-date the documentation of the processes will be needed in IMNs/IOMs. In contrast, the incidents of the three non-normal situations i.e. “Operations with Disturbances”, “Systemic Breakdowns” and “Bricolage” call for knowledge that is primarily based in the minds and hands of skilled operators and technicians. Through our case studies we observed that most often operators were not aware of their knowledge; they just performed a set of tasks. Therefore, tacit knowledge in a manufacturing environment should be observed when an activity is triggered and subsequently enacted. Nor are operators aware of the collective behavior displayed when they are engaged in solving “Systemic Breakdown” or “Bricolage”.

Our case studies revealed that operation units had developed informal modes of dealing with disturbances and systemic breakdowns. An operator experiencing a problem would try to remedy it himself, and if unsuccessful he would as illustrated in the case description in Sect. 1 gradually involve colleagues and supporting technicians and engineers. Especially in company 3, the informal working modes rested heavily on a corporate culture strongly supported by management. In a transfer of manufacturing activities, it is important, but difficult, to establish such informal working modes in the new production site, not to speak of developing a culture supportive of the performance objectives of the company.

Still, it is important to recognize that not all hidden knowledge can or should be transferred to a new site; especially when new technology is introduced or when certain practices are not desirable, therefore unlearning may be needed.

A simple, but systematic approach (Madsen et al. 2008; Madsen 2009) addressing this difficult issue of identifying and transferring tacit knowledge is illustrated below:

1. *Identify a number of triggers*

The first step is to identify a number of triggers, i.e. incidents calling for performing a task that lies beyond "Normal Operation". Examples from the case studies include the discovery of a spot of rust, a burr, a whistling valve, a stop on an automated line, or a malfunction of a welding machine. Our studies identified that operators can relatively easy give examples of what is important in relation to an operation. (What is normal? What is non-normal? Are questions that can be asked).

2. *Enact the operation*

The second step is to let an operator explain what he/she does in such a situation, or to show it in practice by enacting the operation. In the case of "Systemic Breakdowns", a number of good practices are often available. In other areas, for example operation of airplanes, the crew know what to do collectively in case of a fire or an emergency. However, it is not sufficient to hear about instructions in a class room setting but to involve and train persons collectively in a simulated, but real life setting.

3. *Propose ideas for training*

The third step is to propose ideas for training of the various task situations. Training may address four different needs: (1) training the individual operator to a specific job to handle the normal operation including SOP's and other instructions; (2) providing opportunity for the individual operator to develop know-how and supplementary knowledge, which may enable the operator to handle disturbances and uncertainties related to the specific job; (3) preparing and training a group of operators and the team of supporters to be able to handle the operation of a production group or production line with focus on the mutual interplay; and (4) training the group of operators and the team of supporters to be able to handle complex and uncertain situations at the group level.

4. *Design a training program*

The fourth step is to design a training program. Many factors should be considered, for example the motivation on part of the sending organization to share their knowledge which we denote as a Dispatching Capacity, and the absorptive capacity in the receiving organization.

The interaction with the companies during the case studies led management in four of the cases to introduce more specific training with an outset in experienced disturbances. Management realized that they needed to raise the level of skills among operators, and furthermore to build up a more extensive operational support capacity to handle disturbances to supplement the technical support capacity already established.

5. *Using the method*

The method above has been tested in four cases. In case D, which can be regarded as a typical IMN/ION, a group of Chinese engineers visited a Danish site to improve their knowledge in key production processes and to have introduction to the product and the production planning settings. Operators were designated to explain one of the processes and were asked to identify five to ten critical incidents of non-normal operation. At first, they were a bit hesitant, but soon they realized that this was an effective way of opening up for their experience and to get engaged in handling incidents based on their own experience. The same method was used in case E where an internal knowledge sharing program was set up for planners to improve their knowledge sharing within the company. In this case the method described above and the 2 by 2 model illustrated in Fig. 1 was used by expert planners when developing an internal learning program to improve knowledge sharing. Even though this learning program was concerning how to utilize a computer based ERP system the planners emphasized how focus on non-normal operations exposed their challenges and improved their learning and knowledge sharing.

In case F the method was used in a typical IMN/ION i.e. in a Chinese manufacturing plant to give new operators a general understanding of the manufactured product at an internal course by disassembling and assembling a whole product (inspired by Patriotta 2003). In this case the company had suffered from quality issues and a high turnover from blue collar workers and the model proved its ability to generate a general understanding of the manufactured product and thus improving competences.

6 Organizational Challenges When Relocating Manufacturing in IMNs/IONs

Our study of knowledge transfer in IMNs/IONs and in relocation of manufacturing facilities has identified a number of uncertainties and particular two dramatic shifts in the organizational settings were identified to take place through the whole

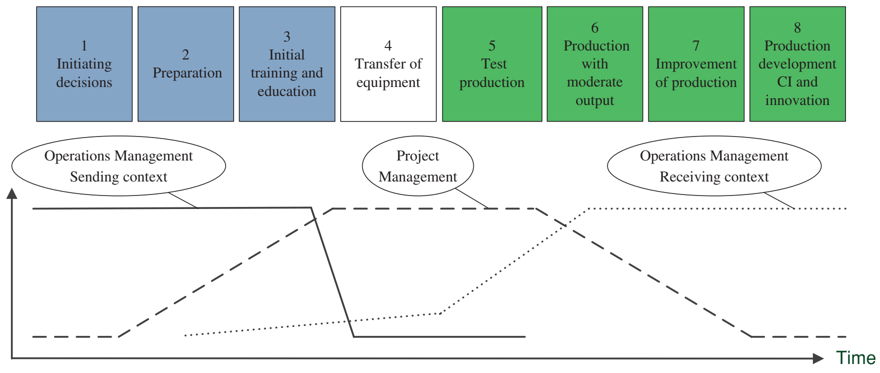

Fig. 2 Organizational changes through a transfer process Madsen (2009)

relocation and knowledge transfer process. The first organizational change gradually takes place before a transfer and in the phases of preparation (the light blue boxes in Fig. 2) where the organization of normal operation is challenged and will experience a huge change as a new project organization is developing. Our field studies identified how a number of extra tasks like: (1) to build up extra stocks, (2) to upgrade documentation and equipment, (3) to identify individual and group knowledge, attitudes and habits particularly about how to solve disturbances, malfunctions and non-normal operations in the dispatching unit and (4) to prepare a training program for employees from the receiving unit are put on the organization of normal operation in the dispatching unit before the transfer.

The shift from Operations Management (OM) where employees are focusing on “repetition, evolutionary change, equilibrium, balanced objectives, stable resources and stability” (Turner 1993) is therefore changing and Project Management (PM) gradually is emerging and overtaking the scene (illustrated in Fig. 2).

The PM organization has a very different approach by being “unique, finite, focusing on revolutionary change, disequilibrium, flexibility, risks and uncertainty and having unbalanced objectives and transient resources” (Turner 1993). However, all the while the PM organization is overtaking the scene from the OM organization in the sending context the OM organization still has to be in full operations and is even more under pressure. Stocks have to be building up, production therefore has to increase, explicit knowledge has to be upgraded and restructured in a way that the receiving organization is able to understand and to use the documents. In addition training programs have to be developed even by involving the receiving organization to transfer tacit knowledge.

From a management perspective this calls for an extra effort among employees in the normal OM organization in the sending unit where the employees also face uncertainties about where to get a new job. Naturally this will influence the knowledge transfer process and management has to consider these extra issues in the knowledge transfer process.

	Absorptive Capacity in receiving context	
	Low	***High***
Green field site	Extremely challenging	Challenging
Brown field site	Challenging	Relatively easy

Fig. 3 Absorptive capacity in relation to *green/grey* field site Madsen (2009)

While the production is down and equipment is moved and set up in the new location (the white box in Fig. 2), the organizational settings can be characterized as a typical PM organization where external employees with the help of selected employees of the normal OM organization are moving equipment to the new location. Then after the transfer of equipment a second dramatic shift in the organizational settings takes place in the receiving unit. This time the organizational settings are shifting from PM and to a new OM in the phases of ramp-up. (Green boxes in Fig. 2).

Supporting the process—the "*Dispatching Capacity*" *and* "*Absorptive Capacity*"

As illustrated above a number of organizational challenges show up when manufacturing facilities and knowledge are transferred to a new location. Our field studies have identified three major parameters in the dispatching unit which can support the knowledge transfer process in manufacturing relocation i.e. (1) to have employees to stay in their jobs as long as needed, (2) to motivate employees to make an extra effort to build up stocks, prepare training programs and to upgrade documentation and equipment before transferring manufacturing equipment and (3) to motivate employees to act as teachers and mentors for new employees in the receiving unit while the employees from the sending unit are getting engaged in new jobs. For this capacity this paper use the term "Dispatching Capacity" which can be regarded as disseminative capabilities (Oppat 2008), and this can be regarded as the counterpart to the "Absorptive Capacity" (Cohen and Levinthal 1990) in the receiving context.

When planning a relocation of manufacturing facilities in IMNs/IONs it is important to plan in relation to experiences of the receiving context and to build on previous experiences. From a learning perspective it may be relevant to challenge the receiving unit through suitable tasks that will meet individuals and groups in the receiving unit. Several researches (e.g. Cohen and Levinthal 1990; Zahra and George 2002; Lyles and Salk 2007) have investigated the importance of "Absorptive Capacity", which is the ability of a firm to recognize the value of new information, assimilate it, and apply it to commercial ends.

The figure above illustrates our findings of these challenges and a brief discussion related to the organizational changes from PM to OM will be made.

Low absorptive capacity—green field site is in Fig. 3 illustrated to be extremely challenging. The context of low absorptive capacity can best be described through case B where a whole production line was brought to a new manufacturing plant built on a green field site. The city was chosen because a number of related industries were in the area. However, as explained by some of the first employees on the managing level; "*At the beginning there was nothing here; we were using garden furniture made of plastic in the offic*e". The whole logistic set up about how to get supplies through customs or where to find spare parts was also challenging. "*We were often driving around to find simple spare parts—remember here we have no Do It Yourself stores where you can buy different parts and tools*", was the comment from a technician on the management level.

Our studies of knowledge transfer in IMNs/IONs have also revealed how it can be difficult to hire well experienced employees on a green field site location having Low Absorptive Capacity. Our studies illustrated that even though operators could have experiences from related industries, management was surprised to experience how long time it took to understand the new product, to operate equipment and to learn how to work together as a team.

An important factor in the transfer of tacit knowledge is therefore to make use of the Dispatching Capacity where operators and technicians from the sending unit act as trainers and teachers. However, this requires flexibility as stated in a focus group interview of blue collar workers and technicians who were reflecting on their training issues in a green field site: "*You need to have some sort of robustness and you need to be flexible—it is no use if you sit down in a corner and start crying because equipment is not ready for production—then you need to be able to find something else to do*".

High Absorptive Capacity—Brown Field Site. On the other hand our studies of IMNs/IONs have revealed how it can be relatively easy to transfer manufacturing facilities and to ramp-up production on a brown field site where a high absorptive capacity is present in the receiving context. In this case an existing production will already be in place and therefore managerial structures of HR, how to handle stocks, logistic, ICT, suppliers etc. will be in place and a new production can be added on.

In this situation the transfer of equipment was not experienced to be a problem basically because the responsible engineers could handle the project management. However, the transfer of knowledge and development of experiences and tacit knowledge including details of logistics, maintenance, who to contact when disturbances showed up etc. were found to be the major challenge through a transfer.

7 Implications: Knowledge Transfer and Manufacturing Relation in IMNs/IONs

A bridge is needed between the sending and the receiving contexts when complicated knowledge like data, information, cognitive knowledge, skills, habits, attitudes and culture has to be transferred. Therefore it is important first to identify the different kinds of knowledge in relation to the different task situations that take place on the shop floor in a manufacturing environment and based on that to develop learning programs particularly to transfer tacit knowledge and to develop knowledge on a group level. However, once a transfer of manufacturing facilities is announced, a number of extra tasks are put on the employees in the sending unit when a complex organizational change from OM to PM takes place in the dispatching unit before the transfer. In the receiving context the employees have to learn individual tasks to be able to carry out their new work. Furthermore employees have to develop habits, attitudes and even a culture of how to work together and this takes place when the organizational structure is shifting from PM to OM.

Within the "agile company development" it is found important to have "users onboard" (Mikkelsen and Riis 2013) and to adjust and to "embrace change" to be able to handle the changes throughout a project. Andersen (2006) finds that in renewable project (e.g. transfer of manufacturing facilities and knowledge) the traditional task-oriented approach developed originally for building and construction projects does not work and in a recent work by Eskerud and Jepsen (2013) the involvement of stakeholders is found to be the most important.

When transferring knowledge in a manufacturing relocation it is therefore important frequently to take two steps backwards to get a holistic overview of technology, plans and the participating people to be able to adjust resources and plans when circumstances are changing. The whole transfer of knowledge involves comprehensive learning at all levels in an organization. Knowledge management research within IMNs/ION is still immature and there seems to be need for much more focus on this field in the future.

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Coordinating Production Improvement in International Production Networks: What's New?

Torbjørn H. Netland

Abstract How can a multinational firm simultaneously improve the productivity of all its factories? A popular answer is to develop and deploy multi-plant production improvement programmes. Inspired by the sustained success of the Toyota Production System, many companies develop their own company-specific production systems (XPS) and implement them in their dispersed networks of plants. This paper explores what is new in how multinational companies coordinate the improvement of operations on a corporate level. A multiple-case method is used to investigate the production improvement programmes of four Scandinavian multinationals: Elkem, Hydro, Jotun and Volvo. It is suggested that an XPS differs from how companies traditionally have organised improvements in production in three ways: First, it is a lasting strategic programme and not a project. Second, it is tailored to the specific characteristics of the company. Third, it creates a common corporate language for production improvement in all parts of an organisation and in all corners of the world, enabling an easier transfer of practices and learning among plants in the network. These characteristics offer several implications for practice, especially for multinational firms that have yet to start coordinating production improvement in their networks of plants.

Keywords Production improvement · International production networks · Multinational companies · Lean production

1 Introduction

The rapid economic and political changes of the past few decades have fundamentally changed the rules of the game for global manufacturing firms. In order to remain competitive today, all plants in a production network must be integrated into a global

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strategy (Ferdows 1989, 1997; Bartlett and Ghoshal 1998). Research on international manufacturing strategy separates between *configuration* and *coordination* issues (Porter 1986). After a rapid global growth in the past decades, many multinationals now face the task of effectively configuring and coordinating an integrated factory network (Ferdows 1997; Colotla et al. 2003). Related to coordination, a timely question to ask is: how can firms effectively increase the productivity of all their plants?

A popular answer has been to develop and deploy company-specific production systems (Netland 2013). A collective term for these systems is 'XPS'. An XPS is a production improvement programme tailored to a specific company. The 'X' stands for the company's name, and 'PS' is an abbreviation for Production System, or similar. Inspired by the sustained success of the Toyota Production System (TPS), companies as different as Alfa Laval, Boeing, Carlsberg, Caterpillar, Ecco, Electrolux, Grundfos, Harley Davidson, Heinz, Honeywell, REC, Scania and Siemens—to mention a very few—have recently introduced their own XPSs. Embarking on such a network approach to production improvement is a serious and costly decision. Failure, even in single plants, is an expensive experience.

Considering the popularity of XPSs in industry, the corresponding academic literature is scarce and underdeveloped. The *multi-plant* aspect of production improvement is an area that is not well understood (Netland and Aspelund 2014), whereas the literature is correspondingly richer on single-plant improvement. This paper explores what XPSs are, and how they differ from traditional improvement projects in plants. It seeks to answer questions such as: what is *new* with XPS? And, importantly, what does it mean for managers who operate global production networks? The literature is reviewed in order to understand the motivation behind the recent trend, and is used to develop propositions for discussion. The propositions are then compared with an investigation of the XPSs of four Scandinavian multinational companies: Elkem, Hydro, Jotun and Volvo.

