Managing the core plant role – key prerequisites from an operations perspective

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Abstract: A core plant should be a centre of excellence, have a central role for knowledge creation, and ensure that the latest knowledge is diffused in the organisation's production network. Core plants can yield a range of benefits, such as increased resource efficiency and decreased costs in the production network. However, core plants face immense challenges in performing their roles, given the different interests of the different stakeholders that need to be satisfied. We use data gathered from an in-depth study of six core plants in Sweden to analyse the prerequisites. We conclude that the core plant prerequisites are influenced by human, organisational, and technological aspects, i.e., successful development of core plant capabilities can only be achieved if all the three components are considered together. Our findings are relevant to operation managers, plant managers, and others interested in developing and maintaining core plant excellence.

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1 Introduction

In their pursuit for operational excellence and competitive production development, many global manufacturing organisations have implemented the core plant concept, also referred to as lead factory (Ferdows, 1997), master plant (Bengtsson et al., 2010) or main plant (Feldmann et al., 2013). A core plant should be a centre of excellence, have a central role for production development, and ensure that the latest knowledge is diffused in the organisation's production network. Thus, the core plant is critical to the overall success of global manufacturing companies. Having a core plant is essential to secure working opportunities as plants with a significant strategic role are less likely to be closed down or moved (Meijboom and Voordijk, 2003; Vereecke et al., 2006). However, despite the assumed importance of a core plant, many companies lack routines for executing its activities.

Having different plant roles assigned to different manufacturing units and using a network perspective can contribute to competitive advantages (Colotla et al., 2003). Global manufacturing companies need to adopt a structure and an organisation that allows the company to respond to the conflicting and ever-increasing demands of its global customers (Bartlett and Ghoshal, 1998). Accordingly, to realise the benefits of the core plant concept, not all plants in the network can have the same role; furthermore, the capabilities of the core plant need to be different and unique from those of other subsidiaries in the network. It is, however, not evident what critical core plant capabilities are required to keep and maintain the core plant role, and how they contrast with those that most of the plants in the network need to strive for. Accordingly, unique capabilities that distinguish core plants from other plants need to be continuously developed, and the prerequisites supporting the development of these capabilities need to be identified to maintain core plant excellence.

The classification of plant roles has attracted considerable attention from prior research (e.g., Cheng et al., 2011; Meijboom and Vos, 2004; Vereecke et al., 2006). The core plant is considered a single production plant that is strategically important and serves as the central knowledge hub of the network (Enright and Subramanian, 2007; Ferdows, 1997). This definition implies that the core plant is the site with the highest site competences and the role that plants in the network want to achieve. However, the focus of earlier research has not been on the plant level, i.e., where the products are manufactured, but on the site level, assuming that other critical functions such as R&D, marketing, and purchasing are situated at the same geographical location. While these research studies have explored capabilities and competences, they typically group together the capabilities for the entire site. Although the examples above provide valuable insights, research focusing on the manufacturing plant and those that manage the core plant role from an operations perspective is lacking, although the manufacturing plant is a key component of the lead factory concept presented by Ferdows.

Accordingly, we chose to have the core plant, i.e., the perspective of the manufacturing plant, instead of the network in this research as our main area of interest. In addition, earlier research has not aimed to propose a conceptualisation of the core plant role and how this can be maintained over time. Currently, there is a lack of consensus in academia and industry regarding what the core plant role fully entails, causing uncertainty for the assigned plants. Against this background, the purpose of our article is to describe prerequisites by which core plant capabilities can be created.

Empirically, we draw on data from a multiple case study project involving seven core plants in the Swedish manufacturing industry. We collected data from interviews with multiple key respondents from both the operations and the strategic level over the course of nearly two years. Studies of company documents and feedback seminars with managers and production engineers further complemented the interview data.

Our article offers several contributions. First, our results show that the core plants studied had multiple prerequisites in place related to human, technological, and organisational aspects, and that successful development of a core plant is only achieved if all three components are considered together. Second, the prerequisites have been developed during a considerable amount of time and many of them are rather tacit and non-imitable by the subsidiaries. Third, our results suggest that specialist knowledge related to key processes is not sufficient for the core plant. Rather, to be able to take on core plant responsibilities, it was necessary to have knowledge about the local prerequisites and regulations, be able to work cross-functionally, have good communication skills, manage cultural differences, and handle many interfaces within and external to the plant. Finally, our findings highlight that several of the identified prerequisites cannot be controlled by the core plant but are highly dependent on the top management.

