Development of Production Management: From Site to Network Optimisation

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In this chapter we shed some light on the relation between operations management and manufacturing networks. After that we focus on the development of network management evolving from site management. The third section is dedicated to three classic optimisation approaches at site level. They are intended to argue in favour of the dire necessity to address the network level as well. Some ideas for the further development of production systems towards production network systems will close this chapter.

2.1 Manufacturing Networks as Part of Production Management

To address the issue of manufacturing networks and its significance as a part of manufacturing management, we must first of all draw up a general definition of manufacturing management. Manufacturing management in a broader sense grapples with the general management of a manufacturing company. It comprises all of the important topics to be discussed in such a company.[1] In the early days, however, manufacturing management was heavily focussed on the plant level and dealt in particular with the organisation of manufacturing at a site.[2] With this as a starting point, research also developed in the field of globalised manufacturing from the conventional site perspective. Interest was primarily focussed on the optimal placement of sites in a manufacturing network.[3] Supplemented by further site-specific questions, concerning for example strategic value added in the network,[4] a research trend developed which focussed on the arrangement of sites in the context

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[1] Cf. Friedli (2006), for example, for an understanding of this term and manufacturing management more specifically.

[2] Rudberg and Olhager (2003), p. 29f.

[3] For example Aikens (1985), Canel and Khumawala (1996) or Kinkel (2004).

[4] For example Ferdows (1997a), Vokurka and Davis (2004) or Vereecke et al. (2006).

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of a company network. This has meanwhile been complemented by a definition of the network which goes beyond the simple aggregation of single sites. The network is seen as an independent and complex system in which the players interact with one another.[5]

The management of such global manufacturing networks as we understand them today plays an increasingly crucial role with respect to the competitiveness of manufacturing companies and provokes correspondingly greater discussion in the literature. Up to now, however, no standardised understanding of the concept has emerged. Hence some authors understand it as the organisation of global manufacturing of a company unit within a network. Other authors use the term manufacturing network in a more comprehensive way and include alongside the network's own sites groups like suppliers or customers.

We follow Shi and Gregory (1998) and Rudberg and Olhager (2003) who defined manufacturing networks as "[...] a factory network with matrix connections, where each node (i.e. factory) affects the other nodes and hence cannot be managed in isolation."

The selection of the specific parts of the manufacturing network depends on the chosen perspective. Rudberg and Olhager (2003) classify research on so-called value networks according to the number of organisations involved and the number of sites per organisation. They distinguish four different levels of analysis: plant, intra-firm/intra-company network, supply chain, and inter-firm/inter-company network (Fig. 2.1).

Studying manufacturing networks, this system view needs to be sharpened by defining its boundaries and the prevailing management scope. Two research perspectives have been dominant in this: the operations management and the supply chain management perspectives. In Fig. 2.2 Rudberg and Olhager (2003) summarise the consequences of this differentiation.

While manufacturing network theory is based upon the operations management perspective focussing on the organisation of the plants, the network, and its coordination, supply chain management stems from the area of logistics focussing on the management of the material flows. Since the former is typically limited to an internal and fully owned network system, it primarily addresses the design of the nodes and their capabilities. The latter, on the other hand, widens boundaries by integrating external suppliers and customers, mainly addressing the (physical) links between the nodes (Rudberg and Olhager 2003).

A further distinctive feature is the geographic spread of the network. It reflects the worldwide distribution of the manufacturing sites. According to Miltenburg there are four stages of geographic spread, based upon the location of sites from the perspective of the headquarters: national, regional, multinational and global.[6] Miltenburg calls the national and regional spread a "simple network", whereas he calls the multinational or global spread a "complex network".

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[5] Shi and Gregory (1998), p. 198 and Khurana and Talbot (1999), p. 2.

[6] Miltenburg (2009).

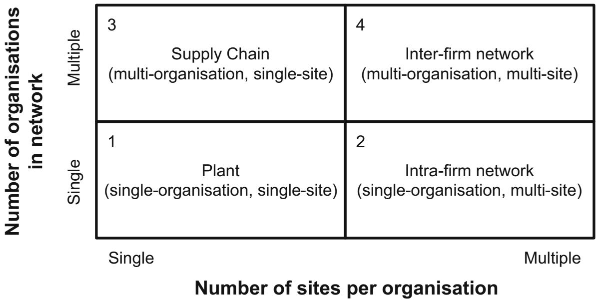

Fig. 2.1 Classification of value networks (Rudberg and Olhager 2003)

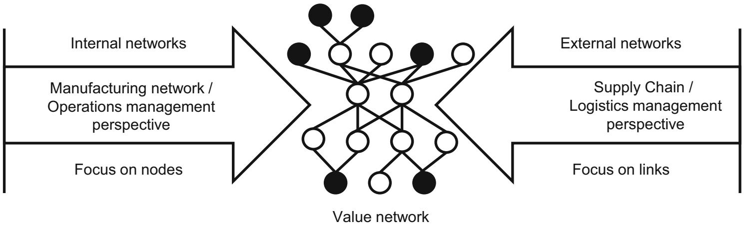

Fig. 2.2 Different perspectives on value networks (Rudberg and Olhager 2003)

2.2 From Site to Network Management

As mentioned earlier, research in manufacturing management has focussed primarily on single, isolated companies or the individual sites of manufacturing companies.[7] It is thus no wonder that most of the literature concerns questions such as how to plan, organise, optimise and operate a manufacturing site, manufacturing area or single manufacturing line. With the increasing globalisation of industry, this perspective remains important, but has to be expanded to include the realisation that a site is only one value adding part of an entire network. In recent years a number of authors have focussed on this perspective.[8]

Although occasionally the necessity of systematic network management and thus the evolution from the production system to a production network system[9] is emphasised, such a system has not yet been adequately developed. In Fig. 2.3 both perspectives are compared.

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[7] For example Shi and Gregory (2005).

[8] Cf. Ferdows (1997b) and De Meyer and Vereecke (1994).

[9] The term production network system was made popular by Shi and Gregory (1998) and Shi (2003).

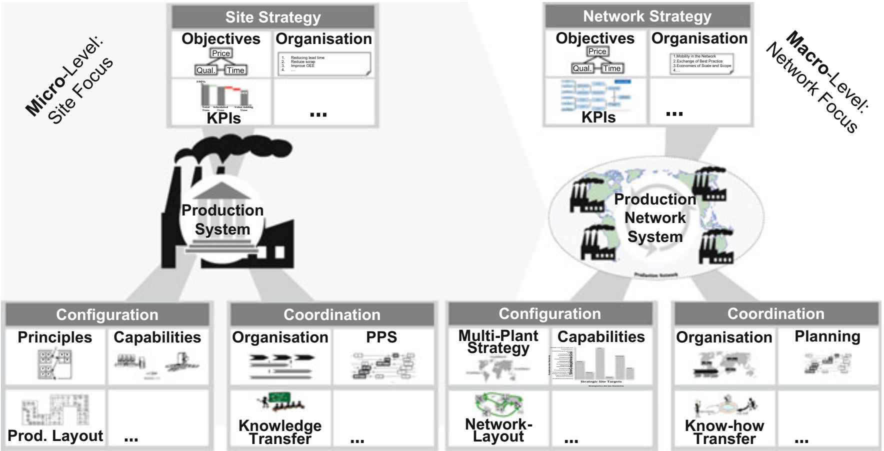

Fig. 2.3 From production system to production network system (Based on Thomas 2013, p. 43ff; Friedli et al. 2011, p. 611)

By analogy with production systems, which determine the development of production as well as functions of production in plants or in plant areas (micro-level), production network systems comprise the basic determinants in decision making for the configuration and coordination of manufacturing activities on a global basis.[10] For example, decisions for the configuration of the production layout (chain-linking of work stations in the plant) are comparable to the configuration of the network layout (chain-linking of sites within the manufacturing network). Figure 2.3 illustrates the relationship between production systems and production network systems.

On the micro-level, focussed on the site, three influential factors shape the configuration of manufacturing systems and thus define the framework of site management: the target system defines the strategy; the structure defines the physical configuration of production; and the infrastructural level influences how activities on site are to be controlled and coordinated.

On the macro-level, and thus on the level of the superordinate manufacturing network, three configuration levels for the so-called manufacturing network system can be identified – network strategy, network configuration and network coordination – which have to be harmonised with one another.[11]

By appropriately adapting configuration and coordination in accordance with the global manufacturing strategy, companies can gain competitive advantages from

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[10] Thomas (2013), p. 44.