2 Literature Review

How to strategically improve production is one of the most fundamental questions of operations management. This question is now gaining importance for companies that operate international production networks. Since the days of Taylor and Ford in the early 20th century, research and practice has suggested several templates for production improvement. Schonberger (2007) offers a useful account of the recent development of such templates. The most popular ones include just-in-time production (Ohno 1988), total quality management (Juran 1988), lean production (Womack et al. 1990), six sigma (Henderson and Evans 2000), world class manufacturing (Schonberger 1986) and business process reengineering (Hammer and Champy 1995). Since the 1990s, following the growth of multinational companies, it has, been an on-going trend to develop XPSs based on these templates (Feggeler and Neuhaus 2002; Netland 2013).

One company that has been remarkably successful in continuously improving over time is the Toyota Motor Corporation. Toyota's sustained improvement is a quality that few other firms have been able to copy (Bateman 2005; Schonberger 2007). The lasting success, which is persistent across Toyota's global production network, is largely attributed to its famous TPS. TPS is a holistic management philosophy developed by Toyota after World War II (Ohno 1988; Shingo and Dillon 1989; Womack et al. 1990; Liker 2004). Since the 1980s, many companies have tried to copy bits and pieces from Toyota without paying sufficient attention to the totality of the TPS (Feggeler and Neuhaus 2002). More and more companies have realised that a systematic approach to production improvement is needed—and develop their own XPSs for that purpose. Therefore, it can be suggested that a novel characteristic is that *XPSs are corporate strategies for lasting production improvement* (Proposition 1).

Contingency theory (Sousa and Voss 2008) suggests that the suitability of practices is dependent on contingencies to the firm. Experience has taught companies that a certain amount of adaptation of the recommended practices and templates is needed for implementation to be successful. Adaptation means that practices are adjusted to fit the specific company. At the same time, Jensen and Szulanski (2004), who study how practices are transferred in intra-firm networks, warn that too much adaptation increases 'stickiness' and hinders effective sharing of the practice. In a literature review on multi-plant improvement programmes, Netland and Aspelund (2014) found that the majority of empirical studies argue in favour of strong adaptation of proven practices. Companies seek to collect and adjust practices so that they fit their characteristics and business better, without allowing full heterogeneity at the subsidiary level—and develop XPSs for that purpose. Thus, it can be proposed that *XPSs consist of known improvement practices that are tailored to the multinational firm's contingencies* (Proposition 2).

After rapid global growth, many multinationals now face the challenge of effectively structuring, managing and operating a globally dispersed production network (Colotla et al. 2003). Global companies see potential synergies for improvement, just as they have done in purchasing, marketing, production, logistics and product development earlier. Seminal research in the field of international business (e.g. Ghoshal and Bartlett 1988; Kogut and Zander 1993; Jensen and Szulanski 2004) claims that the ability to efficiently share knowledge in the intra-firm network is the prime reason for the existence of multinational companies in the first place. A global approach to improvement can ease benchmarking and the transfer of successful practices among sister plants (Szulanski 1996; Jensen and Szulanski 2004). Thus, global companies seek efficient platforms to share production improvement knowledge in the network of plants—and develop XPSs for that purpose. It can hence be proposed that *XPSs are platforms for sharing production improvement know-how in the global production network* (Proposition 3).

3 Research Method

In order to see whether the propositions make sense, a multiple-case research methodology has been deployed. Case studies are well suited to investigate new practices in contingency-rich environments (Voss et al. 2002; Yin 2009; Barratt et al. 2011).

This paper builds on available case studies, which Lewis (1998) suggests is a sound methodology for this type of research. Using convenience sampling (Stake 1994), four renowned Scandinavian multinational companies with their own XPSs are included: Jotun AS, Elkem AS, Volvo AB and Hydro ASA.

All four companies met at a workshop on XPSs in Trondheim, Norway, in May 2011. Subsequent to the workshop, the companies have been visited by researchers for the purpose of gaining a detailed understanding of their respective XPSs. Three master theses, written at the Norwegian University of Science and Technology, have made in-depth investigations of the two case companies Jotun and Elkem. Aa and Anthonsen (2011) and Eide (2012) have studied the implementation of Jotun's XPS in factories in Norway, Indonesia, Saudi Arabia and the United Kingdom. Alvær and Westgaard (2012) studied the implementation of Elkem's XPS in factories in Iceland and Norway. The author supervised these theses and has personally performed research on Volvo (c.f. Netland and Sanchez 2012; Netland and Aspelund 2013), visiting more than 40 Volvo factories worldwide. For the fourth company, Hydro, the author has participated in several workshops and discussions with the corporate XPS office. For all companies, detailed internal documentation of the respective XPSs and their implementation in the companies' networks has been provided.

The presentation of the empirical data follow the typical procedure for multiple-case studies (Eisenhardt 1989; Choi and Hong 2002): each case is first presented separately, then discussed together.

4 Case Descriptions

In this section, the four cases are described individually in succession.

4.1 The Elkem Business System

Elkem is a Chinese-owned manufacturer of the earth minerals silicon and carbon. Elkem is headquartered in Oslo, Norway. Its core competence is high temperature furnace technology and high-temperature process operations. Elkem's global operations network consists of 2,500 employees spread across 12 production plants in Norway, Iceland, the US, Brazil, South Africa and China.

Elkem is a pioneer in Norway when it comes to XPS. Through a joint venture with Alcoa at the end of the 1990s, Elkem got to know Alcoa's XPS (the Alcoa Business System) and decided to develop a similar production improvement system. Key reasons to develop its own XPS was to ensure a long-term improvement strategy in Elkem, and thereby reduce several corporate cost cutting initiatives driven by external consulting groups. The Elkem Business System (EBS) was heavily influenced by the principles, methodology and tools that Alcoa used. Alcoa's system—and hence the EBS—is founded on the philosophy of the TPS. The EBS 'house' is shown in Fig. 1.

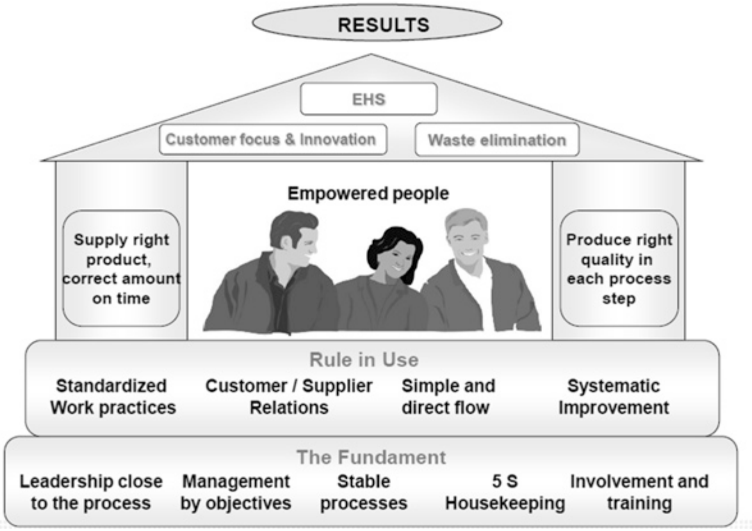

Fig. 1 The Elkem Business System house (*Source* Elkem AS)

The EBS house consists of a foundation with five main principles ('leadership close to the process', 'management by objectives', 'stable processes', 5S housekeeping' and 'involvement and training'). Above the fundament, there are four 'rules in use' ('standardised work practices', customer/supplier relations', 'simple and direct flow' and 'systematic improvement'). Two pillars and 'empowered people' support the 'roof of targets and results'.

To assist in the implementation of EBS in all the plants in the production network, an EBS Center with lean experts was established in 2000 in Norway. The five EBS coaches travel to the plants and offer onsite training in EBS. Elkem emphasises empowerment of employees and the EBS Center aims to accelerate the implementation process by developing the employees' motivation and ability to solve problems. The EBS Center also performs annual EBS audits in the production network and is responsible for regular updates of the EBS per se.

4.2 The Jotun Operations System

Jotun is a multinational manufacturer of paints and protective coatings. Jotun's global operations network consists of about 9000 people in 43 countries. It is a family-owned company headquartered in Sandefjord, Norway. The company has delivered strong results over several years and is still expanding through organic growth. Jotun is a market-driven firm that offers the highest quality of paint solutions.

Nevertheless, sharpened competition and a need to share good practices between plants, made Jotun embark on an XPS strategy in 2007. Since then, Jotun

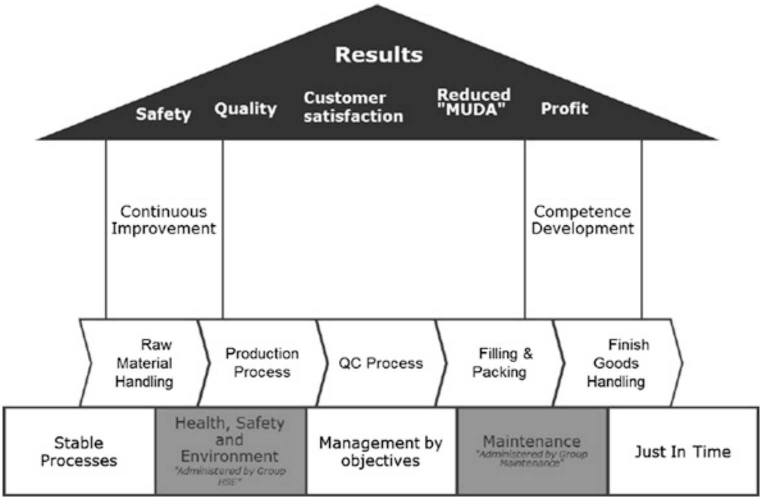

Fig. 2 The Jotun Operations System house (*Source* Jotun AS)

has worked with lean production, developing the Jotun Operations System (JOS) over several years. By including the main manufacturing processes for paint, JOS is tailored to the needs of the industry. The JOS 'house' is shown in Fig. 2.

The JOS house consists of four key components: fundamental operations principles, best practice process management, two pillars of development and, at the top, the expected results. The purpose of JOS is to improve the productivity of all Jotun plants worldwide. Two of the fundamental principles—'Health, Safety and Environment' and 'Maintenance' (grey in Fig. 2)—are of particular importance for Jotun as a chemical processing company.

To assist and govern the implementation of JOS in the global production network, Jotun has established the Group Operations Improvement (GOI). GOI carries out audits of JOS implementation in all plants, facilitates sharing of best practices and coaches the implementation. All plants have appointed a lean coordinator. A special focus in Jotun has been to increase the general knowledge level in both technical operations and lean thinking. Therefore, since 2007, GOI arranges the Jotun Operations Academy with courses and qualifications for all employees worldwide.

4.3 The Volvo Production System

Volvo is a leading manufacturer of heavy vehicles. Volvo's main products include trucks, buses and construction equipment for the world market. Volvo employs about 100,000 employees globally. It is listed on the Stockholm Stock Exchange and is headquartered in Gothenburg, Sweden. After selling off the cars division in 1999,

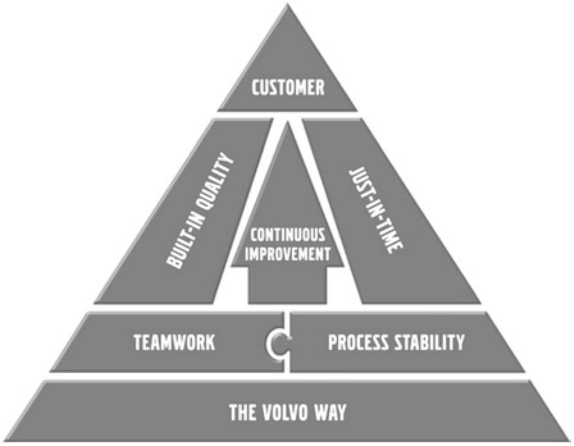

Fig. 3 The Volvo Production System pyramid (*Source* Volvo AB)

Volvo has grown considerably through mergers and acquisitions. Today, Volvo's global production network comprises around 60 plants in more than 20 countries.

Increasing competition on price and a need to increase the competitiveness of its plants resulted in the launch of the Volvo Production System (VPS) in 2007. The VPS pyramid is shown in Fig. 3.

The VPS starts with a fundamental focus on Volvo's corporate values ('the Volvo Way') and ends with an inherent focus on creating value for the customer. In-between are five key operational principles: 'teamwork', 'process stability', 'built-in quality', 'continuous improvement' and 'just-in-time'. The VPS is Volvo's strategic production improvement programme and is strongly influenced by Toyota's original system and lean production.

In Gothenburg, a VPS department is responsible for governing the VPS and supporting its implementation of the global production network. Every plant is assigned a VPS Coordinator, and each regional division is assigned a VPS Global Coordinator. Most plants have their own VPS team. The corporate VPS office also carries out VPS assessments of all plants; finding strengths and weaknesses and suggesting a roadmap for the next steps.

4.4 Hydro's Aluminium Metal Production System

Norsk Hydro is one of the largest industrial companies in Norway. One of its main business divisions, Hydro Primary Metal (HPM) supplies aluminium metal to internal customers in Hydro's extrusion and rolling divisions and to other customers all over the world. HPM's production network consists of aluminium smelting plants in Norway, Germany, Brazil, Canada, Qatar and Slovakia. At these plants, bauxite is transformed into alumina and aluminium through an energy-intensive process of electrolysis. Approximately 5,000 people work for HPM worldwide.

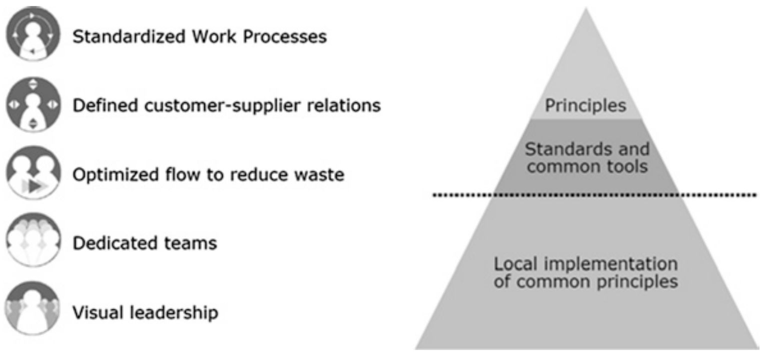

Fig. 4 Hydro's Aluminium Metal Production System (*AMPS*) (*Source* Hydro ASA)

Since the mid-1990s—and up to 2006—HPM had focused on the implementation of total productive maintenance in their plants. However, with foresight of rising energy costs and lower aluminium prices in the global market, HPM believed that a broader approach based on lean production was needed and could deliver a cost advantage to HPM in the market. To develop the new approach, HPM worked closely with Hydro's upstream automotive parts division that had many years of experience with lean and already had its own XPS (the Hydro Automotive Production System).

In 2006, HPM launched the Aluminium Metal Production System (AMPS). Today, Hydro's divisions for aluminium extrusions and rolling have similar systems in place, which are adapted to their specific needs and requirements. Thus, Hydro does not have *one* global system, but rather it has adapted versions for each corporate division (metal, extrusion and rolling). The first live pilot of the AMPS in Hydro was at the Årdal plant in Norway in 2007. Since then, the system has been implemented in all of the smelters worldwide. The standard presentation of the AMPS is shown in Fig. 4.

The AMPS is built around five main principles: 'Standardised work processes', 'defined customer and supplier relationships', 'optimised flow', 'dedicated teams' and 'visible leadership'. Each of these principles has a defined set of standards and tools for each plant to use. Hydro also pays explicit attention to the importance of local adaptation and implementation of the principles (see pyramid in Fig. 4).