2 Theoretical background and literature overview

2.1 Classifying the core plant

Consistent with prior research we understand an international manufacturing network as a "coordinated aggregation (network) of intra-company plants/factories located in different places" [Cheng et al., (2015), p.393]. Our study thus concerns intra-company networks, i.e., the network of one company where multiple plants belong to the same legal entity (Rudberg and Olhager, 2003). Further, we chose to have a core plant perspective, i.e., the perspective of the manufacturing plant in this research, as our main area of interest in contrast to a network perspective, which has a wider focus, such as the global operations network (Pashaei and Olhager, 2017) or the global value network (Srai and Christodoulou, 2014). This enables us to gain in-depth insights into those functions that are responsible for ensuring that the core plant fulfils its role.

Scholars often distinguish between a range of plants in a production network. At one end of the continuum, there are plants characterised by low competence which are primarily established for reasons related to low-cost production, while at the other end of the continuum, there are plants that hold a wide range of competencies and managerial responsibilities (e.g., Feldmann and Olhager, 2013; Ferdows, 1997; Johansen and Riis, 2005; Vereecke et al., 2006). For example, Jarillo and Martíanez (1990) characterise subsidiaries on the basis of the degree of localisation, i.e., to what extent R&D, purchasing, manufacturing, marketing, etc., are performed in one subsidiary and the degree of integration, i.e., to what extent activities performed in another plant are integrated with the same activities in other subsidiaries. Bartlett and Ghoshal (1998) differentiate between four generic types of subsidiaries based on the overall importance to the company's global strategy and available competence. One model that has gained recognition in the manufacturing industry and has been confirmed by, among others, Vereecke and Van Dierdonck (2002) is the framework presented by Ferdows (1997). On the basis of the extent of technical activities and primary strategic reason, Ferdows differentiates between six generic types of subsidiaries. In this article, our emphasis is on the plants that have the highest competencies and responsibilities in the network of plants from an operations perspective, i.e., the core plants. Accordingly, the core plant reveals that it requires different levels of operational performance and distinct capabilities and characteristics in contrast to the other subsidiaries in the network (Colotla et al., 2003). The roles, powers, and responsibilities of plants with low competences must be clearly differentiated and communicated from core plants for smooth and efficient running of the company (Bartlett and Ghoshal, 1998).

2.2 Core plant capabilities

An analysis of previous studies reveals that several dimensions such as responsibilities, scope of operations, competence level and importance of markets need to be applied for the classification of the plants in the network to create an effective manufacturing network (Bartlett and Ghoshal, 1998; Feldmann and Olhager, 2013; Ferdows, 1997; Maritan et al., 2004; Meijboom and Vos, 2004; Riis et al., 2007; Vereecke and Van Dierdonck, 2002; Vereecke et al., 2006). However, these dimensions are not fixed and could change over time. Further, the distinct capabilities of the core plant should lead to increased performance in the entire network of the manufacturing company. As a consequence, it has been emphasised that there is a need to not only consider a plant in isolation (Rudberg and Olhager, 2003; Shi and Gregory, 1998) but also the interdependencies with the other sites in the network and between the core plant and the network itself (Colotla et al., 2003; Miltenburg, 2009). For example, Thomas et al. (2015) discuss the importance of multi-dimensionality, i.e., the importance of considering capabilities that are related to both the specific site and the network.

The core plant is often responsible for industrialising new products, which includes building up secure and efficient manufacturing processes (Bengtsson et al., 2010). Accordingly, the core plant, first of all, has a leading role in production development (Maritan et al., 2004; Meijboom and Vos, 2004; Vereecke and Van Dierdonck, 2002; Vereecke et al., 2006), and production development capabilities are arguably one set of key capabilities that a core plant should possess. Further, as the verified manufacturing process developed at the core plant should be ‘cloned’, i.e., transferred to subsidiaries that implement the standardised process and manufacture the product for other markets (Bengtsson and Berggren, 2008), the core plant is required to consider the needs and prerequisites of all plants in the network. The core plant should be considered a centre of competence with a global presence (Simon et al., 2008) and have a high degree of innovations that are transferred to the subsidiaries (Vereecke et al., 2006).

Further, successful companies work with incremental development in operations that can take place locally at the subsidiaries and at a central level. Bengtsson et al. (2010) point out that a central role of the core plants is to assist the subsidiaries in developing local procedures and structures. It is necessary to coordinate the network in an effective way and to generate knowledge about organisational and functional ties, operational processes, and control mechanisms that play a decisive role in performance, innovation, and knowledge activities within a network (Brass et al., 2004). Accordingly, it is essential that the core plant employees are also present in serial production to support activities such as training, gathering, and validating optimisation ideas, and to generally drive continuous improvement (Simon et al., 2008).