[11] Cf. Porter (1986); Rudberg and Olhager (2003), p. 30 and Friedli et al. (2011), p. 611f.

global manufacturing.[12] In view of the above, we define manufacturing network systems as follows:

Manufacturing network systems define both the configuration of production as well as production's supporting functions in global manufacturing networks. The relevant decisions can be divided into configuration and coordination. When coordinating the single decisions both with the global manufacturing strategy as well as with each other, a manufacturing network system develops which is particularly powerful and cannot be imitated easily. Thus it is a strategic advantage for the company.

Designing the manufacturing capabilities is realised by adjusting the decision categories of the manufacturing system (e.g. Platts et al. 1998; Miltenburg 2009). Once more starting from the site level, operations management literature differentiates between structural and infrastructural decision categories to shape the factory manufacturing system (e.g. Hayes and Wheelwright 1984; Slack and Lewis 2002). Structural decisions are related to the "... physical configuration of the operation's resources [... while infrastructural decisions comprise the ...] activities that take place within the structure" (Colotla et al. 2003, p. 1187). Both categories can be broken down into distinct dimensions; in other words, designing the manufacturing system is realised by shaping its sub-systems. Table 2.1 provides an overview.

A similar discussion was also started concerning manufacturing network systems.[13] Instead of distinguishing between structural and infrastructural components, in the manufacturing network system the network configuration and network coordination are seen as levels for the implementation of the manufacturing strategy.[14]

Consequently, the manufacturing strategy specifies the manufacturing priorities for gaining competitive advantages.[15] It can be supported by different capabilities at network or site level.[16] The arrangement of these capabilities takes place on the configuration level using the design of the structure and the physical conditions of the sites and/or network. This means that decisions have to be taken in regard to the number of sites, their global distribution, competencies, capabilities and facilities.[17] The coordination level addresses the organisation and management of global activities. Here decisions are made regarding the interaction of the sites, what level of autonomy they should have, where resources are to be allocated and how they are to be exchanged. Questions concerning the design of both knowledge and

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[12] Porter (1986), p. 23 "Configuration/coordination determines the ongoing competitive advantages of a global strategy which are additive to competitive advantages a firm derives/possesses from its domestic market positions."

[13] Shi and Gregory (1998), p. 201 and Colotla et al. (2003), p. 1187ff.

[14] Cf. Porter (1986) and Rudberg and Olhager (2003), p. 30.

[15] Wheelwright (1984).

[16] Shi and Gregory (1998) and Miltenburg (2009).

[17] Cf. De Toni and Parussini (2010).

Table 2.1 Manufacturing system's decision categories and dimensions (Based on Leong et al. 1990; Rudberg and Olhager 2003)

	Hayes and Wheelwright (1984)	Fine and Hax (1985)	Hayes et al. (1988)	Samson (1991)	Miltenburg (1995)	Skinner (1996)	Hill (2000)	Slack and Lewis (2002)	Hayes et al. (2005)
Structural categories									
Process technology	✓	✓	✓	✓	✓	✓	✓	✓	✓
Capacity	✓	✓	✓	✓	✓	✓	✓	✓	✓
Facilities	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vertical integration	✓		✓	✓	✓	✓	✓	✓	✓
Infrastructural categories									
Resource allocation and budgeting									✓
Human Resources (HR)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Organisation	✓		✓	✓	✓		✓	✓	✓
Quality	✓	✓	✓	✓			✓	✓	✓
Production planning and control	✓		✓	✓	✓	✓	✓	✓	✓
New product development		✓	✓	✓				✓	✓
KPI/Performance measurement system			✓		✓	✓			✓

information exchange are also addressed at this level. The coordination is thus more about the question of how sites are linked to each other and how they should interact to achieve the company's strategic goals.[18]

In summary, network management is effected by means of the design of the configuration levels and their decision categories. It remains a question for debate which concrete decision categories the single levels comprise in detail, and what form these categories should take. There is similar disagreement about the relationships between the decision categories.

Research from a network perspective deals specifically with questions concerning the design of manufacturing networks and their best possible management. Porter calls these two aspects the configuration and coordination of a manufacturing network.[19] Under the first level – configuration – he subsumes decisions about the geographic distribution of single activities in the global value added chain, as well as the number of necessary sites.[20] The second level – coordination – comprises the coordination and balancing of global activities and sites with one another.[21]

These two levels of global manufacturing networks are again approached in the literature from two directions. On the one hand, from the conventional site perspective, which concentrates on the individual sites and their network roles, and on the other hand from the network perspective, focussing on the superordinate network structure. These two trends will now be briefly presented. Figure 2.4 assists in structuring the discussion.

Developments from the site perspective Some authors focus on the individual site as a component of a manufacturing network. Originally, this perspective stems from the literature regarding the choice of global location. It analyses key factors and develops approaches for using facts to methodologically determine the optimal location for a manufacturing plant. Aside from various forms of mathematical modelling, the discussion in many contributions revolves most of all around the key factors, methods and approaches for location selection.[22]

In the process of globalisation and the development of multinational companies, a further line of research evolved based on literature concerning the strategic role of subsidiaries, which can be seen as the foundation stone of the concept of site roles in manufacturing networks.[23] Bartlett and Ghoshal distinguish four roles based on the

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[18] Meijboom and Vos (1997) and Cheng et al. (2011).

[19] Porter (1986), p. 15ff.

[20] Porter (1986), p. 17.

[21] Ibid.

[22] See Owen and Daskin (1998) for an overview of the mathematical models, Kinkel (2004), Meyer (2006), p. 36ff and Kinkel and Zanker (2007) on the subject of key factors, methods and approaches for site selection. Kinkel and Zanker (2007) also examine various methods for assessing site locations.

[23] See Paterson and Brock (2002) for an overview of the literature regarding the strategic roles of subsidiaries.

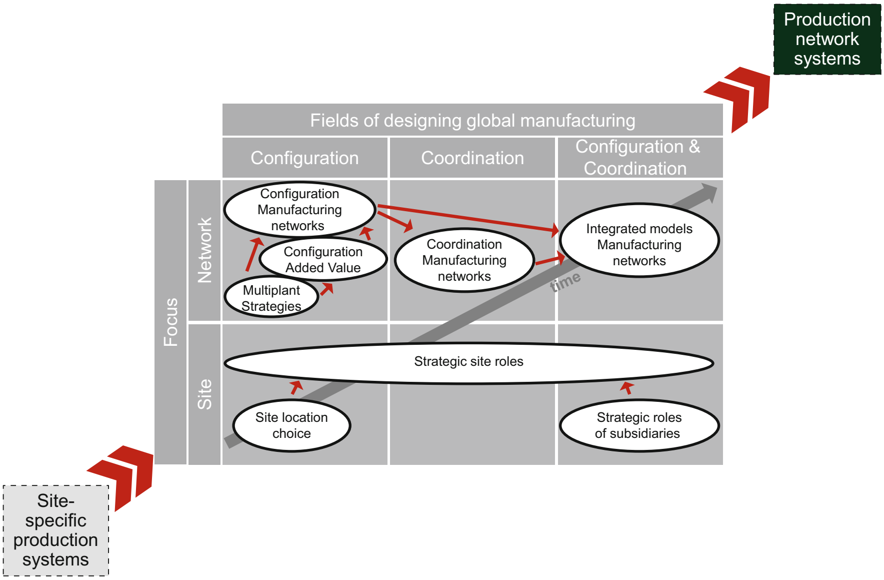

Fig. 2.4 Development of the production network system

competencies of a subsidiary and its strategic significance: strategic leader, contributor, implementor and black hole.[24] Prahald and Doz also identify four roles regarding the responsibilities of the subsidiary and its integration within the entire company.[25] Gupta and Govindarajan differentiate subsidiaries based on their knowledge inflow and outflow as follows: local innovator, global innovator, implementor and integrated player.[26]

In his pioneering research Ferdows combines both of these trends in the literature, making use of them especially in regard to manufacturing sites, and hence in regard to the definition of strategic site roles. The role model he devised distinguishes six site roles based on strategic site advantages (low costs, access to market, access to knowledge) and the competencies at the site.[27] The role model recognised in the literature has been empirically validated several times[28] and is described more explicitly in Sect. 2.3.2.

The literature from the site perspective can be assigned to either the field of configuration or the field of coordination, depending on the contribution. While Ferdows' model, with its focus on site advantages and competencies, addresses significant aspects of configuration, Vereecke for example concentrates on site roles

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[24] See Bartlett and Ghoshal (1990).

[25] See Prahald and Doz (1987).