Even if AMPS, according to Hydro, is 'a global and mandatory platform for improvement', the plants in the network are given a large degree of freedom to implement it according to their local needs and situations. An example of the effect of AMPS is that one of its plants in Karmøy, Norway, was awarded 'the lean company of the year award' in 2012. An important AMPS slogan reads: 'AMPS is not a project—it's a way of operating'.

Hydro has a small global AMPS team located in Oslo, Norway. The team owns the AMPS documentation and supports implementation in the network. It also arranges a training programme, where more than 2,000 employees have participated; including 750 managers and supervisors. All smelters have local AMPS teams. Hydro does not have a global audit programme, but instead uses self-assessments at the plant level for gauging implementation.

5 Cross-Case Analysis and Discussion

The three propositions derived from the review of the literature are now discussed in light of the four cases.

5.1 Proposition 1: Strategic Improvement Programme

For all cases, the XPSs are strategic improvement programmes. This differs from many other stand-alone and isolated improvement initiatives the case companies have undertaken prior to launching their XPSs. Instead of letting subsidiaries figure out their improvements individually, the headquarters offer a shared system for the global production network. All four cases have developed their XPSs with the intention of establishing a lasting strategy and roadmap for improvement.

With the XPS comes top-management attention—a required, but rare, ingredient in continuous improvement (Liker 2004). All cases have explicitly recognised their XPS as a top-priority for their long-term strategies. The XPS is corporate business, and is not left to the plants alone. Because the XPS becomes part of the bigger organisation, the chance for survival of the system is much better, while attention to improvement can easily drop in single plants in difficult periods (Bateman 2005), the XPS will continue in other parts of the organisation, and hence will still be available when the plant is ready to pursue it again.

5.2 Proposition 2: Tailoring of Known Principles to Fit the Firm

The four companies have all developed their XPSs by choosing available principles that best fit them, from a broad pallet of proven lean production principles. Considering the principles of EBS, JOS, VPS and AMPS, it is apparent that the four XPSs have strong resemblance, which is expected due to their common roots. However, even if the principles stem from the same templates, a tailoring to the unique needs of the firm takes place in the development process of the XPS. The argument is that not all principles suit all companies—as suggested by the contingency perspective (Sousa and Voss 2008). The XPS allows for necessary adaptation. Instead of marrying one template (i.e. lean, total quality management, six sigma, etc.) the company can *strategically* choose from all proven production improvement philosophies. An example is that Hydro—a batch producer of aluminium—focuses on 'optimised flow' instead of 'just-in-time'. 'Optimised flow' is a more suitable concept for batch production.

The tailoring is not limited to the content of the systems. Importantly, the companies often lend their own names and designs to the XPSs, similar to all cases in this study. This serious choice symbolises sincerity and durability. It presumably reduces the 'not-invented-here syndrome' and increases employees' ownership of the programme. Off-the-shelf improvement philosophies do not have these advantages.

5.3 Proposition 3: A Common Platform for Improvement in the Global Production Network

The XPSs of Elkem, Jotun and Volvo are shared platforms for *all* plants and employees in the firms' global operations networks. Hydro has separate systems for different divisions, but these systems are common for all plants in the respective divisions. One obvious advantage for all four firms is that not all plants need to develop and maintain their own improvement programmes. This has been a key reason for the development of the four XPSs in the first place. The drawback is that the firms must use global resources to manage and maintain the XPSs, as all four companies do to various degrees. Elkem, Jotun, Volvo and Hydro believe that their global efforts outweigh the sum of the individual efforts if no XPS was used.

An XPS also creates a *common improvement language*, which leads to easier transfer of experiences and good practices between units in the production network. Thus, the firms make use of one of the strongholds of multinational companies by leveraging the global know-how (Kogut and Zander 1993). This advantage of an XPS is presumably more important for multinational companies with sprawling networks of plants, than it is for small and medium sized enterprises.

5.4 Implications for Managing Improvement in Global Operations Networks

Establishing that an XPS is a strategic and tailored multi-plant production improvement programme being implemented in all plants of an international production network simultaneously, a discussion on the implications for corporate managers remains.

After multinational companies have configured their global production networks, a natural step is to start exploiting manufacturing capabilities around the world. The four cases in this research have suggested that developing and deploying an XPS can be an effective way to coordinate production improvement across subsidiary plants. In cases where the same best practices are valid for several plants in a production network, a shared corporate system has clear benefits. A first recommendation for multinational companies, which do not have an XPS, will then be for them to consider developing one. Elkem, Hydro, Jotun and Volvo provide examples of how the implementation of XPSs can be developed, launched and managed in the networks: they have all set up corporate XPS offices, appointed XPS coordinators and teams in all plants, developed audit schemes and shared practices between plants by means of both codified standards and by rotating people among plants. Of course, the resources spent on measures like these must be weighted against the expected benefits.

It must also be emphasised that the four cases investigated in this paper are all established companies operating in relatively mature industries. It is unlikely that an XPS is a panacea for all companies in all industries. There are several pitfalls that warrant discussion. First, in cases where the international production network, or its environment, is quickly evolving, an XPS is likely to have a more limited effect. For example, if the production network of a firm is constantly changing, as in IKEA's 'footloose strategy' (Ferdows 2008), the XPS would naturally have a more time-limited effect. Likewise, in industries characterised by rapid and disruptive innovations in technology, the relative effects of implementing an XPS can be marginal. Hence, in such environments, other improvement strategies might be more appropriate, like for example Intel's successful 'copy exactly strategy' (McDonald 1998). Second, XPSs presumably have limited effects in cases of highly diversified firms, where best practices in one division are not 'best' in others.

6 Conclusions

Over the last ten years, production improvement has gone from plant-specific initiatives to corporate systems, common for all plants in the company's global production network. Development of such *XPSs* appears to be an on-going trend among manufacturing multinationals. However, despite the popularity in practice, the literature has not yet established an own stream for XPSs. This paper analysed the novelty of coordinating production improvement in global production networks.

The four cases of Elkem's EBS, Jotun's JOS, Volvo's VPS and Hydro's AMPS were investigated. The main differences between XPSs and how firms have traditionally organised production improvement are summarised as follows:

- An XPS is a strategic programme; not a project.
- An XPS is specific to the company; not general.
- An XPS is common for the global production network; not local solutions.

First, an XPS is a lasting strategic programme, not a project. Many firms carry out countless temporary production improvement projects. In contrast, the XPS is infinite—meant to sustain the emphasis and focus across the global operations networks over a long time. It comes with implicit managerial support and attention from the corporate level. As part of a bigger whole, the chance for survival of the system in difficult periods is better. The XPS therefore brings consistency and durability to improvements in all plants within the network. However, this comes at the expense of the need for new strategic directions in times of rapid change.

Second, an XPS combines the strength of proven production improvement principles and the unique composition and adaptation of them to the firm's characteristics and needs. It is clear that Toyota's success with the TPS—popularised as lean production—has heavily inspired other XPSs. However, different systems are not identical; each firm tailors the composition of production improvement principles to fit its needs. An alternative would be to make use of readily available improvement solutions in the market place, which do not necessarily require costly development and maintenance of an own XPS.

Third, an XPS creates a common strategy, and language for production improvement in all parts of a global operations network, enabling an easier transfer of 'best practices' amongst units. This way, each plant does not have to 'reinvent the wheel' when it comes to production improvement. This comes at the expense of local autonomy and solutions tailored specifically to the subsidiary itself, which would make sense if subsidiaries are very dissimilar.

The three characteristics of an XPS offer interesting implications for practitioners and research. It has been established that companies struggle to sustain improvements over a longer period (Bateman 2005; Schonberger 2007). Can an XPS help sustain the improvement work across many plants in a global production network? Based on the investigation of four XPSs, I suggest it can—particularly for multinational companies with similar operations in mature and stable markets. Having an XPS, however, is only a prerequisite. Achieving the potential results, and doing so over time, is a challenging task that warrants further research.

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What's High-Value Engineering and Its Influencing Factors in International Network Operations?

Xueyuan Wang and Yufeng Zhang

Abstract High-value engineering (HVE) makes a great contribution in enhancing the competitive advantage of enterprise and in accelerating regional economic and technological development. The effective management of HVE activities in international business networks has become a topic of increasing importance in recent academic research. Understanding its value creation mechanisms and their influencing factors are critical for this research area. With the globalization of the world economy, engineering arranges its activities around the world. It will face a more complex network and a more dynamic environment, and some additional factors need to be considered based on original value creation mechanism. Therefore, after making clear HVE and its corresponding network issues in international operations, its influencing factors are then discussed from the aspects of value creating stages and international network operations. The influencing factors have then been classified into five aspects which suggest an integrating framework for further research.

Keywords High-value engineering (HVE) · International network operations · Global engineering networks (GEN)

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1 Introduction

Engineering makes a great contribution to the economy and to society by transforming innovative ideas and technologies into valuable products and services. Especially, engineering activities in high technology areas often create high profit and value which will significantly enhance the competitiveness of an organization, an industrial sector or a region. Internationalization has presented new opportunities for organizations to access new markets, talents, capital, and technology, which is also helpful for regional or national economies to find new ways of growth. Developing international high-value engineering capabilities has become a strategic priority for many countries and organizations.

High value engineering (HVE) aims to create higher value for its beneficiaries by engaging in primary and auxiliary engineering activities (Porter 1986). Factors associated with various value creation activities will affect engineering's contribution to the sustainability and competitiveness of its beneficiaries. Engineering functions often rely on two basic methods to develop international operations: an equity-based method and a non-equity methods. Equity-based arrangements include wholly-owned subsidiaries or joint ventures built by merger and acquisition or by Green-field Investment. However, with the rapid progress of internalization, a non-equity based arrangement also become more important, and alliances or cooperation among participants are widely adopted. By internationalization, participants of engineering form an international network, which becomes popular and attractive because of its high adaptability and responsiveness. International network operations will face more challenges, such as increased physical distance between buyers and suppliers, higher transportation costs, increased supply chain length in geography and scope (Craighead et al. 2007), and complex customs processes in foreign locales (Fugate et al. 2012). Therefore, some additional influencing factors should be considered.

Research interests in value are enduring over the past decades; however, what value is and how the value is created in engineering operations have largely been neglected. As HVE in international business networks has not been well understood this paper will consider this issue first. T Although engineering factors analysis has been done by other researchers before, they seldom analyze influencing factors from the value creation perspective, which is the key for understanding and managing engineering activities in the current business environment. In practice engineering usually focuses on various value creation stages, and the key influencing factors which differ. Meanwhile international engineering operations bring in additional influencing factors, which should also be considered. Therefore, factors will be studied which combine aspects of value creation stages and international operations, which can help managers and policy makers prioritize their efforts and create higher value.

2 What's High-Value Engineering and Its International Network Operations?

1. High-value engineering. Previously, the focus of value was mainly on tangible value such as the decrease of capital utilization and the increase of profits and cash flow. As the business environment has become more dynamic and the competition of technology become much fiercer, most researchers pay greater attention to intangible value, such as relationship value and value constellations (Maila et al. 2011). Also they focus on the ability to realize sustainable development by increasing the power to resist risk, to keep and expand market share, to get more added value by innovation, to utilize resources more efficiently and to get capital more easily. Accordingly high value not only means creating high profits but also the power to establish new markets, enlarge the market share, create new dominant technologies, get specific solutions for customers (Corsaro and Snehota 2012), and get a leading role and competitive advantages.

For whom the value is created is not consistent. Customer value theory considers the fact that enterprise should create and offer more value for customers; however, the final purpose is to meet customer demand and realize the expansion of their market share and the sustainable development of the enterprise (Hallikas et al. 2012). The shareholder value theory contends that an enterprise should focus on their operation to realize maximum benefit for investors in order to guarantee the capital supply and the development of the enterprise (Payne et al. 2001). Porter and Kramer (2011) put forward the concept of shared value between societal and economic needs; accordingly they propose that the indirect beneficiaries should also be considered, such as the government, NGO, community and the natural environment. Although the related beneficiaries of enterprises not only contain shareholders, customers, and society but also creditors, managers and so on, the realization of an enterprise maximum value can also be helpful to increase the benefits to all the beneficiaries. In that sense, creating enterprise value becomes the most important thing for enterprise management, and accordingly value-based management theory becomes popular.

High-value engineering (HVE) aims to create more value and continuously make a contribution to direct beneficiaries (e.g. participants, customers, and investors, etc.) and indirect beneficiaries (e.g. government, NGO, society, etc.) to help them get more benefits and keep their competitiveness and realize their sustainable development. The most important aspect of HVE is value creation, as factors influencing its value creation should be managed to guarantee its effective operation.

2. Value creation mechanism. From the so-called functionalist perspective (Sanchez et al. 2010), value can be created from volume function (preventing fragmented purchases), safeguard function (guarantee a certain level of supply), innovation function (cooperation of two or more agents) and market function (contacts with prestigious exchange partners), and so on.

From the relation perspective, value can be created from cooperation and friction. Some researchers consider collaboration and cooperation are beneficial to value-creation (Lee et al. 2012). Ulaga (2003) points out collaborative relationships in business markets offer significant opportunities for companies to create competitive advantages and achieve superior results. Others have found that firms with a competitive advantage prefer industries with less, but not zero frictions, and also that the competitive advantage increases with frictions (Chatain and Zemsky 2011).

From the participants perspective, valued can be co-created (He et al. 2012) with customer, supplier and alliance partner. Customers can offer ideas to improve product value and innovation performance. Berghman et al. (2006) proved that suppliers pleaded for selective collaborations with customers to reap their ideas for additional value. To improve the flow of ideas and materials, many buying firms now work with a smaller number of suppliers and relegate to them product design and producing coordination in the form of outsourcing or off-shoring. While some state that desirable value can be created through strategic alliances, which depends upon the partners' motives and the resources provided to the alliance (Nasiriyar and Dominique 2006).

From the resource-based review, value can be created by employing tangible and intangible resources, e.g. capital, labor, skills, etc. In recent years, researchers contended that value created by intangible resources can hardly be imitated by others; and value is added and created in the process of resources exploration and multi-resources integration (Michel et al. 2008). Resources don't have value naturally-as static resources realize their value only by putting them into application and through the creation of profits (Cristina et al. 2010).

From the process perspective, value can be created in different stages including idea generation, product innovation, production, service and so on. Customers' direct and active participation in idea generation is valued by the enterprises (Witell et al. 2011). Tegarden et al. (1999) found that switching to the dominant design is associated with increased chances of survival and market share. Parthasarathy et al. (2011) point out that a firm's product innovation successes will have a positive relationship with its value creation. Products and services nowadays are becoming increasingly intertwined and the value delivered to customer is not only through products but also through services (Hallikas et al. 2012). Thus, value can be created in different stages.

According to these viewpoints, high-value engineering is to create value for its direct and indirect beneficiaries based on integrating different functions and subjects as well as resources along the whole value creation stage, the interaction among which (including cooperation and friction) finally causes value creation. Thus, the factors influencing the integration of resources, participants and functions on each value creation stage should be studied individually.