[26] See Gupta and Govindarajan (1991).

[27] See Ferdows (1997a, 1989).

[28] See Vereecke and Van Dierdonck (2002).

on the basis of the integration of a manufacturing site in the knowledge exchange within the network and thus addresses coordination aspects. There are also authors who combine both perspectives. The central question in their research deals with how individual site roles are managed differently. Using Ferdows' role model as a basis, they take a closer look at the level of autonomy in the individual site roles. The contributions of Maritan et al., as well as those of Feldmann and Olhager are of particular relevance here.[29]

Developments from the network perspective The second part of the literature does not concentrate on the individual site, but looks more closely at manufacturing networks from a superordinate network perspective. Authors using this perspective point out that manufacturing networks may not simply be considered as aggregate units.[30] In their view, a manufacturing network is more than just the sum of its sites. Hence, they are convinced that an integrated view of the manifold interdependencies between the sites must be considered.[31]

Based on Skinner's Focused Factory Concept, according to which the concentration of production on strategically relevant goals improves their performance, Hayes and Schmenner developed so-called "multiplant strategies".[32] These transfer the basic idea of specialisation in manufacturing to the network level. Hayes and Schmenner distinguish between two contrary multiplant strategies in their work: the manufacturing strategy and the process strategy.[33]

In a network specialised on products, each plant is entirely responsible for one product range. In networks with process orientation, each plant concentrates on a specific sub-process in product manufacturing. In this way, a multiplant strategy supports consistent decisions concerning the spectrum of products and processes of the plants within a network. In later works, further multiplant strategies were described, such as the market strategy in which each plant is responsible for a specific market.[34] Section 3.2.2 takes a closer look at the concept of multiplant strategies.

While multiplant strategies represent basic strategic decisions, model-based manufacturing network optimisation techniques are summarised by the configuration of value creation. The literature on this topic can be subdivided into three areas: tactical optimisation approaches, strategic-static optimisation approaches and strategic-dynamic optimisation approaches.[35]

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[29] See Maritan et al. (2004) and Feldmann and Olhager (2009b, 2011).

[30] Shi and Gregory (1998), p. 197.

[31] Shi and Gregory (1998), p. 197f.

[32] See Skinner (1974).

[33] Hayes and Schmenner (1978), p. 110ff.

[34] See Schmenner (1982) and Hayes et al. (2005).

[35] Jacob (2006), p. 29ff.

Tactical optimisation approaches look at the allocation of resources, orders or products to sites in the network. An example is Hartweg's model, which rates single allocation scenarios on the basis of the resultant costs. Strategic-static optimisation approaches consider a number of factors in the global distribution of value creation, for example characteristics of manufacturing processes, transport processes, sites etc.[36] Strategic-dynamic optimisation approaches additionally integrate dynamic elements such as changes of input parameters (e.g. factor costs or productivity) over time. An example of this is Jacob's work.[37]

The literature concerning configuration in a narrower sense has developed from these two branches. Here, the authors look at the classification of manufacturing networks on the basis of their configuration. In most cases, they consider the geographic distribution of the sites, from national to regional and multinational up to a global distribution of production.[38] Other authors take the internal interconnections of services and supplies as the basis for classification. Stremme, for example, identifies mono-centralistic manufacturing site structures with a centralisation of the inter-company flow of goods, in which foreign plants support the main plant as an extended workbench. These he distinguishes from linked manufacturing site structures, with manifold connections between the single sites, and insular manufacturing site structures, in which the plants mainly act independently.[39] Based on the importance of the effects of scale and scope, and the significance of local adaptation, Meyer and Jacob distinguish five configurations: world factory, local for local, chain, network, and hub and spoke.[40]

In addition to configuration, some authors talk about the coordination of manufacturing networks. This literature originates in the research on multinational companies. Authors like Ghoshal, Tsai and Luo look in their work at the degree of autonomy, the transfer of knowledge and innovation, the exchange of resources or the communication behaviour within multinational companies.[41] This knowledge serves further authors as a basis for research on the coordination of manufacturing networks. Flaherty proves in her research on five companies of the electronic, chemical and capital goods industries, that synergy effects can be achieved by coordinating the supporting functions in manufacturing and the technical field.[42] Ferdows looks at coordination from the perspective of knowledge transfer in manufacturing networks.[43] From the nature of production expertise, he derives ideal transfer mechanisms and shows coherences with competencies required at

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[36] Cf. Meyer (2005) as an example of the strategic-static optimisation approach.

[37] See Jacob (2006).

[38] DuBois et al. (1993), p. 309ff; Miltenburg (2009), p. 6185f, and Shi and Gregory (1998), p. 211.

[39] Stremme (2000), p. 214ff.

[40] Meyer and Jacob (2008), p. 164ff.

[41] Ghoshal et al. (1994); Tsai and Ghoshal (1998) and Luo (2005).

[42] Flaherty (1989), p. 95ff.

[43] See Ferdows (2006).

other sites.[44] Jacob et al. give recommendations concerning the choice of organisational structure and the distribution of responsibilities between the company headquarters and the plants.[45] Rudberg and West present a conceptual model for the coordination of manufacturing networks. Based on Ericsson's approach, they focus in particular on the functions that are needed for network coordination in their model factory concept.[46] In addition to the plants, which they divide into those with and those without product responsibility (micro factories with master responsibility and micro factories with clone responsibility), their concept encompasses a kind of virtual control unit (model factory) which assumes the design of the manufacturing network and the production in the plants, as well as of expert groups for the transfer of knowledge and for the specification and review of the required standards in the network.[47]

Although the work on global manufacturing networks looks in most cases at configuration and coordination separately, authors repeatedly point out the tight connection between the two dimensions. Established authors such as Porter, Mejboom and Vos or De Meyer and Vereecke regularly emphasise the necessity of an integrated approach.[48] McGrath and Bequillard already show in their earlier work that different coordination aspects, depending on the manufacturing network's configuration, should be designed differently.[49] The approach of Cambridge University's Institute for Manufacturing, centred on the contributions by Shi et al., Shi and Gregory as well as Shi, takes for the first time a holistic perspective, looking at a large number of design factors for both configuration and coordination together.[50] From their research they derive seven different types of manufacturing networks, which they subdivide into four groups based on the two axes of configuration and coordination. In their work they link configuration with the strategic capabilities offered by the network for the first time. Miltenburg builds upon this knowledge (among other things), and in his conceptual model connects manufacturing network strategy (strategic capabilities which have to be provided by the network) with elements of configuration and coordination. Not only does he unify the dimensions of configuration and coordination, but he at the same time links together concepts of both the site and network perspectives. The latter has only been employed by a few authors up to now. Apart from Miltenburg, Colotla's work should also be mentioned, which looks at the interactions of site and network capabilities in the achievement strategic objectives.[51]

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[44] See Ferdows (2006).

[45] Jacob et al. (2006), p. 274ff.

[46] See Rudberg and West (2008).

[47] Rudberg and West (2008), p. 95ff.

[48] See Meijboom and Vos (1997), De Meyer and Vereecke (1994).

[49] See McGrath and Bequillard (1989).

[50] See Shi et al. (1997); Shi and Gregory (1998) and Shi (2003).

[51] See Colotla et al. (2003).

From this overview of the literature it remains to be said that both dimensions, configuration and coordination, are of central significance for the design of a manufacturing network for providing the network's strategic capabilities. The aim thereby is not only to evaluate discrete aspects of configuration or coordination in an isolated way, but to strive for a holistic perspective. Manufacturing networks should not be viewed aggregately from a site perspective, but demand an integrated view from the network perspective. Manufacturing networks are more than the sums of their sites. Consequently they need a holistic manufacturing network system for their design and management.

2.3 Management Approaches at Site Level

In the following, three established approaches for design and optimisation at site level are presented in detail. Firstly, location decisions, secondly, the site role concept, and thirdly, Lean Manufacturing as a widely applied optimisation approach.

2.3.1 Site Location Choices

The literature on decisions regarding site location offers methodological support for the assessment and choice of the right site for a new manufacturing facility. Originally mainly cost-based, in the meantime a number of other qualitative factors are also taken into consideration. Nevertheless, quantitative approaches remain the focus. In addition to environmental factors, company-specific factors also play a role, which find their way into mathematical programs and simulations.[52] These methods are complemented by more generic process models, which move the focus from decision support to systematic decision making.[53]

In addition to these rather technical approaches to the selection of sites, Bartmess and Cerny are among the first to have introduced a capability-driven perspective to the selection of sites. To achieve capability-driven financial returns, they suggest subdividing the strategy of a company or a network into capabilities and to search for a location based upon the site's impact on those capabilities.[54] In doing so, they link external factors such as proximity to the customer, the market or the supplier, with internal relations between the different sites in the decision-making process.