3. Value creation stages and its international network operations. The synthesis of processing networks is a complex and multidisciplinary problem, which involves many decisions at engineering levels including design, R&D, optimization of production, etc. (Alberto et al. 2012). Engineering design before manufacturing is important; Dixon (1990) states engineering design refers to the development

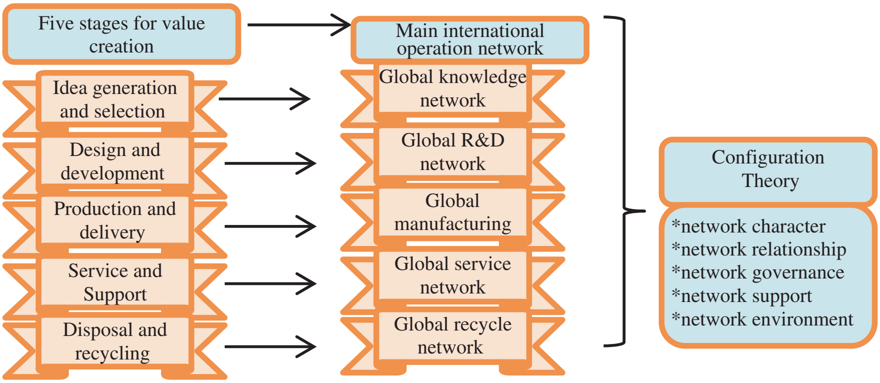

Fig. 1 Five value creation stages and mainly associated international network operations

of a product through its technical conception and ideas through detail design. As for delivery, it connects with product development and customer orders (Karim et al. 2010), which should also be paid great attention to. Nowadays, engineering service has become one of the important value creation stages, "Service-led project refers to projects that are driven by a client's business plan, complementing the delivery of a capital good with services" (Alderman et al. 2005). Additionally, interest in recycling has surged due to environmental concerns over material production and disposal, and laws designed to improve material recycling rates. Wolf et al. (2013) present a new approach to modeling by analyzing, designing multistage separation systems to meet specified performance goals in terms of recovery/grade. Engineering value creation stages from conception, design, production, delivery, service to disposal and recycling are researched separately by academics. While some put them into one framework to do related research, value chain theory considers value can be added in the stages of purchasing, production, sales and delivery as well as auxiliary activities (Porter 1986). Zhang and Gregory (2011) point out that an engineering value chain consists of five categories of activities through which engineering operations may contribute to customer value and thus the overall competitiveness of a firm—idea generation and selection, design and development, production and delivery, service and support, disposal and recycling. Different stages have different strategies and targets, and show that the influencing factors will differ.

Engineering now expands different value creation activities in a global scope. The five value creation stages in international network operations are mainly associated with global knowledge network, global R&D network, global manufacturing/production network, global service network and an individual global recycle network. Therefore, factors influencing the integration of the five stages will be researched. Finally these factors will be divided into five aspects according to configuration theory, which is also the integrating framework for further research. The relation can be seen in Fig. 1.

Table 1 Classification of literatures on influencing factors and their searching tactics

Influencing factors (Classification of literatures)		**Searching tactics** (The criterion that meets at least one of the following condition in the fields of title, abstract or key words)
Value creation	Idea generation and selection	Knowledge + value; idea generation + value/factor; scheme/idea selection + value/factor
	Design and development	R&D/research/design + factor; R&D/research/design + value
	Production and delivery	Production/manufacture/delivery + factor/value
	Service and support	Engineering/project service + factor/value; Engineering/project support + factor/value
	Disposal and recycling	Ecological + engineering/project + factor/value; disposal/recycling + factor/value
International operation	Global knowledge network	Global/international + knowledge network + factor
	Global R&D network	Global/international + R&D/development network + factor
	Global manufacture/production network	Global/international + manufacture/production network + factor
	Global service network	Global/international + service network + factor
	Global recycle network	Global/international + recycle/disposal network + factor

3 Influencing Factors

A literature survey is used to develop a framework for factors influencing high-value engineering in an international network. The literature research included journals published by numerous publishers, particularly in Elsevier, EBSCOhost, Web of Science, SwetsWise, Taylor & Francis and some journals such as Journal of operations management and International Journal of Operations and Production Management, etc. In order to make a comprehensive survey of influencing factors of international high-value engineering network, we make a classification of the literatures on influencing factors. The classification of literatures on influencing factors and their searching tactics can be seen in Table 1.

For the sake of rigorousness, dissertations, textbook, unpublished working papers and conference papers were almost excluded, unless they have a really close relationship with this paper or if they can offer concepts or opinions that are remarkably different from other papers that we found. The remaining papers were selected based on the principles as follows: ① papers or journals that are often cited as important contributions for the research of international high-value engineering network; ② papers that have a much closer relation with the international high-value engineering network; ③ papers that explain the same questions from different aspects and views; ④ papers answering the same questions are usually ones selected from the current year unless papers are found from the previous years that are proved to have very important contributions to this field of study.

3.1 *Influencing Factors on Five Value Creation Stages of High-Value Engineering*

1. Idea generation and selection. Idea generation could be realized from the knowledge integration of different participants and technological fields. Customer ideas will help the product to easily get market acceptance and also increase enterprise capability to anticipate the market (Berghman et al. 2006); university knowledge often has a high degree of novelty, which provides important business opportunities (Cohen et al. 2002); Köhler et al. (2012) argue that while customer knowledge is more strongly associated with market-driven search and imitation success, university knowledge is more related with science-driven search and innovation success. Apart from the customer and university focus, it can also be shown that supplier involvement is also a good way for improving idea generation. Lack of employee involvement will limit the number of potential innovations, as employees from different units engaging in R&D or marketing or managing can offer different ideas and viewpoints to guarantee idea quality. Thus, participant's involvement of idea generation has significant importance.

How much knowledge is needed? Abundant knowledge sources from participants will enrich ideas, while in-depth knowledge will enhance the idea quality (Laursen and Salter 2006). A vast amount of information and knowledge will influence the in-depth search, therefore knowledge searching should make a good balance between breadth and depth.

The value of the knowledge source is much more important (Köhler et al. 2012) for idea generation, and accordingly participants' original information of existing designs, market knowledge, and customer requirements as well as knowledge selecting methods and processes could affect idea generation and selection.

The culture of innovation (Klintong et al. 2012) and each participant enthusiasm could also influence knowledge integration and idea generation quality.

2. Design and development. Finical/fiscal support including public funding and enterprise R&D intensity (Albors and Rodriguez 2011), might impact design and development.

Besides capital resources, human resources are also needed, such as qualified personnel and a reasonable qualified team. Apart from traditional qualified personnel, some new professional figures are emerging, such as the integration experts who are able to select and integrate external knowledge and manage complex structures due to their knowledge. These are urgently needed for R&D organization. Actually, the right personnel and the right team are also imperative. Howard (2001) considers that employing the right types of developers, can greatly improve the success of development projects. Different tasks dictate the adoption of teams with different structures, and also adopting appropriate members. Team structure for achieving predetermined goals is also a curial step, which requires a great deal of care (Jitamitra and Suvrajeet 2010).

The managing mechanism will directly influence the quality of design and development. Hamid and Mohammad (2012) point out that innovation is a process of organizational learning. However, different team members come from a wide variety of functions, disciplines, and locations, which is a major challenge to keep everyone focused in the same direction. Therefore, team training and learning, knowledge transfer and sharing, definite goal and performance management as well as supervision strategy are also needed in successful design and development.

3. Production and delivery. Resources and material supply is crucial for production, and in the "knowledge economy", with intellectual capital perhaps supplementing traditional resources, which becomes an important influencing factor in production. In order to avoid resources shortage resources available for production (Minarro et al. 2005) should be grasped beforehand.

Engineering tools can make producing and delivering a process to become even more efficient. The implementation of an Enterprise Resource Planning (ERP) system not only can identify resources but also can help to make good use of resources and proper production arrangement. Toyota Production System (TPS) can generate production schedule, forecast outside demand, and adjust production capacity to avoid over production. Therefore, tools for resources arrangement and production are essential for creating more value in this stage.

Formulation design, part procurement and handling (Sanchoy and Atipol 2011), instrumentation and automation, process concurrency, formality and adaptability in producing, continuous monitoring, feed forward or feedback control (Vaithiyalingam and Sayeed 2010), can lead to the continual improvement of manufacturing technology, and eventually impact the performance of manufacturability. Therefore, an effective and efficient producing control and management strategy is important.

As for delivery, to make a reasonable linkage of product development and customer orders, basic data and information on sales orders with an accurate promised date, available stock, procurement and distribution times of any raw materials from external sources (Karim et al. 2010) should be forecasted/predominated. Data collection and processing tools, delivery planning and controlling models are looked-for in order to realize an effective assignment. In international high-value engineering network, relationship among production, inventory, delivery and customer requirement and orders becomes much more complex, a new control method should be studied by comprehensively considering cost in inventory holding, lost sales, production and delivery setup (Katsuhiko et al. 2010).

Besides these internal factors, some other external factors might also have great significance on production and manufacturing, such as regulation and policies, facility location, intensity of competition, and the stages of industry (Birsen and Ilker 2010).

4. Service and support. Service and support is a totally different market, the customer requirement is therefore different, and also how to offer services to meet their demands meets a new challenge. Previous knowledge and technology should therefore be renewed. Different actors and institutions may work together to offer a service, which puts new requirements on the organizational structural and management.

Firstly, it is important to grasp the needs of the customer. The requirements for innovation, the supporting infrastructure, and the long-term service component all stem from customer needs (Alderman et al. 2005).

Secondly, information and knowledge sharing infrastructure and mechanism are essential. Gann and Salter (2000) consider that the quality of technical documents and the transferring of technical data, and the mechanisms for integration are all very important in a service-led project. Some firms have adopted an approach to sharing project information aimed at extending the market for their services. In the US, the engineering firm RM Parsons has developed new Computer-Integrated Project systems which has resulted in internal business process changes and also in a new relationships with clients. Service-led project transactions are more focused on the acquisition of a knowledge or learning mechanism. The implementation of enabling structures and learning capability building is necessary and referred to in terms such as 'adding value' and 'service delivery' (Leiringer and Brochner 2010).

Thirdly, the servicing concept, method and tools might influence value creation in this stage. Collaborative relationships in service-led projects often require new skills and sometimes also new attitudes. IBM proposed the concept of 'service science, management and engineering'. Service science aims to develop a general "theory of services with well-defined questions, tools, methods". Dominguez and Neubert (2013) consider that interdisciplinary and cross-disciplinary managing approaches are required to understand how services should be designed, delivered and supported. Service engineering can be understood as a technical discipline concerned with the systematic development and design of services using suitable procedures, methods and tools. Therefore, service concept, method and tools adopted in this stage will greatly influence service and support performance.

5. Disposal and recycling. Ecology is a societal megatrend, which will substantially affect the future management of distribution channels, disposal and recycling and turns out to be an important stage for value creation.

End-users' requirement is the main driver for enterprise, so there should be real business incentives existing to develop sustainable products (Fuller and Ottman 2004) if consumers have high environmental protection awareness.

The type of materials used (renewable/recycled materials or non-renewable resources) in product or package and where the ingredients come from Kotzab et al. (2011) will influence the performance of product disposal and recycling. Not only are the materials used important, but also the environment friendly and sustainable development concept adopted in the whole process is crucial (Hallstedt et al. 2010), from product design which can easily be recycled or reused, to product manufacturing and marketing. Companies with a strategic approach under this concept will increase their chances to identify new market opportunities, to win "talent wars", and to improve their brand value. In response, a vast range of product design concepts, methods and tools have been developed, including Environmental Management Systems (EMSs), Life Cycle Assessments (LCAs), cleaner production and eco-design and so on. Besides design tools, sustainable technology and its innovation is also needed to transfer sustainable and environment friendly design to real products (Fuller and Ottman 2004).

Finally, top managers' support and adoption of ecological indicators in engineering performance evaluation is also important in this stage. Kalleitner et al. (2012) research on Haberkorn—Austria's biggest industrial wholesaler, proves that the management board's profound interest in sustainability and all product line managers and employees common view on sustainable development and innovation let Haberkorn realize its goal—creating a sustainable assortment.

3.2 Influencing Factors in International Network Operations

1. Global knowledge network. As for idea generation in knowledge network, it is very important to balance international linkages for knowledge sourcing and information exposure (Sverre et al. 2010). An open cooperation mind-set or culture (Nakagaki et al. 2012) is very helpful for idea generation in a global network.
2. Global R&D network. The adoption of organization structure and interaction and communication among dispersed R&D centres will influence global R&D network operation (Birkinshaw 2002). Slone et al. (2011) consider that geographic and time differences, cross-cultural difference, will add complexity for R&D management. Accordingly, appropriate structures, tactics for coordinating knowledge and technology flow between headquarters and regional headquarters as well as subunits, turn to be important factors for network management. Slone et al. (2012) further point out that the roles and responsibilities of subunits, the mechanisms by which knowledge is obtained and transferred back to headquarters, and the effective management of human resources in a foreign market are critical for global R&D network.
3. Global manufacturing/production network. Network structure, communications system, knowledge sharing have great impact on global manufacturing network (Rodríguez and Ramón 2010). To make smooth coordination among participants in different nations, developing common policies regarding manufacturing structure and infrastructure are needed. Therefore, creating clear and standardized guidelines for manufacturing and related activities are benefical to coordinate manufacturing network operations (Jaehne et al. 2009). As for knowledge sharing, the leading producers' guidance and local producers' capabilities in assimilating and adapting are also crucial (Dieter and Linsu 2002). It seems that this stage receives much more influence from external factors; global production network not only is influenced by national-level regulation (particularly government agencies) and formal international agreements, but also the codes of conduct regarding labour or environmental standards. In some cases the trade unions, employer associations and Non-government organizations (Henderson et al. 2002) will also affect the strategy of the global production network operation. Yang et al. (2009) point out the configurations and characteristics of global production networks, are shaped by the geographically differentiated social, political, and cultural circumstances in which they exist.

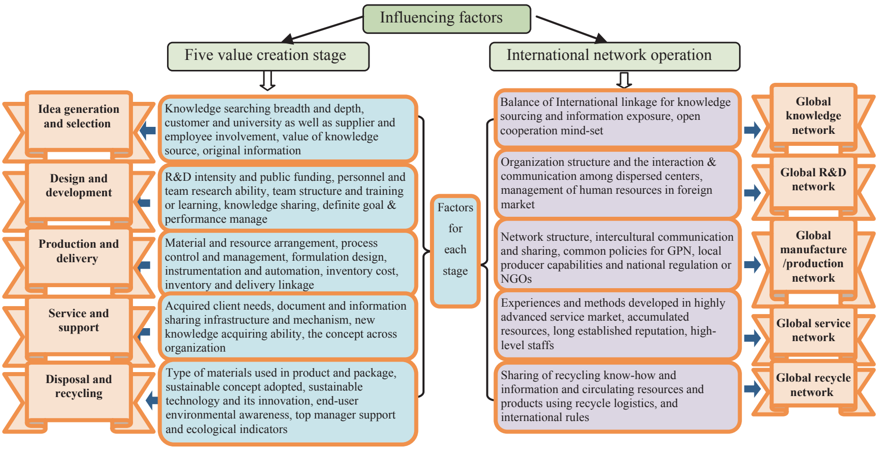

Fig. 2 Influencing factors on high-value engineering value creation stages and its international network operation

4. Global service network. After the transfer of manufactures, global transfer turns to service industry. Service network competitive advantage will be influenced by the experiences and methods developed in highly advanced service market in the home countries. Day-to-day accumulated resources, long established reputation, image of the companies gained in fierce international competition, and abundance of high-level human capital will affect value creation in global service network (Zhang 2010).
5. Global recycle network. Kanzawa and Takahashi (2005) argue that regional recycle systems should not only function independently but also be closely coordinated and developed into a global recycle network. The sharing of recycling know-how and information, circulating resources and products using recycle logistics based on international rules, are key factors affect global recycle networks objectives.

There are some common factors for engineering international network operations and engineering integration. Bryant (2006) argues that the differences of national contexts often create boundaries between teams from different nations. In fact, globalization experience, distances in the global network (including culture distance, geographic distance and linguistic distance), and international, functional, and the organizational complexity of engineering network will all influence the different value creation stages and their integration into international network operations.

Figure 2 shows the factors influencing value creation and international network operation. The left section presents the factors alongside the five stages of the engineering value creation. The right section introduces the factors stemming from international business networks.

In summary, knowledge managing and different participant involvement, team cooperation and learning and training, material and resource arrangement and process control, client needs and document sharing, end-user environment awareness and sustainable concepts among network participants are important for five different engineering value creation stages individually. When engineering in an international operation, the balance among knowledge sourcing and information exposure, foreign team utilization, common policy and local regulation, previous reputation, recycle logistics and international rules should also be considered in the different value creation stages.