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[52] See Aikens (1985); Love et al. (1988); Canel and Khumawala (1996) and Canel and Khumawala (2001).

[53] See Schill (1990); Kinkel (2004) and Meyer and Jacob (2008).

[54] Bartmess and Cerny (1993), p. 84.

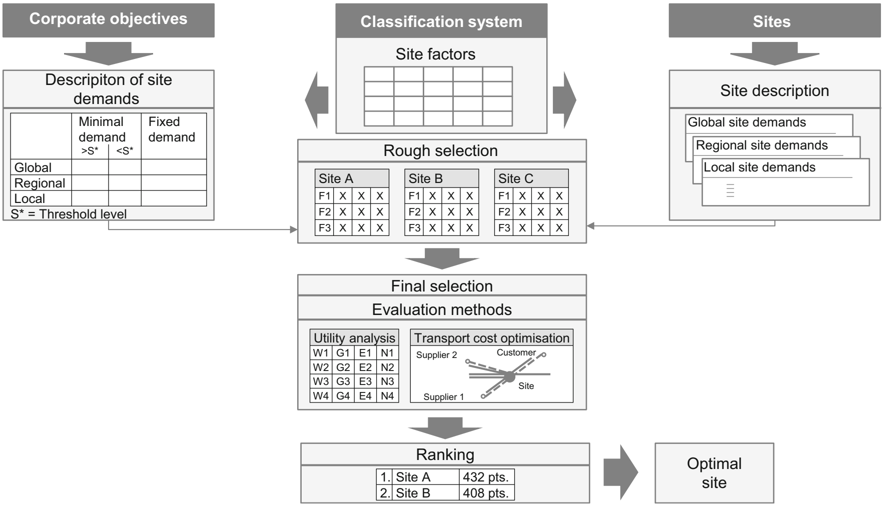

Fig. 2.5 Site location planning process (Based on Eversheim 1996)

A proven method concerning site planning was developed by Eversheim (Fig. 2.5).[55] It is essential that a holistic decision is supported, and that the criteria are chosen in a way that enables this. In addition to cost considerations, considerations of both long-term potential and competitiveness must play a role.

Planning takes place step by step from rough to detailed planning. For an evaluation of the sites during the ‘final selection’ step, a cost-utility analysis needs to be carried out. In doing so, as mentioned above, not only the costs associated with the site play a role. Schmenner states: “It is important to evaluate these costs, but they seldom tell the complete story nor do they sometimes differ significantly enough to make a location choice strictly on their merits.”[56] It is therefore imperative that qualitative and intangible factors be considered in the assessment.

Perceiving developing countries as an enlargement of the range of options for a Western European manufacturing company leads to a kind of “imperial industrialisation”: these companies have to possess the ability to identify countries with potential for production, to ready them for manufacturing within a short period of time[57] and while doing so keep the investment so low that the site can be changed again after having been used for an economically reasonable period of time.

First of all, however, it has to be calculated based on market demand what should be produced at the local site, and what can be produced in a foreign country without

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[55] Eversheim (1996), pp. 9–44.

[56] Schmenner (1979), p. 132.

[57] This point should not be underestimated. Since a system needs to be set up for the interchange of information, to enable an adjust level of manufacturing. Cf. also Galbraith (1990), p. 59.

problem. Increasing customer demand has led multinational companies to change their views in recent years: "[. . .] the increasing sophistication of manufacturing and product development and the growing importance of having world-class suppliers are causing more multinationals to place less emphasis on low wages when they are choosing foreign manufacturing sites."[58] In this, there is a close connection to the optimisation of the vertical range of manufacture, while a long-term capital commitment in foreign sites is avoided if possible. This development, mainly in high-technology companies, is according to Galbraith based on a difficult environment, which demands more and more investment in R&D but at the same time provides hardly any possibilities to make money which can then be re-invested: "Confronted with such unprecedented technological and competitive pressures, an increasing number of technology based corporations are rethinking their manufacturing strategy and moving toward smaller, mobile, more efficient geographically decentralized facilities."[59]

The manufacturing sites are then no longer seen as non-changeable fixed assets, but as variable units which can be adapted, moved or completely abandoned if necessary.[60] Reich sketches the corresponding picture of a global manager who is able to address promising opportunities everywhere: "The emerging global manager invests in the most promising opportunities and abandons or sells off underperforming assets – no matter how long they have been part of the corporate family or where there may be located."[61]

2.3.2 Site Roles

The capability-driven perspective paved the way for the concept of strategic site/plant roles. Plant roles combine the idiosyncratic competencies of a plant with its strategic reason for or contribution to the network. One of the most popular approaches is the lead factory concept by Ferdows (1997a). He differentiates three strategic reasons for establishing and running a site; these are (1) access to low-cost production, (2) access to skills and knowledge, and (3) proximity to market. Combining these reasons with the competencies available at the site, he identifies six distinct plant roles as given in Fig. 2.6: source, offshore, contributor, server, outpost, and lead factory. According to Ferdows (1997a), plants seek to evolve in their strategic roles, and it should be of central managerial interest to actively design and review their plant roles.

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[58] Ferdows (1997b), p. 74.

[59] Galbraith (1990), p. 56.

[60] Rifkin (2000), p. 41 cites Harvard professors Stan Davis and Christopher Meyer with the following statements: "Capital as inventory of capacity must give way to 'just-in-time' capital as access to the use of capacity" and "use it, don't own it."

[61] Reich (1991), p. 78.

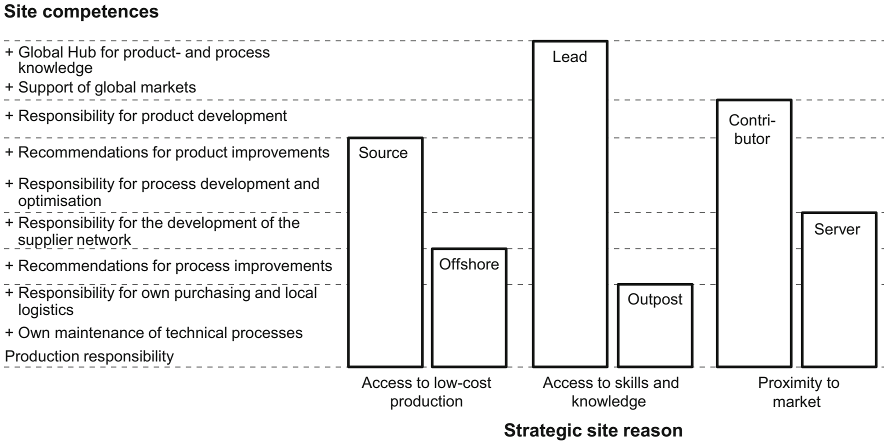

Fig. 2.6 The roles of factories in foreign countries (Based on Ferdows 1997a, p. 77ff)

Several other authors have validated, tested and modified Ferdows' lead factory concept, both quantitatively and qualitatively in case studies (e.g. Vereecke and Van Dierdonck 2002; Fusco and Spring 2003; Meijboom and Voordijk 2003). It has also served as a 'playground' for related studies. Meijboom and Vos (2004), for example, redefine the vertical axis of the original model, promoting a framework to track the dynamic evolution of a single plant. Feldmann and Olhager (2009a) shed some light on the development of site competencies and capabilities; studying a sample of more than 100 Swedish plants, they propose that competencies are typically assigned step by step as bundles to a site, starting with production-related, supply chain-related, and finally development-related competencies. Maritan et al. (2004) analyse the decision autonomy of a site regarding planning, production, and control mechanisms based on the plant role model of Ferdows (1997a). Moreover, Feldmann and Olhager (2009b) study the decision autonomy of plants depending on their strategic site reason and competencies. Based on the intra-network flows of innovation and people and the communication between sites, a different plant role typology is provided by Vereecke et al. (2006). The (1) isolated factory, (2) receiver factory, (3) hosting network player, and (4) active network player participate to a different extent in the "internal information and knowledge network". Further, Vokurka and Davis (2004) analyse the product and process structure assigned to a plant identifying three types: (1) standardisers, (2) customisers, and (3) automators. They investigate differences in each of these types with regards to competitive priorities and performance levels.

In Ferdows' model, the lead factory has a strategic leading role in the network. It opens up local knowledge and technology sources, performs supporting activities at other manufacturing sites and carries comprehensive decision-making competencies. It develops new processes, products and technologies for the network. Alongside the lead factory, there are the outpost sites. Next to production, their (second) task is to collect information about competitors, research centres, customers and suppliers. They are consequently set up in locations close to progressive suppliers or competitors.

The site roles contributor and server supply local and national markets. Their strategic necessity is based on the adaptation of the product to local circumstances, the reduction of transport costs, taxes and customs, as well as the reduction of currency risks. The contributor plants have comprehensive competencies and compete with the manufacturing sites in the country of origin concerning the pilot role in introducing products, processes or systems.

The source and offshore plants mainly have to ensure the cost-effective production of products and components. Investments in technical or management-related resources are minimised. In contrast to the offshore sites, the source sites also carry responsibility for process optimisation and for the development of a supplier network. Locations for such roles need a well-developed infrastructure and qualified staff.

In the beginning, Ferdow's model was criticised as it was based on purely conceptual research. As a result, different authors have tried to develop his basic strategic site objectives further. Vereecke and Van Dierdonck, for example, expanded these three objectives to eight. Feldmann et al. extended them to nine: proximity to knowledge and skilled employees, proximity to logistics hubs, proximity to markets, socio-political climate, proximity to cheap labour, proximity to energy, proximity to raw materials and proximity to competitors.[62] Most of these extensions are effectively itemisations, which do not however challenge the validity of the three objectives Ferdows suggested.

The site competencies have also been subject to an intensive discussion. In particular the order of implementation of the competencies at sites raised questions. Feldmann and Olhager pointed out that competencies are normally introduced to the sites step by step in competency bundles. First, production, second, production and supply chain, finally, production, supply chain and R&D competencies.[63]

The fixed role assignment in Ferdows' model has also been criticised. Vereecke and Van Dierdonck found evidence that lead factories do not necessarily need to have access to knowledge as a strategic objective, but instead the proximity to market can also serve as a basis.[64] As a further point of criticism, other authors name the fixed development paths of manufacturing sites: in Ferdows' model the sites always develop unidirectionally further towards becoming lead factories.

As a result, two further role models are discussed in the literature: Vereecke, Van Dierdonck and De Meyer's model and Johansen and Riis' model.[65]

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[62] Feldmann et al. (2009), p. 105f and Vereecke and Van Dierdonck (2002), p. 513.

[63] Feldmann and Olhager (2009b), p. 1ff.

[64] Vereecke and Van Dierdonck (2002), p. 509.

[65] Vereecke et al. (2006), Johansen and Riis (2005). A number of role models for multinational companies have also been researched (see for example Gupta and Govindarajan (1991) and Prahalad and Doz (1987)). They are not presented here as they are not explicitly related to manufacturing sites.

Vereecke et al.'s role model is based on the perspective of a knowledge network and rates the sites with regard to both the intensity of innovation and employee exchange, and the communication between the sites. Hence, the researchers identify four different roles[66]:

- The isolated factory, which only maintains a low degree of innovations exchange, employee exchange and communication intensity.
- The receiving factory, which accepts innovations, but hardly exchanges employees and maintains only a low degree of communication intensity.
- The harbouring network player practices innovations exchange, trains employees from other plants and maintains communication with other plants.
- The active network player practices active innovations exchange, intensive exchange of employees and an intensive communication within the network.

Johansen and Riis describe five different production roles in their model[67]:

- Full-scale production, which is responsible for the manufacturing of products in line with the market. The objective is competitive production.
- Benchmarking production, which primarily serves to keep the knowledge of the production of a company's products within the company. The main part of the production is carried out by external contract manufacturers.
- The ramp-up of the production aims at the quick development and realisation of new manufacturing systems, for instance the development of a new type of assembly system. After successful implementation, these systems are given to other sites.
- Prototype production is specialised in the manufacturing of new products and/or manufacturing plants.
- Laboratory production is oriented towards the development and testing of new materials, processes and technologies. Experimentation is the main task, to strengthen the company's future core competencies.

The determination of the site roles and the ability of the sites to fulfil these roles become the core tasks of the network manager. With it, the specific environment of the site, as well as its interaction with other network players have to be taken into consideration. Furthermore it is to be expected that sites (want to) develop further and thus outgrow their defined roles.[68] It should be noted that a site's development influences other sites, and that this leads to changes in the entire network.[69] However, there is nothing to be gained from only establishing sites with a high competence level. Indeed, the aim must be to create a balanced network.[70] For these purposes, a holistic view of the local conditions is necessary.

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[66] Vereecke et al. (2006), p. 1741f.

[67] Johansen and Riis (2005), p. 210ff.

[68] Ferdows (1997a), p. 78f.

[69] Cheng et al. (2011), p. 1315.

[70] Vereecke and De Meyer (2009), p. 9f.

2.3.3 Lean Manufacturing

In 1990 Womack, Jones and Roos sparked the "lean manufacturing"[71] movement with the publication of their book "The Machine That Changed the World".[72] This movement is even today one of the most important in the field of production organisation, and in particular the continuous improvement of site performance.[73] The starting point for the survey which led to the description of the lean manufacturing approach was the realisation that Japanese industry had overtaken America's in many fields.[74] This gave the impulse for a more comprehensive study, which is seen as "[. . .] the most comprehensive industrial benchmarking exercise ever undertaken."[75] In this study Japan became the global benchmark of automotive manufacturing, although it was also shown that there were successful companies in Western Europe and the USA, and the authors pointed out that it was wrong to consider "lean" as Japanese and mass production as Western.[76] The study showed in particular that not technological, but rather organisational and cultural[77] differences correlated to the differences in performance of the various participating companies.[78]

Lean manufacturing can be understood as a combination of the principles of craftmanship and mass production.[79] "Toyota was the great innovator here, taking the minds + hands philosophy of the craftsmen era, merging it with the work standardization and assembly line of the Fordist systems, and adding the glue of teamwork for good measure."[80] Lean manufacturing placed higher requirements on the employees, in particular, who had do be able to react more flexibly towards changes in production. It involves the coordination of human resources,

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[71] Cf. also Friedli (2006), p. 145ff and Friedli and Schuh (2012), p. 47ff.

[72] Womack et al. (1990, 1991).

[73] It is, for example, today being considered whether or not this approach lends itself to being applied to the rather shabbily treated manufacturing of pharmaceutical companies. Discussions are underway with the industry for conducting a large-scale study in collaboration with ITEM-HSG.

[74] A whole series of studies attested to this advantage, see for example Abernathy et al. (1983) and Altshuler et al. (1984).

[75] Jones (1994), p. 141.

[76] Womack et al. (1991): "It is wrong to equate 'Japanese' with 'lean' production and 'Western' with 'mass' production." Krafcik (1988), p. 41 talks of the need to dispell this myth: "I mention this example as means of overturning a common myth about the auto industry - the myth says productivity or quality performance is more or less predetermined by an assembly plant's location." Pilkington (1998), p. 33 determines that the study was heavily dependent on Toyota.

[77] By which the reference is to company and not national culture.

[78] Krafcik (1988), p. 42: "We have found overwhelming evidence that high technology is often not the solution to poor manufacturing performance if the technology is employed without a suitable production management policy."

[79] Womack et al. (1991); Krafcik (1988) and Jones (1994).

[80] Krafcik (1988), p. 43.

technologies and strategy, which for a long time was not understood by Western producers, but was likewise highlighted by the study.[81]

The realisation that a new type of process organisation was at the heart of lean manufacturing later unleashed the "business process engineering"[82] wave: "Central to this new concept of management is its focus on the stream of activities that add value to the product, what might be called a value stream. The objective is to make this flow as smooth and uninterrupted as possible and to ruthlessly eliminate all activities that stem the flow or do not add value."[83] Jones summarises lean production in three principles[84]:

- Integration of each step of the manufacturing process to ensure a seamless flow of parts. This also includes the elimination of buffer stocks.
- Application of pull processing. Customer orders start the process, no production for stock.[85]
- Maximisation of the whole process capacity (not of one isolated machine) by elimination of all random disturbances and fluctuations. This also includes concepts of preventive maintenance and quality management methods such as *poka-yoke* etc.

Additionally, consideration of the supply chain should be mentioned. In lean production the first-tier suppliers are already integrated in product development, whereas in mass production they receive finished drawings. Apart from that, the internal *kanban* system is also applied to suppliers, so that supply deliveries can be made just-in-time. So as not to endanger the entire system, manufacturers using the lean system try to level and smooth production, as there is high product-mix flexibility on the one hand, but only low volume flexibility on the other. This smoothing is also useful for the suppliers, who are able to utilise machines and employees in a better way.[86]

Two further essential components of this concept are continuous improvement and team responsibilities: "These teams recombine the key skills separated out to specialist departments and relate them to the day to day process knowledge of the operators.