From the above analysis, we can see that traditionally research on design and development, manufacturing and delivery are still under research, engineering service and support receive great attention and interest from academics currently, and gradually several literatures have begun to do research on the value creation stage of idea generation and selection, and disposal and recycling. However, further research is needed to find out how to create and add value on these two stages and how to deal with the influencing factors in international operations. Especially, there should be some network original focus on the one value creation stage, while it now makes transformation to the other stage, as well as looking at how to successfully make this transformation, and in what condition and what should be prepared for this transformation should be analyzed much deeper.

In network operation management, lots of conflicts will occur, such as knowledge sourcing and exposure, knowledge sharing and protection, participants diversity and consistencies in culture and concept, knowledge/information broad and deep searching, standards in global operation and different local requirement, centralized structure and decentralized structure selection, etc. These conflicts were pointed out in the literature, while how to deal with these conflicts will need further study; different types of network has a different preferential pattern, and how to choose the balance for a different network can be researched.

3.3 An Integrating Framework

Engineering global value chain and engineering activities are still in research, while more and more academics are focusing their attention on the engineering network. Network structure, relationship and other character impact on engineering performance are researched currently, while definitive confirmation on network configuration and their influence on network operation still need further research. In order to comprehensively have a longitudinal (value creation stage) and transverse (network configuration) understanding of high-value engineering network influencing factors, an integrating framework is needed.

The character of network and network relationship are two important aspects to configure a network (Koendjbiharie et al. 2010); governance and support can also be used to analyze engineering network configuration (Zhang and Gregory 2011); international high-value engineering environment changing dynamically, which will greatly influence network operation, and should also be considered. Accordingly, the above factors will be classified into five aspects based on

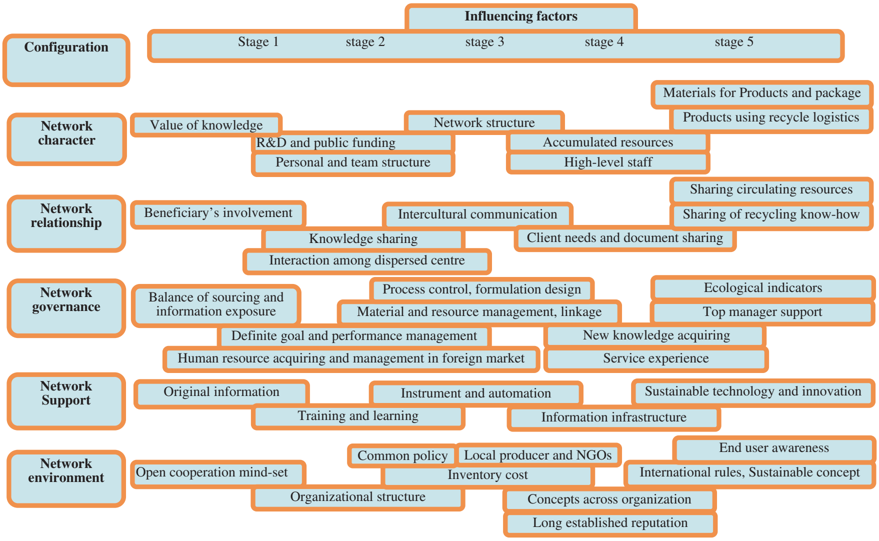

Fig. 3 Influencing factors integrating framework of high-value engineering in international network operations

configuration theory—network character, network relationship, network governance, network support and environment, which can be seen in Fig. 3. The integrating framework will be used in the future to identify factors of importance and their influencing mechanism for high-value engineering in different countries—China and Europe.

4 Conclusion

High-value engineering not only means creating high profits but also enhancing the power to establish new markets, enlarge market share, create new dominant technologies, get specific solutions and achieve competitive advantages. Value is created by integrating different functions, resources and participants along the whole value creation stages. High-value engineering in international network operations deploy and arrange its activities and resources across national boundaries, and some additional factors should be considered. Therefore, factors are analyzed from the aspects of value creation stages and international network operation. Senior managers should pay attention to these factors.

While influencing factors are different at each value creation stage, managers can confirm managing priority on factors according to engineering value creating activities. Integrating framework is established based on configuration theory for further study. However, these factors are obtained only by literature review. Industry investigation and case studies will be done later to check whether those match the practice well. This study presents a comprehensive analysis of influencing factors, while the study on the factors importance is not accomplished. Therefore, large-scale data collection will be done to check factor importance and their influencing mechanism for engineering network.

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Exploring Trajectories of Distributed Development: A Study of Two Danish Manufacturers

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Abstract While some firms have successfully turned their global operations into a formidable source of competitive advantage, others have failed to do so. A lot depends on which activities are globally distributed and how they are configured and coordinated. Emerging body of literature and practice suggest that not only standardized manufacturing tasks, but also knowledge-intensive and proprietary activities, including research and development (R&D), are increasingly subject to global dispersion. The purpose of this chapter is to explore structural and infrastructural arrangements that take place in industrial firms as they globally disperse their development activities. The study employs qualitative methodology and on the basis of two case studies of Danish firms it highlights the challenges of distributed development as well as how these challenges can be dealt with. The chapter outlines a variety of practices used by the companies in order to achieve control and coordination of distributed development activities. Three propositions are developed to advance our understanding of the continual search for an optimal organizational form for managing distributed development.

Keywords Distributed development · Configuration · Coordination · Case studies

1 Introduction

Increasingly complex and knowledge intensive activities are being relocated to areas that previously were only associated with high volume low cost production (Statistics Denmark 2008; Lewin et al. 2009; Amaral et al. 2011; Ellram et al. 2013). Foreign subsidiaries of multinational enterprises (MNEs) are transitioning

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from being satellites that solely exploit capabilities from the home base to capable entities with growing competencies in basic research, applied research, product development and design (Manning et al. 2008; Sun et al. 2007). Among the main drivers of the globalization of R&D are: cost minimization, access to new human resources and knowledge, and often required proximity to foreign production sites and markets (e.g. Eppinger and Chitkara 2006; Lewin et al. 2009; Slepniov et al. 2013). This process has been further facilitated by an increased standardization of specifications and protocols.

Although global distribution of knowledge intensive activities is likely to present acute challenges for years to come, it also carries numerous benefits for companies in terms of knowledge creation (Doz and Wilson 2012). Hence, the debate has progressed from whether or not globalizing R&D is beneficial to deciding which activities to offshore and how to successfully complete tasks in a distributed setting. We attempt to contribute to this debate by addressing how companies can organize the transition to dispersed R&D. As global R&D presents opportunities to international firms, effectively managing the global R&D network has become a precondition to being and staying competitive. While global distribution of production tasks is well covered in the literature (Ferdows 1997), R&D organization needs further research attention (Doz and Wilson 2012). In this chapter we limit our attention to the development activities and address these research questions: How do transitions from domestic to dispersed development take place and how do companies coordinate and control their development network?

The chapter has four parts. First, the conceptual background section presents the constructs and theories employed in the study. It is followed by the methodology and the empirical base of the chapter. The third section presents the major findings and propositions of the study. The chapter closes with conclusions of the study.

2 Conceptual Background

2.1 Distributed Development

In the literature, R&D function is often treated as a black box containing a number of rather homogeneous knowledge intensive tasks. However, we can distinguish between two broad categories of tasks: research and development. Whereas basic research is the exploration of the nature of materials and phenomena, applied research is the usage of basic research to develop new technical knowledge. Development, on the other hand, focuses on transforming that technical knowledge into useful products and services. In the discussion of the R&D globalization, a clear distinction between research and development is very important. While development follows production, technical service, and sales, research follows know-how and development. In analyzing location patterns of various activities, Boutellier et al. (2008) find that research tends to stay close to home based activities, in research institutes and universities, while development has been more widely internationalized. As stated above, this chapter centers on the development part of the R&D function.

Previous research has addressed various aspects of process and product development conducted across organisational and geographical borders (Eppinger and Chitkara 2006; Sinha and Van de Ven 2005). Distribution of development activities can take various inter- and intra-organizational forms, including offshoring, outsourcing, and alliances. Offshoring can be defined as the relocation of a business process or entire manufacturing facility to a foreign country (Aron and Singh 2005; Jahns et al. 2006). The offshoring term is used to describe a very broad spectrum of dynamic scenarios which can be differentiated in terms of their contractual and location implications For the sake of conceptual clarity, these scenarios can be grouped into two broad categories: (1) captive offshoring and (2) offshore outsourcing. Captive offshoring refers to the process of relocating company's activities overseas without giving up their ownership and direct control. Offshore outsourcing, on the other hand, can be viewed as a complete or partial discontinuation of in-house activities and, thus, refers to externally supplied or 'outsourced' activities. Captive offshoring and offshore outsourcing represent two extreme scenarios which can be further detailed in terms of contractual arrangements and involve joint-ventures, strategic partnerships and alliances (Kotabe and Murray 2004).

The dispersion of product development activities is not a one-off incident; it should rather be seen as a process, which develops over time under the influence of numerous internal and external factors. Among these factors offshore sites capabilities and their maturity play a significant role.

2.2 *Offshore Capability Maturity*

Drawing upon the maturity perspectives of Kuemmerle (1999) and Bessant et al. (2001), offshore site roles and competencies can be related to the sites maturity (Fig. 1). The figure describes different stages in the relationship between the home base and subsidiaries/development partners: Stage 1 is 'Pre globalization' with no offshore capabilities; Stage 2 is 'Dispersed impulse' with ad hoc capability building; Stage 3 involves building a 'Centralized network' of activities; Stage 4 involves 'Global Reconfiguration where mature dispersed processes are actively managed; Stage 5 shows an ideal aspiration state where new configurations are optimized and integrated.

As shown in Fig. 1, when the first dispersion impulses received foreign subsidiaries start exploiting competences from the home base. As their own competences grow, they start to give back to the home base, becoming home base augmenting sites. The final stage shows a network of complementary centers of expertise with mutual interdependence, where the coordination authority for process and product development is based on individual unit's level (Niang and Waehrens 2010). This phenomenon is accompanied by changes in configuration and requires coordination mechanisms.

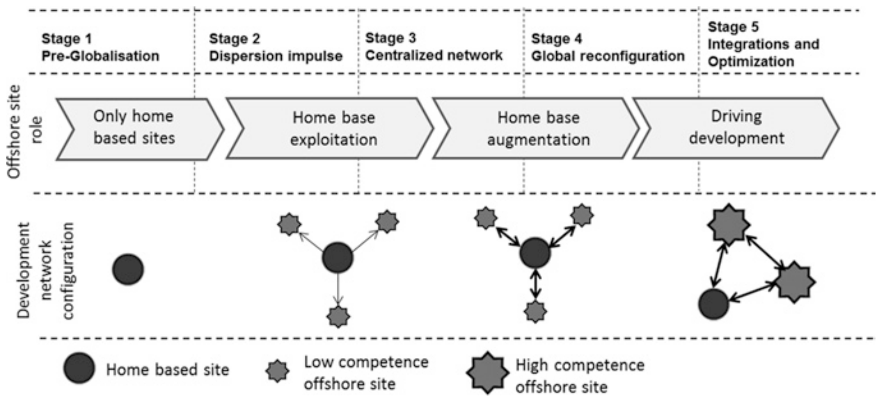

Fig. 1 Offshore maturity and network configuration

2.3 Coordination and Control

Coordination mechanisms are the glue of the organization, allowing for coordination of work related processes and steering individual activities towards organisational aims (Thompson 1967). The coordination process enables collaboration, cooperation and sharing of technical knowledge between all parties involved in the development process (Iansiti and Clark 1994). Anderson and Joglekar (2005) view coordination in product development as increased integration of activities.

The new product development process involves a higher degree of process, marketing, creative, and technical uncertainty than typically found in other operations such as production management. As activities are relocated to foreign locations, coordination becomes a key priority and challenge for the firm. The information-processing model in the organisational theory literature (Galbraith 1973; Sinha and Van de Ven 2005), suggests that organisational coordination mechanisms are created to deal with this challenge. Those mechanisms range from hierarchies, to contracts or incentive structures, information systems, and modularization of tasks.

Finding the right level of control of the distributed activities is also important. Traditionally, centralized R&D is touted as being favourable to radical innovation generation whereas decentralized R&D, in which the decision-making process is dispersed, allows for more incremental innovation (Gassman and Von Zedtwitz 1999). Commonly, technology driven firms adopt dynamic, hybrid approaches (Gassman and Von Zedtwitz 2003). Centralization is likely to dominate if the required knowledge to carry development activities is tacit or difficult to externalize. It makes sense then to keep activities in close proximity and with centralized decision making authority. In contrast, a high degree of 'codifiability' of the required technical knowledge would ensure that information can flow between teams without ambiguity. In this case, decentralized development activities become possible with sub-teams focused on different modules and able to control their own resources.

3 Research Methodology and Case Studies

3.1 The Case Method

The empirical part of the research is based on two exploratory case studies. The case method enables understanding of particular contemporary issues or concepts which have not been deeply investigated (Eisenhardt 1989; Yin 2009). Moreover, case studies are generally preferred for answering 'how' and 'why' questions about a contemporary phenomenon over events in which the investigator has little or no control over (Yin 2009). Therefore, the case method is well suited for this investigation.

The cases were selected on the basis of two key criteria: (1) a strong commitment to global reconfiguration of R&D-related activities; (2) sufficient access to potential data (including commitment of interviewees, availability of documents, etc.). For each case, three to four two-hour interviews were conducted with key actors directly engaged in the offshoring process, including R&D managers, senior product development managers, and head of design. The first set of interviews focused on developing a holistic view of the companies' global operation networks including their structure, infrastructure, and the interrelations between different functions. Follow-up interviews were directed at the R&D-specific problems and critical firm practices used in developing a global product development organization. Additional data was collected through company publications and secondary sources. Furthermore, follow-up telephone conversations with managers were carried out.

3.2 Case A: Industrial Equipment Firm

Company A is a Danish equipment manufacturer holding a market leader position. With its various value chain activities in 55 countries, it is working from a strong international base. The company has been acquiring two to three companies every year since 2000, signaling a change of mindset from making everything in-house in Denmark to more open and globally dispersed operations. After acquisition some of the newly acquired firms still controled their own R&D agenda, while others were fully integrated. The pace of acquisition quickened recently in par with the restructuring of their main product's market characterized by increased concentration, and firms moving from component to system suppliers, adding more competencies. When referring to Product Development at Company A, an executive characterized it as a '*Centrally driven, global approach with a local presence*'. The mother site in Denmark had a strategic vision and remained in firm control, but business units had their own budget and latitude to select projects, allocate resources.

The company considered China as its Second home market and had been operating in China since 1994. The unit in China was fully established with a full scale operations, including sales, after sales service, production, R&D and Technology development activities. The R&D and Technology centers started their operations in China in 2007 with one of the objectives being to support the Second home market strategy and gain access to resources and talent base in China. An intense interaction occurred between Production, Product Development (PD) and the Technology Centre (TC). Technology Centers, including the one in China, were responsible for technology development and establishment of production lines for its two internal customers, namely Production and PD. With an increasing number of the PD projects moving out of Denmark, it made sense that TCs followed this global expansion. Cooperation between foreign units was limited to brief collaboration on assignments and sharing of patents. However, there was a shared agenda at a higher level in relation to operations in different market segments. Though R&D man power in China was growing fast, they had not launched any product range on their own, solely supporting central development activities.

It was expected, however, that in the future responsibilities of developing some products would be taken over by the unit in China. In time, each "Triangle" (TC/Production/PD) would grow increasingly specialized, replicating best practices, but developing own particularities, compatible with local culture and markets. TC Denmark, which designed production equipment for all factories including testers and tools, was to remain the lead unit, but the global organization was to be nurtured through a positive iterative process by gradually increasing the level of complexity of tasks. For example, both China and Hungary had cast iron mechanical construction units that were routinely assigned tasks by the project manager in Denmark. These parallel activities in Denmark and abroad would continue until it made sense to move key competencies abroad.