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[81] For example, the comparison of GM's new, highly-automated plants with the joint venture between GM and Toyota (NUMMI) proved very interesting. Although of a lower level of automation, NUMMI's performance in terms of productivity and quality were markedly better (Krafcik 1988, p. 45). Pilkington also held that an understanding of lean manufacturing as merely JIT and TQM falls short (Pilkington 1998, p. 32): "By the 1990s, analysts were questioning the rise of single techniques for manufacturing supremacy, as faltering firms discovered that individual techniques required an overlapping complex of supporting systems."

[82] See for example Hammer and Champy (1993).

[83] Jones (1994), p. 143.

[84] Jones (1994), p. 144.

[85] Central element being the *Kanban* system, see Pilkington (1998), p. 35: "Apart from designing a system with low levels of labor costs, the heart of making the Toyota system work is the kanban - a system that links one production operation to the next, matching the production of parts closely to the demand established in the final assembly area."

[86] Womack et al. (1991), p. 158f.

Team members need to learn a whole new set of process, problem solving and team working skills perfected by the Japanese. Specialist departments and functions do not disappear but act as centres of expertise supporting the process teams."[87]

Central to this concept is the unitary view of the whole system. In 1996, Womack and Jones talked about companies which had not understood this integration: "When we looked more closely, we found plenty of just-in-time delivery systems that involved nothing more than the relocation of inventories from the company we were visiting to the next company upstream. In offices and plants, we found unlinked islands of lean operating techniques." And "[. . .] they had stumbled when it came to putting them all together into a coherent business system." Consequently, the authors increasingly enlarged their concept, talking then of "lean thinking",[88] meaning the optimisation of the whole value added stream beyond company limits, i.e. the supracompany implementation of lean management approaches.[89]

Lean manufacturing was and is a crucial step towards greater efficiency as well as flexibility in production, focussed at site level. Nevertheless, the full relevance of the necessary coordination of production flexibility with market demands and company strategies and positioning was rarely fully recognised. In addition, the concept was all too often copied to other branches without scrutinising the conditions for implementation. There is truth in Burgess' remark that "despite the ability of lean production to cope with lower volume and higher variety than traditional mass production it is still basically a system developed for high volume/low variety environments."[90] The limits can be seen clearly in highly dynamic environments: "[. . .] the limitations of lean can be reduced to two primary elements: inability to deal with turbulent and consistent change; and the pursuit of perfection to the extent that any scope for flexibility has been eliminated. Lean depends on a stable environment in which to maximise efficiencies of scale."[91] Today, efforts for continuous improvement are increasingly discussed and developed under the keyword OPEX (Operational Excellence).

> Operational Excellence describes the continuous strive for improvements at a manufacturing site in all dimensions. As a benchmark for improvement a balanced measure of performance is used, which encompasses effectiveness and efficiency criteria, and thus provides a basis for examining improvements in this context. Operational Excellence is supported by providing a holistic model with elements for the description of the implemented instruments, methods and management. Big companies possess structures for the definition and implementation of projects for Operational Excellence or the management of initiatives for Operational Excellence.[92]

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[87] Jones (1994), p. 145.

[88] See Womack and Jones (1994).

[89] Cf. Womack and Jones (1994), although even in the original study by Japanese manufacturers, great attention was paid to the integration of suppliers (Womack et al. 1991, p. 145ff).

[90] Burgess (1994), p. 24.

[91] McCurry and McIvor (2002), p. 81.

[92] Friedli and Schuh (2012), p. 142.

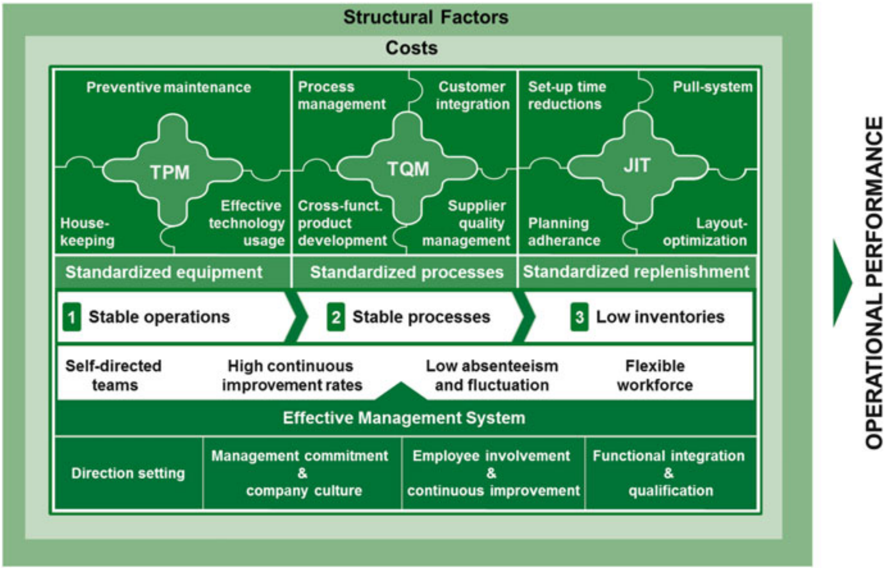

Fig. 2.7 St. Gallen "Operational Excellence Model"

Figure 2.7 shows a model for Operational Excellence which we brought to the discussion in 2003 as the basis of a benchmark concerning the status of the pharmaceutical industry in terms of Operational Excellence.[93] It is briefly explained below.

Using the findings of a comprehensive assessment plus visits to pharmaceutical manufacturers, a holistic model was constructed for the design of a possible development path leading to a company of Operational Excellence. It is clear that the components shown in the upper part of the graphic (TPM, TQM and JIT) also describe the logical order of a possible introduction of Operational Excellence.

The goal of the first phase is to improve the total productive maintenance (TPM) performance, and to create the best possible foundation for error-free and reliable processes in stably operating plants. In the second phase, the main focus is the stability and reliability of production processes (TQM). Together, TPM and TQM ensure the stability of the manufacturing system (stable processes in reliable plants). In phase 3 the optimisation efforts are aimed at the efficiency of the whole process (JIT) whereby the reduction of the use of resources is the first priority. Whilst this sequence is rationally comprehensible, depending on the 'philosophy' of the approach its Operational Excellence can easily be strayed away from. There are companies, for example, which permanently challenge the basic system by concentrating on efficiency, only to then have to continuously

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[93] This benchmark is today considered the largest independent benchmark of Operational Excellence in the pharmaceutical industry, see also Friedli et al. (2006, 2010, 2013).

find new possibilities for stabilisation. This is based on the idea that stocks obscure a lot of problems, and that only through diminishing stocks do problems become visible.

1st Phase: Improvement of TPM performance The investigated companies showed a high level of correlation between the amount of unscheduled maintenance and the rejection rate, which is an argument for the early introduction of a TPM programme. In pharmaceutical processes, significant derivations in the product quality are already evident with only a low variance in the initial parameters. The stability of the process technology used is an important factor. It is measured on the basis of the amount of unscheduled maintenance. In the study, a strong correlation could be seen between housekeeping or standardisation and unscheduled maintenance.

Furthermore, the high asset costs at manufacturing sites in relation to total costs are another argument for an early implementation of a TPM programme. In order to reduce investment costs in the medium term, the efficient use of existing technologies should be sought. The improvement of overall equipment effectiveness (OEE) is, amongst other things, at the centre of optimisation efforts.

2nd Phase: Improvement of TQM performance After having stabilised the amount of both unscheduled maintenance and equipment malfunctions, the next step is to eliminate all machine-independent disturbance variables and thus stabilise the entire production process.

3rd Phase: Improvement of JIT performance In the last phase the reduction of waste must be the focus of the optimisation efforts, building upon mostly resilient and error-free processes. The central issue here is not to minimise the rate of rejections or complaints, but to minimise further types of waste such as overproduction and stock levels, non-value added movements or transport activities, waiting times, and non-value added processes. It is clear that JIT performers were much further on the way to Operational Excellence than the other companies in this benchmark study. The study shows that JIT performers use a much more holistic approach for the optimisation of processes and implement a variety of holistic production system elements. This assertion is also supported by the experience that JIT performers show a high TQM and/or TPM performance.