3.3 Case B: Firm in the Fashion Industry

Company B is Danish MNE working in the fashion industry. It was among the first Danish manufacturers to use robotics and computerized production lines, setting the firm to become a leader in comfort technology. A key particularity of Company B resided in its high level of vertical integration: the firm controlled the value chain from raw materials to R&D, production, and retail outlets. Company B had offshored most of its core processes across 11 business units. Development activities were following production abroad partly because of the importance of speed and lead times in the industry. The focus was mainly on early concept development or what is supposed to go to market next season. A constructive dialogue between Design, Product Development and related channels was needed to ensure delivery of time-sensitive fashion items. Similarly, a dialogue between Production, Engineering and Design enabled the teams to meet requirement of different projects. An important task in design was to consider market needs, innovation, and limitations of production, but to challenge the existing standards.

At the time when the research was conducted, all new concepts and designs (tooling, design, and new material idea) decision were made in Denmark. The remaining activities upstream and downstream were shared with the foreign sites. High scale production had been offshored to Indonesia, Thailand, China, and Slovakia. The original factory in Denmark was limited to a small montage unit for prototypes and samples, some tooling, as well as a workshop. Set up in 1984, the first foreign factory opened in Portugal, but its production had been downscaled as the focus switched to development. Because of relative high production costs compared to the Far East, the Portuguese site had a great sense of urgency. '*They are on a burning platform and fighting hard to stay alive*' commented one of managers. A local team of engineers optimized production techniques as manual labor was more costly: technologies such as laser roughing had been developed by the unit and later distributed to the whole network.

Thailand had a development center and a large production unit. Having a direct source of information, the local team was able to deal swiftly with a range of technical issues. On the development side, they were responsible for functional gear. China and Indonesia focused on production, however some development tasks take place depending on the specific factory needs. Slovakia had a similar set up, but focuses on automated tasks as labor intensive jobs go to lower cost areas. The in-house activities of the company accounted for about 80, with the remaining 20 % coming from outsourced partners. All internal activities were accomplished using a proprietary injection process that guarantees superior quality and comfort. Since 2004, in-house production based on more traditional production methods had been discontinued and allocated to a Chinese outsourcing division that deals with outsourced partners. Two routes of production meant two streams of R&D and design. One totally internal and the other that went from the design team in HQ to China, where a technical team redistributes assignments to partners in China, Indonesia, Thailand, India, and Vietnam. Development occurred also in the tanneries which constituted another business unit, which was distributed across four countries: Holland, Indonesia, Thailand, and China. The high level of integration and control of the value chain was a result of a strategic decisions made by home base. Although, all decisions were still made in Denmark, the process of competences dispersion was clearly visible in the practices of this company.

4 Analysis and Discussion

4.1 Challenges of Distributed Development

Both cases have gone through a significant structural reconfiguration of their operations set-up. The main characteristics of this reconfiguration have become increasingly common among manufacturing companies from traditional industrial centres. Cost minimization, and local market knowledge seeking drivers triggered the Danish case companies to offshore part of their development activities.

The shift from having full control over a facility in a well-known home base to a far-flung and widely scattered network of internal and external providers (often physically and cognitively distant) highlights a number of challenges. First of all, the case companies have to deal with an increase in number of offshore development sites, many of which are at their early stages of maturity. Furthermore, infrastructural elements of the set-up, such as policies and measures of coordination and control, are also lacking behind.

Evaluating the offshore capability maturity of the case firms, we find that case A and B may be positioned on Stage 3 'Centralized network' of activities (Fig. 1). The case companies struggle to shift from home base exploitation towards augmentation. A number of endogenous development projects have been executed by the offshore sites and subsequently shared among the network partners. However, these still represent the minor share of the development activities output in the cases.

Staying close to production is important for both companies. For instance, the 3D design process within company B raises the need to have production within close proximity in order to maintain a required close interaction between the two functions. The co-location is a necessity in this case, but for now Danish designers have to travel to bridge the physical gap between activities and to manage the processes.

With internal and external factors driving dispersed development, distinguishing between core and peripheral activities is proving increasingly difficult. Ketokivi and Ali-Yrkkö (2009) found that unbundling R&D and manufacturing is not always possible. Inter-linkages between tasks and commoditization of previously high-value added activities bring the need to question current configurations and practices. Managing dispersed development activities requires coordination mechanisms which take time and additional investments to develop.

Next significant challenge for the case companies was related to the make-or-buy dilemma. The captive offshoring model with its focus on vertical integration and the offshore outsourcing model with its focus on specialization are two strategic choices that both have their advantages and disadvantages and have implications for firms' practices. In the case of offshore outsourcing, both the operational and structural risks are severe. They may potentially lead to the loss of control over activities, loss of critical skills, excessive dependence on external suppliers, or miscommunication (e.g. Aron and Singh 2005). Need for rigor and simplification in production processes may undermine uniqueness of products and processes and lead to declining innovation by the parent company (Kotabe and Murray 2004). A high offshoring quota may also lead to erosion of the firm's home base capabilities making 'backshoring' and repatriation option costly and difficult if not impossible (e.g., Ellram et al. 2013).

During the implementation, organisational issues such as the degree of trust, the level of communication and coordination also play their role. Parker and Anderson (2002) showed the importance of product integration in distributed development. The dispersion of development activities in the cases complicates product integration. With more diverse and globally dispersed actors involved, organisational barriers multiply with the physical and cognitive distance of partners. For instance mismatches between the Danish and Chinese culture made it hard for the case companies to have a unified approach to quality requirements. Managers also reported the need to fight a lack of trust; a main obstacle to global product development. The home base often feels that the subsidiaries are not able to take on complex work, which is not always the case. The issues also involve IPR, transferability of activities and knowledge, and the sustainability of firms' core competences.

4.2 Challenges of Distributed Development: Corresponding Practices

In the light of existing challenges, how do these firms organize their dispersed development activities? Both companies kept their R&D activities centralized in a sense that all major strategic decisions are made by the Danish home base.

Both case companies face the make-or-buy dilemma and both made their choice in favour of hierarchies as a dominant mode of governing the relationships between the globally distributed development units. Boutellier et al. (2008) argues that rigid structures (functions and hierarchies) enable routines tasks. With the support of effective information systems such rigid structures may help to cover a wide range of problems involving synchronization of Product Lifecycle Management (PLM), exchange of bills of materials, and virtual customer interfaces. However, rigid structures and information systems may be not enough for moving to the augmenting stage which entails independent creative tasks. To account for this, we suggest the following proposition:

Proposition 1 *Informal coordination mechanisms positively affect the development of home augmenting capabilities of offshore sites.*

Indeed, as the cases show, overlaying structures consisting of informal links that enable cross-unit interaction appear to bridge gaps between teams and processes. For instance, Company B holds workshops between Design, Branding and Product development in order to share a common understanding of the dispersed development process and identify problems related to product delivery performance and technical development, new materials, and tools. As coordination mechanisms are affected by the dispersed environment, a key priority for the firm becomes how to balance formal and informal control and coordination of the network. Boundary spanners provide another example of mechanisms that create necessary links between the dispersed units. For instance Company A has technology centers that play an important role in new product introductions when they coordinate requirements of dispersed production and product development units, while Company B has a special office in Dongguan China which handles all issues related to outsourcing to foreign partners. Boundary spanners are effective ways to coordinate, but Martin and Eisenhardt (2010) warn about overinvestment in boundary spanning.

The study of the cases also suggest that the areas where companies have to deal with coordination challenges, spread beyond the boundaries of one functional area in focus of this chapter, i.e. development activities. The situation was much more complex, as the players sought to establish positions where they could best exploit resources and at the same time explore new resources. The cases show that despite only some of their development activities were physically affected by relocation and offshoring, the system was affected as a whole due to the overarching interdependencies. Put in other words, the decision to offshore development task did not only affect development function in the home base, but also production function and vice versa. We therefore suggest the following proposition:

Proposition 2 *Locations of development activities are increasingly dependent on locations of production activities.*

Lastly, the cases show that during the transformation, the role of the home base remains essential. Indeed, the home base must closely monitor the co-evolution of units. Even when the network reaches the optimal sate of interdependent integrated sites, the role of the home based site must remain clearly defined and active. Ideally, the home base should establish standards and facilitate sharing of best practices in the network. This translates into a focus of the development network on decentralized execution supported by orchestration from the home base. Decentralized control enables the firm to combine the advantages of centralization and decentralization. Thus, we would like to state the following final proposition:

Proposition 3 *Scale and scope of offshore development activities affect the role and capabilities of the home base sites.*

5 Conclusions, Limitations and Further Research

Firms have varying motives to initiate distributed development. Nevertheless, they face similar challenges and aim to increase control and coordination through a range of practices. The key problem related to the globalization of the value chain is the integration of distributed activities. Regardless of the ownership of the value chain, the quest for integration is a key requirement to global configuration of dispersed development activities. We propose that the nature of coordination mechanisms, cross-functional interdependence and the role of home based sites play an important role and will have to be taken into account by firms embarking on the journey global dispersion of development activities.

The study has a number of limitations, which were beyond of the scope of this chapter to address. First, rather than providing definite answers, the findings of this study should be seen as propositions that open avenues for future research. Second, there are several methodological challenges originating from the use limited number of case studies. The next obvious limitation of the study is its geographic delineation. Despite some generalizable parallels, the best way to determine which findings are country-specific is to replicate the study elsewhere. Future studies should more closely examine the global functional integration challenge and interrelations between functions during the development process.

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Global Operations: A Review and Outlook

Yang Cheng, Sami Farooq and John Johansen

Abstract This paper starts from reviewing (1) the history of globalisation/internationalisation and related theories and (2) the history of global manufacturing and related studies. A figure is developed to illustrate the overview of the research trajectory of global (manufacturing) studies. Furthermore, the paper emphasizes that global manufacturing can further be accompanied by the internationalisation of other related value chain activities. In this case, discussions are naturally extended from global manufacturing to other global activities as well as their corresponding functional networks. The paper further shows the importance of addressing individual manufacturing, sales, service, engineering, and R&D functional networks simultaneously. Four factors are identified to be critical when addressing each functional network as well as their interactions. A similar development trend can also be observed with regard to the externalisation of both manufacturing and other value chain activities. An internationalisation and externalisation matrix is provided to illustrate the mentioned development trends in a holistic framework. Last but not least, practical implications are given ranging from micro to macro level.

Keywords Global manufacturing · Global operations · Globalisation/internationalisation · Externalisation

1 History of Globalisation/Internationalisation and Related Theories

Globalisation is not a new phenomenon. In fact, international trade has existed since recordkeeping began. Herodotus, known as the "Father of history", wrote detailed reports about the trade in spices, silk, glass, porcelain, and incense

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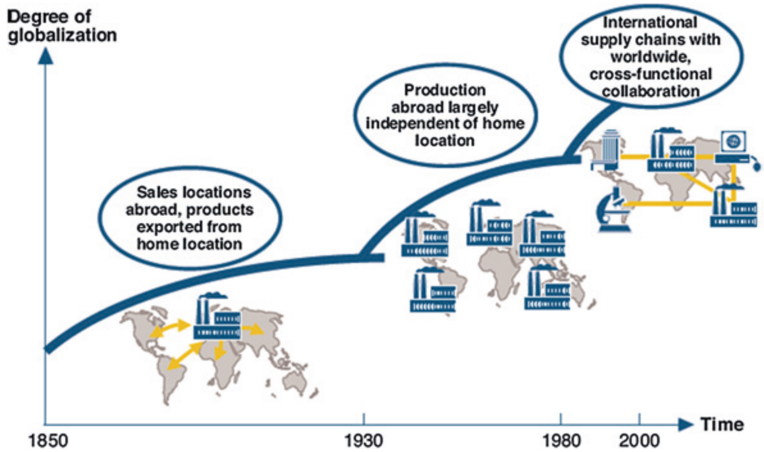

Fig. 1 Development of globalisation in three phases *Source* Abele et al. (2008)

between Asia and Europe along the Silk Road around 430 BC (Jacob and Strube 2008). Entering the 15th century, large regional price differences made trade in specific items attractive despite the rudimentary transport available. Ever since then, i.e. the Age of Discovery, global trade has advanced steadily. However, globalisation only entered a new era with the dawn of the Industrial Revolution. Generally, three phases can be distinguished, from cross-border trading to globalisation in its current form, as shown in Fig. 1.

From around 1850 onwards, sweeping technical innovations such as the railroad promoted the cross-border exchange of goods. The introduction of stock corporations at that time also facilitated access to capital and loosening restrictions on freedom of movement. Enabled by these two aspects, the simultaneous rise of mass production and its corresponding economies of scale further motived the newly emerging stock corporations to expand their customer and supply markets, intensify their international trade relationships, and set up sales outlets abroad in order to sell their products of large unit volumes. Nevertheless, this process was interrupted to some extent by World War I and the subsequent economic recession. Accordingly, production facilities abroad did not start to multiply substantially before 1930.

After World War I and the world economic crisis, powerful companies arose that continued to grow fast and steadily. Organic growth and acquisitions formed industry giants that were able to tap major economies of synergy and scale. Their financial strength generally helped them to open foreign production facilities and develop new markets via local production. However, due to World War II, its spread was again slowed down until the third quarter of the twentieth century. This slowdown can also partly be attributed to the inward-looking policies pursued by a number of countries in order to protect their respective industries. It was not until the 1960s that both global trade and foreign direct investment began to increase again and more explosively. Since then, the term “globalisation” started to be widely used by economists and other social scientists. Accordingly, the pace of globalisation was quickening and continued to have a growing impact on business organisation and practice (Friedman 2008).

During the 1980s, it was impossible for companies to withstand the trend of globalisation, as they required access to all three major industrial centres, namely Western Europe, North America, and the Far East countries (Flaherty 1989). Besides, there were actually more advantages if companies chose to be global (Yip 1989). In order to understand and explain this phenomenon, different theories were accordingly proposed.

Early market entry theories were concerned with the choice between exporting and foreign direct investment (FDI) (Colotla 2003), such as Hymer's theory (1976), which suggests that "the possession of advantages" such as economic of scale, cost or knowledge advantage, or product differentiates "as a case of international operations" (Hymer 1976) and identifies corporate internal capability as a critical promoter and qualification for internationalisation. Afterwards, the **transaction cost** (Williamson 1985) or the **internalisation theory** further advanced by Buckley and Casson (1998) was proposed. This theory, focusing on increasing efficiency in firms through internalising foreign market trading into corporate international production or FDI, has gradually become the predominant theoretical framework for explaining organisational boundary decisions (Geyskens et al. 2006). Another influential theory is the **product life cycle model (PLC)** proposed by Vernon (1966) that identifies several stages in the life of a product, each of which has different implications for the location of production activities. Synthesising the earlier contributions such as the ones listed above, the **eclectic paradigm** (Dunning 1988), as its name suggests, forms a holistic framework with the aim to "identify and evaluate the significance of the factors influencing both the initial act of foreign production and the growth of such production" (Dunning 1988). The eclectic paradigm argues that firms engage in international activities on the basis of ownership-specific, internalisation-incentive and location-specific advantages. While the eclectic paradigm combining economic theories of monopolistic competition, location and transaction costs, a number of studies have been proposed differently based on more behavioural approaches, according to which internationalisation is frequently described as a sequence of stages (Colotla et al. 2003). The **Uppsala School's internationalisation process theory** (Johanson and Vahlne 1977) of the firm argues that the internationalisation of a firm is a process in which the enterprise gradually increases its international involvement, normally starting from exporting to a country via an agent, later establishing a sales subsidiary, to eventually, in some cases, beginning production in the host country. Accordingly, global manufacturing has gradually become one of the popular topics.