As a crucial element, the management system is also shown in the model. In numerous projects it could be seen that it was the management which constituted the main difference between the sites. An effective management system can and must support the process of change described, using the appropriate structures, aims and training measures. Thus the necessary preconditions needed for implementing the measures for change can be set up in each phase.

In comparison to other design models for Operational Excellence, the following characteristics set the model apart:

- Generality
  The model can be used cross-industrially and is to the largest extent universally valid. It is not oriented around individual or industry-specific methods. This is true for the four core principles (TQM, TPM, JIT, basic elements and management system) as well as for the 17 elements of production systems (e.g. process management and set-up time minimisation).
- Holistic model
  The model is based on the assumption that a holistic production system is an open system. Areas close to production (e.g. purchasing and R&D) as well as the external environment (customers, suppliers) are considered in the reference model. The reference model does not constitute a partial model.
- Consideration of socio-technical aspects
  Technical/structural aspects and those of the management system are considered in the model. The requirements of the socio-technical system's approach are thus sufficiently considered.
- Logically consistent presentation
  The central dimensions of holistic production systems are subdivided into three aggregation levels of core principles, elements and methods. In this way, they are logically structured and are similarly weighted. The sub-division by core principles and basic elements allows a largely non-overlapping classification of dimensions and a consistent form of presentation.

It remains to be said that the described approaches are widespread, but the improvements that can be achieved at site level in an environment of increasingly intense competition are no longer sufficient, which is why the focus is shifting to a consideration of the entire network level.

2.4 Management Approaches at Network Level

In the following we lay a foundation for our general understanding of network management by means of shaping the decision dimensions. Additionally, we present two already existing network management frameworks. Subsequently, we shed some light on quantitative and qualitative optimisation approaches on network level.

2.4.1 Framework Models and Management Frameworks for Network Management

Management frameworks either concentrate on a distinct decision layer or single decision dimensions; or they are integrative, combining configuration and coordination aspects with strategy. Since the first have already been touched upon, when

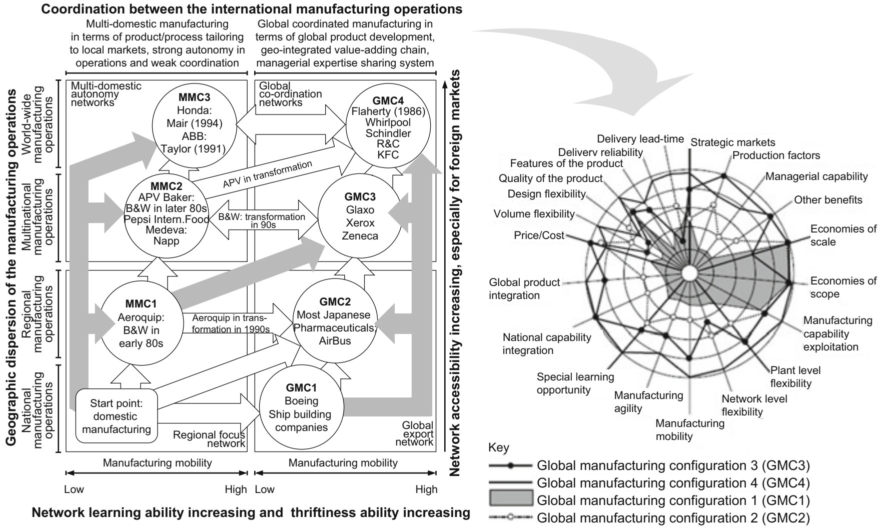

Fig. 2.8 Configuration framework for international manufacturing networks and capability profile grid

introducing the separate layers, the following discussion focusses on the latter targeting an integral management view.

Among these, Shi et al. (1997) and Shi and Gregory (1998) introduce a map of international manufacturing network configuration as outlined in Fig. 2.8. The map is based on two dimensions: (1) the geographic network dispersion, which ranges from national to worldwide describing the expansion of operations to design, produce, and sell goods on a global scale, and (2) the degree of coordination between the scattered manufacturing sites. Coming from domestic manufacturing, seven additional generic strategies[94] are derived and linked with the four previously discussed network capabilities: accessibility, thriftiness, mobility and learning. Each configuration is enhanced by an ideal network pattern. The patterns, termed “capability profile grid”, comprise distinct characteristics to assess the network capabilities. They are appropriate as a benchmarking profile for evaluating a company’s actual network capabilities. Although mentioned explicitly, the framework’s link to coordination is weak, which is only addressed in terms of a low or high degree. No support is given as to how to specify the degree of coordination for a certain strategy or how to design appropriate coordination mechanisms.

Consequently, Miltenburg (2009) substitutes the coordination axis by what he calls pressure for local responsiveness, i.e. the necessity to adapt the manufacturing activities and practices to local needs and requirements. As depicted in Fig. 2.9, he

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[94] For a detailed classification of each strategy see Shi and Gregory (1998).

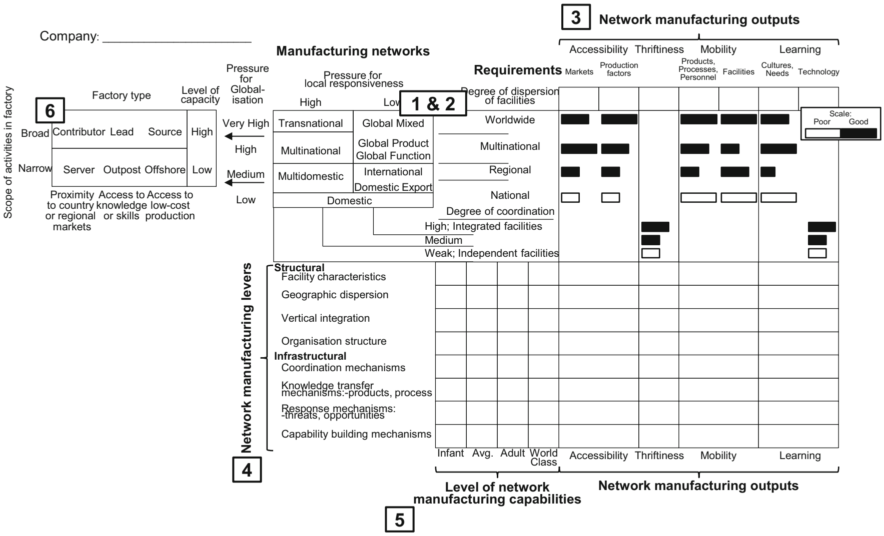

Fig. 2.9 Manufacturing strategy framework for a manufacturing network (Miltenburg 2005, 2009)

promotes his own holistic model for manufacturing strategy in international manufacturing networks.

The model links six distinct frameworks, so-called “objects”, which are well-founded in operations management literature. Based on three case studies, Miltenburg applies the model to map the current state of the corresponding networks and to derive implications for their future development.

Although linkages between the individual objects are of conceptual and descriptive nature only, this approach gives a unique example of how to combine single frameworks into an integral management model.

To sum up, framework approaches are valuable to understanding distinct network mechanisms. Nonetheless, most approaches are rather exploratory and lack a systematic and procedural character to analyse, design, and improve the network. Moreover, the network coordination layer is neglected or only superficially addressed by them.

While management frameworks cover the content of manufacturing networks, design and optimisation approaches add a procedural component. Two different types shall be distinguished: (1) strategic approaches mainly based on workshops and qualitative discussion with key persons to design future network scenarios and (2) quantitative approaches based on detailed data analysis and mathematical programming to evaluate and concretise those scenarios.

2.4.2 Quantitative Design and Optimisation Approaches

Quantitative network optimisation approaches focus on a detailed evaluation of selected network options/scenarios. A classification is given by Jacob (2006), who differentiates between static and dynamic methods and between checklists, economic business calculations, model-based simulation, and optimisation techniques[95]:

Checklists are utilised to assess network options along a set of (weighted) criteria. They can be executed with very little IT support, thus bridging the gap between quantitative and qualitative evaluation. Economic business calculations analyse the investment decisions for selected network options concentrating on cash-flow considerations.

Simulation approaches build upon the design of a model to evaluate the behaviour of a selected target dimension. Simulation can be supported by spreadsheets, system dynamic, discrete event simulation, and business games (Kleijnen 2005). Optimisation approaches extend simulation models by an algorithm typically maximising or minimising the target dimension.