2 History of Global Manufacturing and Related Studies

Since the late 1980s, manufacturing, as the single largest type of foreign direct investment (FDI) in most countries (Ferdows 1997a), has become more international. Manufacturers can generally benefit more from being global as trade barriers fell, transportation became easier, and communication technologies improved (Ferdows 1997a). In other words, global manufacturing provided an unparalleled opportunity for companies to grow into new markets while at the same time boosting their competitiveness. Therefore, manufacturing companies have tried to globalise their geographically dispersed plants in the last decades. Their role has accordingly changed from supplying domestic markets with products, via supplying international markets through export, to supplying international markets through local manufacturing.

However, global manufacturing did not attract much attention in the operations management (OM) community until the 1980s. At that time, manufacturing was fairly geographically concentrated even if markets became global, so each factory was essentially treated as a separate single facility (Schmenner 1982). Therefore, the earlier research was mainly concerned with plant location decisions (Meijboom and Voordijk 2003) and merely referred to the selection of the least costly site (Meijboom and Voordijk 2003). However, ever more research argued that cost evaluation seldom tells the complete story nor does it sometimes differ significantly enough to make a location choice strictly on its merit. In response to this, much research has attempted to identify the possible drivers for allocating production facilities in specific locations, especially those intangible and qualitative features (Ferdow 1989, 1997b; Vos 1991; Dubois et al. 1993; Bolisani and Scarso 1996; Meijboom and Vos 1997; Vereecke and Van Dierdonck 2002). The identified drivers include (1) lower manufacturing cost; (2) low-cost energy; (3) overcoming tariff and non-tariff barriers; (4) taking advantage of currency fluctuations; (5) proximity to market; (6) proximity to suppliers; (7) access to peculiar skills, e.g., knowledge, infrastructure, or sources; (8) availability of labour; (9) availability of business expansion; (10) access to complementary services; (11) emulation of competitors' decisions; (12) taking advantage of a highly qualitative environment (air, water, noise, climate) to create a high quality of life for employees; (13) the place of residence of the owner; (14) seizing a provided opportunity.

As expected to contribute more than just low cost, plants were recognised to have possibilities of playing different roles (Ferdows 1989, 1997b). Discussions on plant roles generally began with an examination of the roles of subsidiaries in multinationals, but it was Ferdows (1989, 1997b) who first translated the strategic classifications of subsidiaries into the manufacturing classification of plants. His model distinguishes plants based on two dimensions, namely plant competences and location advantages, and identifies six types of plants labelled as offshore, source, server, contributor, outpost, and lead plant. The Ferdows model has gained academic recognition, and is, therefore, the springboard for much research (Vereecke and Van Dierdonck 2002; Fusco and Spring 2003; Meijboom and Voordijk 2003; Meijboom and Vos 2004; Maritan et al. 2004; Feldman et al. 2009). In addition to Ferdows' model, other researchers have introduced different typologies of plants based on their perspectives, for instance, Vokurka and Davis (2004) and Vereecke et al. (2006).

Since companies had more distributed plants located all over the world, they might have potential to benefit from not only the individual capabilities of each plant (Colotla et al. 2003). Actually, in the early 1980s, there was already a growing realisation among scholars of the need to manage not only a single factory but also multi-plant organisations, although research at that time was mainly concerned with the plant location as introduced above. Nevertheless, with passage of time (late 1980s), it became more compulsory to address the increasing distribution of plants all over the world in the context of the internationalisation of companies and manufacturing. Therefore, more scholars attempted to develop new knowledge about global manufacturing by extending the boundaries of traditional manufacturing systems. More recent works, e.g. Ferdows (1989, 1997b), Flaherty (1996), Shi et al. (1997), Shi and Gregory (1998) and Colotla et al. (2003), attempted to make the link between manufacturing strategy concepts and views from those internationalisation models and frameworks mentioned previously (Vereecke and Van Dierdonck 2002). This development has further resulted in a widespread restructuring of manufacturing systems, which have moved from a focus on the plant to one on international manufacturing networks (Rudberg and Olhager 2003). Accordingly, global manufacturing studies paid more attention to multi-plant discussions and showed a growing consensus around the idea that one of the most useful keys for understanding the complexity of the global economy is the concept of the network (Coe et al. 2008). Thus, international manufacturing network (IMN) gradually became one of the research foci.

An IMN is normally viewed as a factory network with matrix connections, underlining the need for a wide perspective covering geographic dispersion and interdependent coordination rather than the traditional focus on separated manufacturing sites (Shi et al. 1997; Shi and Gregory 1998; Shi 2003). Generally, research on IMN has its roots in the disciplines of production/operations management and manufacturing engineering. It seeks to extend traditional manufacturing system boundaries from a single factory toward a multi-plant system, and further, to globally dispersed and coordinated factory networks (Shi and Gregory 2005). Nevertheless, it at the same time has to face the complexity of managing such a network (Prasad and Babbar 2000; Colotla et al. 2003).

To some extent, IMN can still be seen as the manufacturing system but with many different characteristics from the classic model. Therefore, similar to the traditional plant-level manufacturing system, two types of decisions can generally be distinguished related to global manufacturing network: configuration and coordination (Colotla et al. 2003). On the one hand, configuration indicates the location of plants and the inter-facility allocation of resources along the value chain (Meijboom and Vos 1997). It concerns issues, such as the building of a network of plants, with particular emphasis on the differentiated structural requirements of different environments (Pontrandolfo and Okogbaa 1999). Hence, configuration may be thought of as the structure of multi-plant networks (Colotla et al. 2003). This aspect had its origins in multi-plant research and was dominated by location-based criteria of various sorts (Dubois et al. 1993; Ferdows 1997b). Later, since ever more researchers recognised the importance of the entire production network, studies gradually shifted from plant location decision-making to (multi-plant) international operations strategy (Prasad and Babbar 2000; Prasad et al. 2001). Furthermore, derived from the multi-plant discussions, a number of typologies

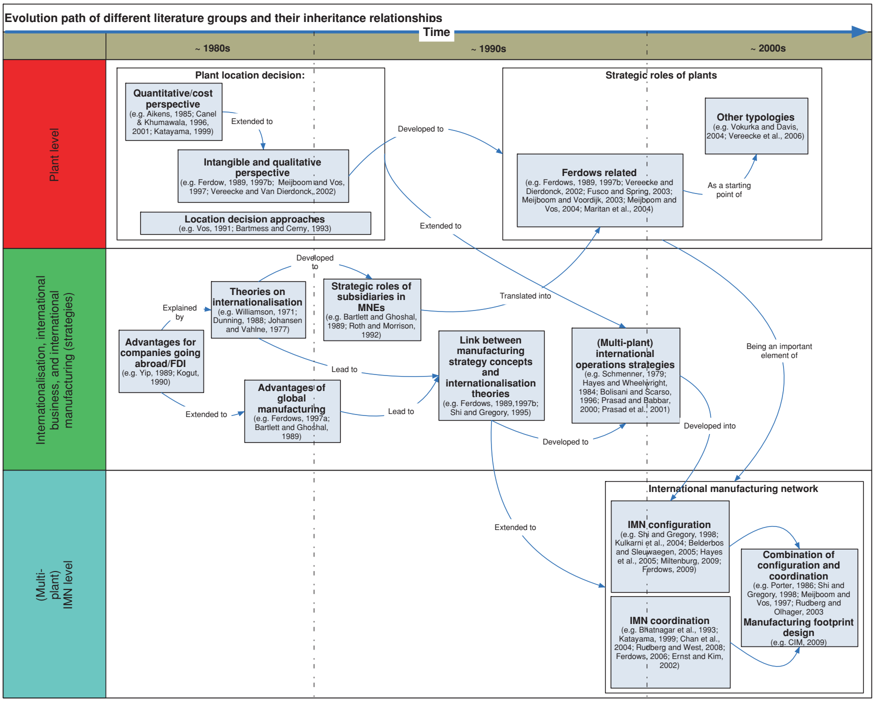

Fig. 2 The overview of the research trajectory of global manufacturing studies

or classifications about configuration were accordingly proposed, e.g. Shi and Gregory (1998), Hayes et al. (2005), and Ferdows (2009). On the other hand, as indicated by Hayes et al. (2005), designing an IMN is like designing any operating system, in that choices must be made not only regarding its configuration (size, location, scope, and specialisation of the units belonging to the network), but also regarding its coordination (degree of centralisation, policies, incentives, measures and controls). Thought of as an infrastructural process, coordination is about the management of a network and refers to the question of how to link or integrate the production and distribution facilities for the purpose of achieving the firm's strategic objectives. Its aim is to achieve the efficient and effective planning of the physical and non-physical flows between the networks plants, (Pontrandolfo and Okogbaa 1999). Generally, three streams of studies on coordination are identified from the reviewed literature, which are the introduction of practices related to coordination (e.g. Rudberg and West 2008), the transfer of production technologies and knowledge (e.g. Ferdows 2006; Waehrens et al. 2012), and the optimisation of physical distribution (e.g. Katayama 1999; Chan et al. 2005). Last but not least, the configuration and coordination decisions are strictly related. Thus, some attempts have been made to integrate the two issues in order to obtain an overall view of global manufacturing network (Shi and Gregory 1998; Rudberg and Olhager 2003).

In summary, research related to global manufacturing has gradually evolved through several phases. Figure 2 is developed to illustrate the overview of the research trajectory of global manufacturing studies. In doing so, the evolution path of the relevant research on global manufacturing is tracked and their inheritance relationships are illustrated in a holistic and detailed way. This further provides an integrated and intuitional view on the development of global manufacturing research, which can be significant for deepening our understanding on global manufacturing studies.

3 From IMN to International Operations Network

Manufacturing (or sales) is normally the first value chain activity to be redistributed. This is because, internally, manufacturing is normally viewed as a lower value-added and less knowledge-intensive activity, but at the same time comprises a large part of the investment and cost; externally, emerging developing countries provide good locations for companies to offshore/outsource their manufacturing activities in order to reduce their cost. It appears that many companies, after the initial stage of getting on steam with the production of relatively simple products, engage in moving additional activities abroad as well. In fact, the redistribution of manufacturing triggers the transfers of other related value chain activities (e.g. procurement, product/process improvement and R&D/new product development as shown in the three case companies), which accordingly creates a snowball effect. Thus, discussions are naturally extended from IMN to other global activities as well as their corresponding functional networks.

3.1 Global R&D and Engineering Network

It is recognised that the internationalisation of the R&D activities of MNEs has generally lagged behind that of their production activities. While firms have long globalised their manufacturing activities, significant globalisation of R&D remains a relatively more recent phenomenon (Gammeltoft 2005). Although still less globalised than production, the share of corporate R&D that is undertaken abroad has been continuously growing since the last decade (Dunning and Lundan 2009) and and the innovative activities of MNEs have become more geographically dispersed than has been the case before (Dunning and Lundan 2009). To some extent, global manufacturing is frequently seen as one of the key forces inducing the decentralisation of research and development, i.e. R&D (Blanc and Sierra 1999). Because of multiple systemic linkages between both production and R&D along the entire life cycle of a product, any company establishing a global manufacturing structure has to consider how to integrate R&D (Simon et al. 2008). However, the rationale for a company's R&D site is not necessarily guided by the same principles that determine a company's manufacturing location. Though factor costs and market proximity do play a role, access to top-calibre engineers and the nurturing vitality of a deep-rooted knowledge cluster are often the key drivers. As a result, the global R&D footprint of a company may not match the footprint required by its highly globalised manufacturing. Accordingly, global manufacturing and R&D are usually discussed independently.

R&D globalisation is simultaneously enabled and driven a host of push and pull factors resulting from changes in global markets and competition, technological change, policy environments, and corporate management and organisation (Chiesa 1996; Karlsson 2006; Sachwald 2008). Gammeltoft (2005) further summarised these factors into six categories: market-driven, production-driven, technology-driven, innovation-driven, cost-driven, and policy-driven.

Built on these enablers and drivers, and other dimensions, various typologies have been proposed for classifying the different roles that MNCs assign to their international R&D sites (Gammeltoft 2005). Ronstadt (1977, 1978) proposed four categories of roles that R&D sites can play: transfer technology units, indigenous technology units, global technology units, and corporate technology units. Hood and Yound (1982) proposed a three-category taxonomy of laboratories, including support laboratories supporting foreign local operations, locally integrated laboratories performing local product/process development, and international independent laboratories linking to global corporate R&D programmes. In addition to supporting local operations, Pearce and Papanastassiou (1999) argued that R&D site could also support non-local operations by advising on the adaption of the products to be produced or processes to be used. Differently, Birkinshaw (2002) identified three types (roles) of individual R&D centre, which are self-contained R&D centres, modular R&D centres, and home-base R&D centres.

Furthermore, in conjunction with historical evolutions, through either mergers and acquisitions or home-based expansions or both, the R&D organisations of multinational companies gradually differ in the degree of cooperation between individual R&D sites and the dispersion of their internal competencies and knowledge bases in a network context (von Zedtwitz et al. 2004). This transformation further implies the importance of R&D networks and, in turn, leads researchers to pay closer attention to this field. Similar to the research on IMN, the studies about global R&D network can also be classified into two groups, i.e., configuration and coordination. Chiesa (1996) described major types of international R&D (network) structures in terms of each activity category, Von Zedtwitz and Gassmann (2002) proposed four archetypes of R&D networks by specifically distinguishing between research and development. On the basis of his three types (roles) of individual R&D centres, Birkinshaw (2002) identified two different configurations of R&D networks, namely an integrated network and a loosely-coupled network. Corresponding to these configurations, different coordination mechanisms were further proposed, such as, structural/formal, informal, hybrid, and internal markets (Reger 2004).

3.2 Global Sourcing and Procurement Network

Global sourcing/procurement was identified as a field of interest for practitioners and as a separate research topic in the late 1980s (Kotabe and Omura 1989). It has normally been viewed as the integration and coordination of procurement requirements across worldwide business units (Faes et al. 2000; Monczka and Trent 1991; Rozemeijer 2000), with other functional groups, particularly R&D and manufacturing, within business units (Kotabe 1992; Trent and Monczka 2003) as an internal interface (Gelderman and Smeijn 2006). The catalyst for global sourcing has been the worldwide competitive pressure forcing firms to reduce costs and to improve quality and responsiveness (Birou and Fawcett 1993). There are six primary reasons for a company engaging in global sourcing: (1) offset requirements, currency restrictions, local content and counter-trade; (2) lower prices; (3) quality; (4) technology access/access to new markets; (5) shorter product development and life cycles; (6) comparative advantage (Bozarth et al. 1998).

The growth of global sourcing in a company normally goes through a five-phase development process, progressing from strictly domestic purchasing arrangements to the development and implementation of global procurement strategies (Monczka and Trent 1991; Trent and Monczka 2003). In developing viable sourcing strategies on a global scale, companies certainly have to think about manufacturing costs, the costs of various resources, and exchange rate fluctuations, but more importantly, they should also take availability of infrastructure (including transportation, communications, and energy), industrial and cultural environments, the ease of working with foreign host governments into consideration. Meanwhile, the complex nature of sourcing strategy on a global scale spawns many barriers to its successful execution (Kotabe and Murray 2004). One issue is how to manage purchasing synergy on a corporate level, without losing the benefits of decentralised purchasing while the other can be how to source major components and where to source them. It is therefore crucial to distinguish between sourcing on a contractual basis and sourcing on an intra-firm basis when examining the relationship between sourcing and competitiveness of multinational companies (Kotabe 1998). Relative to these, four types of sourcing are proposed as illustrated by Fig. 3. More recently, research in global sourcing has been considerably extended. The focus has been suggested to shift from the management of global procurement and purchasing operations, internally to the coordination with R&D and manufacturing (Trent and Monczka 2003) and externally to inter-firm supplier relationships (Kotabe and Murray 2004).

3.3 The Importance of International Operations Network

As Skinner (1996) argues, manufacturing today comprises “the value chain of product realisation”, including research and development (R&D), procurement, production, distribution, customer service, and warranty repairs. It has been

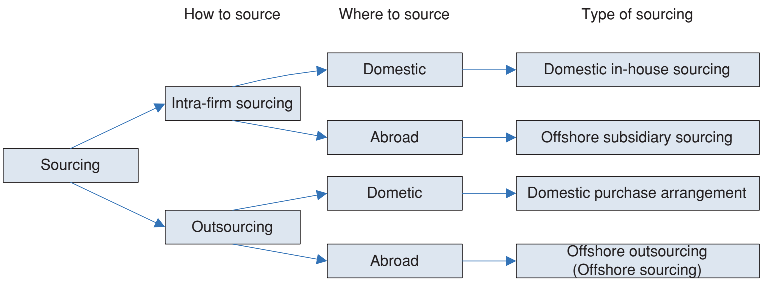

Fig. 3 Four types of global sourcing (Kotabe 1998)

recognised that in today's world of global competition and high-speed product development, the linkage between R&D, manufacturing, and marketing is more vital to successful business than ever before. Companies are faced with the challenges of delivering competitive products to the market at the right time, with the right specifications, and at a low cost under the complexity of marketing, R&D, and manufacturing located in geographically dispersed areas around the globe (Berminghan 1996).

Therefore, global manufacturing should not be an end, but a starting point. As described above, it can further be accompanied by the internationalisation of other value chain activities, including global sourcing, global engineering and global R&D. Actually, with globally distributed plants and other centres of service, sales, engineering, and R&D, companies have to extensively look into their international operations networks (IONs) and address individual manufacturing, sales, service, engineering, and R&D functional networks simultaneously. This means that network configuration decisions based on traditional geographical advantages or sub-optimisation of the IMN might no longer provide sufficient competitiveness.

As shown in the previous sections, it is certainly not difficult to find studies addressing various global functional networks and covering the globalisation or internationalisation of relevant value chain activities. However, the existing research remains fragmented and disintegrated, exclusively focusing on the networks of specific facilities (i.e., R&D centres, engineering centres) and discussing them independently. According to our knowledge, except for Wang et al. (2008), there is no evidence of research on global operations management that offers a comprehensive and integrated framework for managing multi-functional networks of geographically dispersed operations along the value chain. The interactions among different kinds of networks are general ignored. However, as the internationalisation of manufacturing, R&D, sales, and service is clearly interrelated and the developments of the corresponding networks mutually interact, it has become ever more important to incorporating each value chain activity, coordinate different functions, and align them with the location of global operations, to increase the performance and to minimise risks of a company. When addressing each functional network as well as their interactions, it seems that four key factors should be taken into consideration, ranging from micro to macro level.

- *Flows of products, processes and knowledge between sites*: Products, processes and knowledge flow among different sites frequently, accompanying the redistribution of value chain activities. Specific products, processes and knowledge tend to be transferred outwards from some sites and then received and absorbed by other existing sites or newly established/acquired sites. This activity then leads to the portfolios of products, processes and knowledge for relevant sites to be changed from time to time. In turn, producing more products, holding more processes and having more knowledge enhance the site's capability and further facilitate the redistribution of value chain activities. However, it is also important to notice the characteristics of products, processes and knowledge. They have great impact on the redistribution since not all the products, processes and knowledge are matured enough, or ready, or easy to be transferred.
- *Site capability*: Once the companies choose to establish their ION, they have to face a long-term, slow, iterative, sequential, and progressive process then. During this process, any further globalisation of value chain activities appears mostly when sites have proper capabilities to handle more and/or complicated tasks. In other words, even with lower cost and/or bigger markets, the sites might still not be allowed to take on more responsibilities and perform more value chain activities unless they have the capabilities. However, the sites are able to develop their competencies based on accumulation of their knowledge and experience with relatively simple operations and specific investments on technology and equipment. Gradually, they achieve a certain level on their capabilities of specific areas, enabling more products and processes moved to and more tasks given to these sites. In addition, it is important to emphasize that site capabilities can also be developed based on the support of headquarters, as explained later below.
- *Site location* (*such as regulations, local business environment, currency, etc.*): The conditions of site location change dynamically, which might have both positive and negative impacts on the redistributions. In the wake of the Great Recession, the global economy has entered a period of high volatility and uncertainty that has been particularly challenging for companies. Some forces relate to location are already being felt, including the shift of global demand toward developing economies, they dynamics of currency fluctuations, and the rising wages in low-cost locations. Others are just emerging, such as a growing scarcity of technical talent in some countries. In addition, governments also play an important role as they are attempting to make their nations more attractive expansion sites for multinational corporations in terms of different forms. These include incentives to support local industry, which are spreading to a broader set of countries and also include measures such as reducing corporate tax rates, not even to mention redeveloping new regulations.
- *Network strategic decision*: Last but not least, any globalisation efforts, in terms of e.g. establishment, development or closure of production/R&D facilities and transfers of production/R&D activities between sites, reflect the strategic decisions of the headquarters. Therefore, even if the specific sites had already held proper capabilities, the further globalisation efforts still have to be eventually

proved by the top management when they when they recognise opportunities and attempt to make relevant decisions, which are unlikely to be initiated by local mangers.

4 What Is More?

Related to the internationalisation of manufacturing activities, another trend often observed is externalisation from traditional vertical integrated firms in almost every sector (Shi 2004). Due to the increased focus on externalisation or outsourcing, the traditional manufacturing system boundaries are naturally extended from a single factory along the ownership dimension. This extension makes the externalised (inter-firm) supply network a new unit of analysis with more features than the classical plant (Shi 2004). Setting its roots in physical distribution, materials management, and outsourcing, research on supply chain/network usually takes a logistical perspective and tends to analyse the network as external with facilities owned by different organisations. Similar to IMN, the supply chain/network also has its own missions, architectures, mechanisms, and strategy process. It is generally accepted that the research on externalised (inter-firm) supply network focuses on the links between the nodes (and, to some extent, distribution nodes), whereas IMN research tends to focus on the (manufacturing) nodes themselves (Rudberg and Olhager 2003). Compared to studies on IMN, research in the field of supply network has quite a different focus, such as physical distribution, materials management, collaboration, partnerships, trust, customer relationship management, customer service management, demand management, order fulfilment, and procurement (Lambert and Cooper 2000).

In fact, there is abundant empirical evidence that the boundaries between internalisation and externalisation of the traditional manufacturing system are in a continuous state of flux (Coe et al. 2008). For example Shi and Gregory (2005) discuss internationalisation and externalisation of manufacturing in a holistic framework by addressing intra-firm and inter-firm (external) networks at the same time. They further propose that a concept of global manufacturing virtual network (GMNV), which can actually be considered as the synthesis of views on IMN, international strategic alliances and virtual organisations. To some extent, their conception of GMVN shares some similarities with the insights of the global production network (GPN) proposed by social scientists, including, remarkably, economic geographers (Ernst and Kim 2002; Sturgeon 2002; Hendersons et al. 2002; and Coe et al. 2008). The latter (GPN) is, however, defined much more broadly as a conceptual framework that is capable of grasping the global, regional, and local economic and social dimensions of the processes involved in many (though by no means all) forms of economic globalisation (Hendersons et al. 2002).

Today, the trend of specialisation and collaboration between firms is actually not limited only to manufacturing tasks but also extended to other non-core

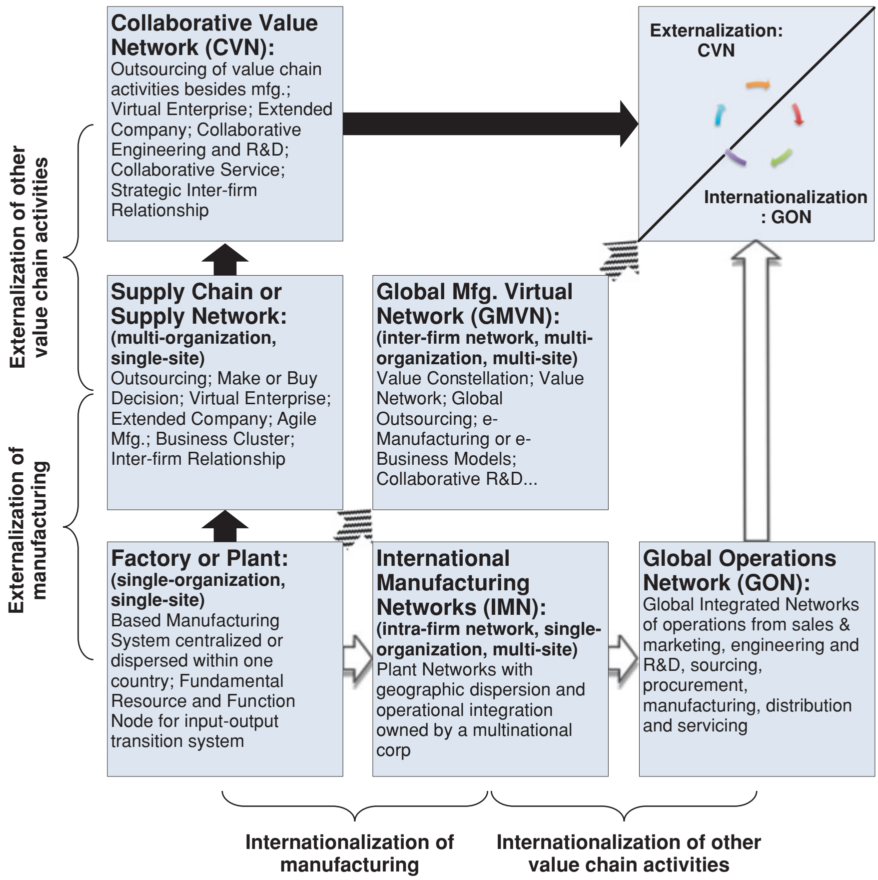

Fig. 4 An internationalisation and externalisation matrix

value chain activities, such as procurement, product/process improvement and innovation activities. In other words, the concept needs to be broadened to include the general integration of all functions and business processes throughout the total value chain, including marketing, manufacturing, distribution, R&D, etc. (Cheng and Johansen 2013). Similar to the extension from IMN to ION, this new development goes beyond the traditional make-or-buy decision and creates another type of network, which tends to concern new value proposition and new strategic collaboration in the supply or, more clearly, value network.

More importantly, there also exists the evidence to prove that companies are actually trying to internationalise and externalise their value chain activities at the same time. This further implies that the network that companies need to face and manage will be not only an ION or a collaborative value network but also a combination. This development can be briefly illustrated by Fig. 4.

5 Practical Implications

5.1 Micro Level Implications

It is no doubt that leaders of 21st-century manufacturing companies will be the ones that manage across functional silos and across their companies' boundaries to collaborate seamlessly with partners and suppliers (Manyika et al. 2012). As manufacturers craft strategies in response to the trends that will arise as mentioned above, they will be challenged to balance the need to make long-term investments with the need to manage near-term volatility and uncertainty.

In the near-term, companies firstly need to open their mind and recognise the possibility of internationalising and externalising not only manufacturing but also other value chain activities. Considering the dynamics of internationalisation and externalisation, manufacturers should understand the nature of the uncertainties and monitor multiple alternative factors that could affect their strategies and operations during the development. Furthermore, they have to become more agile, being able to respond quickly to any expected and unexpected changes of multi-dimensional factors including those mentioned previously, by adjusting the distribution of the corresponding value chain activities globally and/or between suppliers. Although more dispersed sites and more suppliers bring higher complexity to management, they enhance the possibility of achieving higher flexibility meanwhile as companies have more choice to arrange their value chain activities globally to meet business challenges.

Being agile, companies can easily shift to another prepared strategic scenario, Even if things do not go as planned (Manyika et al. 2012). However, building agility to handle uncertainty is normally a long-term and sequential progressive process. During this process, competitive environments are not static and competitors always react. Thus, companies have to continuously take into account all variables and consider the scenarios for how factors evolve over time, as the solution that works in one scenario may not work for others. The relevant decisions and strategies should not be conceived at different organisational levels at different times and by different people (Colotla et al. 2003), but efforts across groups must be coordinated to avoid conflicting and overlapping efforts. In this case, specific persons who can proactively coordinate the internationalisation and the externalisation of value chain activities are needed at the company's headquarters. They need analytical views and contingent thinking on these factors of intra-firm sites and inter-firm suppliers to create alternate future scenarios and further use a dynamic, risk-adjusted process to build agile strategy and operations applied across the value chain to accommodate every scenario.

5.2 Macro Level Implications

On a macroeconomic level, the evolution of an economy from industrialisation through to eventual deindustrialisation appears to be an inevitable development. There are good arguments for moving in step with the tide and perhaps even shaping your path through it. While the effects are naturally country-specific, three economic groupings can be distinguished (with overlaps due to the heterogeneity of the countries): industrialising/emerging economies, highly industrialised economies, and post-industrial economies. Evidence is mounting to suggest that countries working proactively to trigger a phase-shift can actually accelerate their progress, reaping multiple benefits throughout the transition.

Industrialising economies are, to some extent, the net beneficiaries of the value added by foreign companies that are optimising their global value chain footprints. Obviously companies in high-cost locations wish to take advantage of the low wage levels in developing and emerging economies. They do not only move simple production processes out of high-cost locations, but are also keen to transfer technology-intensive steps of their value chain activities as fast as lower-cost regions can handle them. Moreover, the present of multinational corporations and their subsidiaries fosters start-ups by giving talented individuals the opportunity to gain experience and accumulate capital. They further reinforces the technology base in the industrialising economy, while strengthening its education system via the feedback loop of the transplant's demand for qualified staff on a regular basis. As a result, they lead to the upgrading of many social and legal standards, but at the same time wage levels. Nevertheless, there are also some problems, such as the enormous discrepancy between poverty-stricken rural areas and wealthy enclaves, and the immediate proximity of dramatic income disparities caused by migration into urban centres.

Highly industrialised economies generally refer to those countries that have already successfully navigated a long period of industrialisation with rising per capita incomes, and are now on the cusp of deindustrialisation, such as South Korea. Actually, until recently, these countries were themselves in the position as industrialising economies, but now they often find themselves locked in a new competition. While production and other vale chain activities in these highly industrialised economies profited heavily in the past from the wide range of production opportunities, related sourcing options and others, it is now undergoing redefinition in two main ways. First, companies are relocating production steps that are too expensive to industrialising economies in order to reduce the cost gap. Meanwhile, they are investing in new technology to reduce the know-how gap vis-à-vis competitors in post-industrialised economies. In other words, direct investments from highly industrialised countries have increased both in post-industrialised economies for technology reasons and to expand market share, and in industrialising economies to meet cost targets. Accomplishing this shift requires a readiness to abandon legacy industries that are losing competitiveness in their current constellation. This is indeed painful and can lead to considerable friction, but the costs of economic adjustment can be disastrous if this shift is delayed too long.

Last but not least, post-industrialised economies are actually facing the decline of their manufacturing and process industries as a share of GDP, which is at the same time accompanied by a surge in knowledge-based service activities. New information and communication technologies as well as others have triggered a dramatic change in value creation activities, which have further accelerated the deindustrialisation process of these post-industrialised economies, i.e. shifting focus towards more service-oriented. Although the service sector now still accounts for a smaller relative share of GDP, inflation-adjusted industrial value added in the post-industrialised economies, such as Germany, the United States, and France, has actually increased over the past 20 years. As long as being able to keep up their innovation, and have (and continue to build) a matching HR pool, the post-industrialised economies can benefit hugely from the new knowledge economy and are able to remain attractive for investments and competitive for the production of goods and services that can be exported in order to finance the imports of lower-value goods.

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