A recent evaluation of these approaches – mainly for simulation and optimisation techniques – can be found in Justus (2009) and Ude (2010); the latter compares 21 approaches that have emerged since 1995. He further proposes a novel process promoted by the Institute of Production Science at the Karlsruhe Institute of Technology (Lanza and Ude 2010; Ude 2010). A detailed positioning of his method against the Cambridge approach can be found in Grallert et al. (2010). As with most quantitative approaches, the Karlsruhe approach mainly focuses on the "Where" phase of the network configuration. This phase is backed by an initial sketching of potential network scenarios and a detailed evaluation of different options based on discrete-event simulation and a quantitative and qualitative multi-criteria analysis.

2.4.3 Strategic-Qualitative Design and Optimisation Approaches

Strategic approaches typically integrate single management frameworks into a structured method. Colotla (2002, 2003), for instance, proposes an approach for global manufacturing strategy definition. It incorporates the bricks of a generic manufacturing strategy formulation process as put forward by Hax and Majluf (1995), breaking down the business strategy into a manufacturing strategy and aligning internal strengths and weaknesses with external opportunities and threats to support this strategy. The analysis of internal strengths and weaknesses comprises both site and network capabilities.

The process is purely concentrated on strategy formulation, not touching any aspects of network design and improvement. Further, it is of conceptual character only, hence lacking any proof of practical applicability.

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[95] Jacob (2006); Justus (2009) and Ude (2010).

The above described coordination framework also provides an anchor for network optimisation. Shi (2003) integrates the map as a tool for a systematic assessment of the network's configuration and capabilities into a generic global manufacturing strategy process; contrary to Colotla (2002, 2003), here, design aspects are also addressed. The approach is based on four interrelated modules[96]:

- Identifying the requirements of globalisation, including a structured analysis of the products, markets, customers, and competitors, an evaluation of future trends, and a discussion of the current and targeted manufacturing strategy
- Assessing the current network and its capabilities, comprising the analysis of the current network configuration based on the introduced configuration map and the qualitative assessment of the network capabilities based on the "capability profile grid"
- Identifying the manufacturing mission and the network design, addressing the formulation of the future network mission, the choice of the aspired network configuration, and the design of the underlying decisions in terms of product allocation, dispersion, and coordination mechanisms
- Fostering the network transformation based on the derivation of implementation plans, the initialisation of project management initiatives, and the transformation of the factories to support the network strategy

Uniquely to this approach, a workbook serves as toolkit, with tailored worksheets underlying each module. The worksheets, basically sheets for qualitative data collection and single frameworks, facilitate both the academic research and the practitioner's design process, since they provide structure and traceability of the information and data collected, offer a system and guidance for discussion, and ensure a combination of theoretical exploration and practical validity.[97]

The workbook approach also lays the foundation for a second method presented by the University of Cambridge's Institute for Manufacturing (IfM). Titled "Making the Right Things in the Right Place", a step-by-step process is promoted, guiding operations managers through the challenge of (re-)designing their networks. The so-called "Cambridge approach" covers four iterative phases (Christodoulou et al. 2007; Grallert et al. 2010)[98]:

- The "Why" phase strives for a common understanding of the motivation and need for modifying the network. Internal and external drivers for change are mapped and a future network vision is designed in joint workshop sessions.
- The "What" phase addresses the make-or-buy decisions. It comprises the identification of the current make-or-buy strategy, a risk assessment, and the establishment of guidelines to clarify and communicate the future strategy.
- The "Where" phase creates the design of the future network configuration. This most comprehensive phase starts with the definition of a 'common framework' to set the preconditions for analysis and involves the creation of a joint language

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[96] Colotla (2002, 2003).

[97] Platts and Gregory (1990); Shi and Gregory (1998) and Shi (2003).

[98] Christodoulou et al. (2007) and Grallert et al. (2010).

with regards to variables and key assumptions. Second, network options are designed by (1) evaluating the current and defining the future site role portfolio (cf. Sect. 5.3), by (2) adding coordination mechanisms, and finally by (3) deriving promising configuration options. The options' design is aided by the plant role portfolio, in which the aspired network specialisation is sketched. Third, these options are assessed according to their impact on network capabilities and cost dimensions. Fourth, the future network configuration, which is often established for a global product line, is put into a company-wide context by discussing the interactions with other internal networks, hence striving for an integral global solution.

- The "How" phase initiates the change by mobilising the stakeholders, works out the details, such as exact location decisions and the organisation of the product transfer, and finally aims at closing the loop by measuring the success of the transformation.

The "Cambridge approach" enhances the workbook process by Shi (2003) and Shi et al. (2001). It is one of the most elaborate approaches combining academic concepts with practical experience. Primarily targeting the design of network options with qualitative tools, most of the work is carried out in workshops and interviews with the top management, striving for commitment and common understanding rather than for a detailed evaluation of these options; this is left to the company's experts (Grallert et al. 2010).

The process covers a wide range of strategic considerations, which tailor it to the needs of the network management. Nonetheless, according to Grallert et al. (2010), it leaves some room for enhancement, especially with regards to measuring success in the "How" phase. While key performance indicators (KPI) on the plant level are well-known, a definition of measures on the network level is lacking. Further, although explicitly pointed out as part of the approach, the determination of coordination principles in the "Where" phase is rather superficial. It is based on a simple matrix, allocating selected decision responsibilities between centralised and decentralised functions.[99]

2.4.4 Critical Evaluation of Existing Approaches

In conclusion, quantitative optimisation approaches have a long history, especially within the scientific areas of operations research, mathematics, and engineering. They rely heavily on the availability and quality of data and on the expert knowledge of the persons involved in creating models. If these preconditions are met, their results provide valuable implications and a high depth of detail for the network design. Nonetheless, for the sake of quantification, these approaches have a strong cost and time focus, tending to impede the view of superordinate strategic questions.

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[99] Christodoulou et al. (2007).

Strategic approaches can bridge this gap. They are less dependent on the availability and quality of data than on the commitment and participation of the network's key decision makers. Rather than enabling a detailed evaluation of possible scenarios or options, they can be used to map the current network state and to create potential design alternatives. This tailors them to the needs of the network management in the conceptual design phase, which calls for a high degree of information condensation and for tools, stimulating and fostering strategic thinking, rather than hindering it with too much detail. Management frameworks and worksheets, in turn, seem to be promising to underline these approaches. Moreover, a detailed quantitative analysis can be used complementarily to evaluate the derived conceptual options.

Again, the literature review reveals some major limitations. Generally, qualitative strategic approaches for network analysis and design are rare compared to quantitative methods, and little is known on how they succeed in practice when supporting the network management in decision making. Second, regarding the structure, there is no common understanding on how such approaches should be carried out and in what sequence the distinct steps shall be applied best; nor is it clear if a strict proceeding is realistic at all. Third, regarding the content, most of the introduced frameworks and worksheets remain oversimplified, missing any proof of academic validity and practical applicability. Further, among the discussed single frameworks and strategic approaches, the configuration layer is clearly dominating. The coordination layer is neither sufficiently addressed by frameworks or tools for analysis and improvement nor – or only basically – integrated into the existing strategic network design and management approaches. A systematic management support is missing.

2.5 Summary

The tools of conventional production management only serve in coping with the demands of a global network to a certain extent. Since their emergence on the production line, they have hardly developed away from the microcosm of the single site. The list of examples of successful lean transformations and homemade production systems – mainly in mechanical engineering and the automotive industry – has grown consistently.[100] However, a unified production system at all of the global sites is not a guarantee for a functioning production network. Instead, independent methods for analysing, (re)-designing and optimising the whole production network – embedded in a holistic management paradigm – are needed.

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[100] The success story of Toyota's production system and lean manufacturing can be found in Liker (2007) and elsewhere.

The implementation of quantitative mathematical simulation methods for the optimisation of site localisation and the inner-company flow of materials is a step in this direction[101]; but even this promises only limited success if the strategic perspective lacks a holistic view. The high data dependency and attention to detail of these tools tends to overlook the essentials, and for quantitative reasons focusses too strictly on time or cost aspects. This makes them practicable for evaluating alternative network scenarios, but less so for systematically and strategically deriving them. By establishing a holistic network architecture and integral strategic optimisation approaches, this gap can be closed.[102] But theory and practice have until now provided only limited solutions.

In Chap. 3, a management framework is introduced which is geared to the concept of production network systems and addresses a holistic optimisation approach. By operationalising single dimensions on the basis of single qualitative management frameworks, this framework is transformed into a network architecture in the sense of an empty framework for network management.

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[101] Ude (2010), p. 54 provides an up-to-date overview of such approaches.

[102] Network optimisation approaches are covered in Shi and Gregory (1998); Shi (2003) and Christodoulou et al. (2007).