Finally, the core plant is an active network player with a high degree of communication with the employees of the subsidiaries and a higher outflow of employees than an inflow of visitors (Vereecke et al., 2006). Therefore, network abilities, i.e., interaction with the subsidiaries in the company’s production network, are indispensable. In other words, as activities become increasingly distributed, the skills in management of the production network become critical (Slepniov et al., 2010).

In summary, the core plant needs to have capabilities that are related to production development (both incremental and radical) and networking. A proficient execution of the core plant could be particularly important with regard to the potential benefits associated with the core plant role (Ferdows, 1997). However, as pointed out above, prior literature has so far not accounted for the prerequisites that need to be in place from an operations perspective to optimise a plant's contribution to the goals of the network and achieve the desired outcomes.

3 Research design

A multiple case study approach was selected as the research method to gain in-depth understanding of a fragmentarily documented phenomenon (Voss et al., 2002). Applying a case study approach also provides a comprehensive evaluation of the activities carried out by the core plant (Edmondson and McManus, 2007). Finally, the case study method was selected to ensure a methodological fit, given the limited amount of prior research on the core plant role from an operations perspective and to show that the developed knowledge is practically applicable (Yin, 2009).

Seven core plants in Sweden at six global manufacturing companies were included in the study (see Table 1 for a detailed representation). All companies had assigned their plants in Sweden as core plants, and the role as a core plant was deemed as critical to all plants studied. More precisely, the competitive advantage of Swedish manufacturing companies critically depends on competitive production development and role models, thus making them ideal cases for a study of the core plant role. The units of analysis were manufacturing plants that operate as core plants, and more specifically we address the prerequisites associated with the enactment of the core plant role, as the plants need to be managed and organised to be able to achieve excellence as core plants.

Data was collected in seven cases as one of the case companies had different business units included in the study. The primarily data sources were 50 semi-structured in-depth interviews. The interviews ranged between 33 and 133 minutes and were primarily single interviews made face-to-face. A few Skype interviews were conducted owing to, for example, a great distance between the interviewer and respondent, and a few group interviews including two respondents were conducted either owing to planning issues or requests from the interviewees. The respondents were chosen based on their involvement in core plant management. Most respondents were organisationally positioned at the core plants but often had global responsibilities. All interviews were recorded and transcribed.

Two variants of the interview guide were used with regard to the respondent's organisational position. For respondents at the core plant, at central organisations, and in top management, the questions covered the respondent's role and background information, the manufacturing network structure and prerequisites, and the core plant role, responsibilities, and related challenges. For respondents at the subsidiaries, the questions instead covered the respondent's role and background information, the subsidiary plant structure and prerequisites, and the expectations on the core plant. Owing to the exploratory nature of the research, the interview guides were slightly altered during the progress of data collection to apply new insights and relevant aspects that emerged.

Table 1 Overview of the case companies and data collection

Case	*Line of business*	*Core plant responsibility*					*No. of subsidiaries in direct network*	*No. of plants in extended network*	*No. of respondents*	*Role of respondents*
		Product resp.	*Process resp.*	*Intro. plant*	*Support to subsidiaries*	*Lead in NPD*				
A	Automotive	X	X	X	X	X	2	15	11	Head of project management and global support (core plant/central), project manager in the global support department (core plant), general plant manager (core plant), vice president and general plant manager (subsidiary), assembly manager (subsidiary), operations director (subsidiary), maintenance manager (core plant), quality and logistics manager (core plant), production manager (core plant), assembly manager (core plant), and finance manager (core plant).
B	Rail industry			X	X		5	15	8	Head of manufacturing (core plant), operations director (core plant), head of internal supply chain (management), head of operations – internal supply chain (management), operations strategy manager (management), manufacturing engineering manager (management), and two heads of operations (subsidiary).
C	Automotive	X	X				1	8	6	Director of manufacturing research and concepts (core plant), productivity engineering manager (core plant), manufacturing engineer (core plant), Simulation engineer (core plant), manufacturing research and simulation manager (core plant), and senior expert in manufacturing engineering (core plant).

Table 1 Overview of the case companies and data collection (continued)

Case	*Line of business*	*Core plant responsibility*					*No. of subsidiaries in direct network*	*No. of plants in extended network*	*No. of respondents*	*Role of respondents*
		Product resp.	*Process resp.*	*Intro. plant*	*Support to subsidiaries*	*Lead in NPD*				
D	Pharmaceutical	X		X				27	2	Senior advisor (core plant) and lean process manager (core plant).
E	Aerospace				X	X	11	62	11	Global head of manufacturing engineering (central), head of lean management (core plant), global functional head of engineering, technology and quality (central), four functional heads of manufacturing engineering (three at core plant, one at subsidiary), first line manager (core plant), coordinator (core plant), general manager (subsidiary), and industrial engineer/project manager (core plant).
F	Automotive	X		(X)	X		4/6 + DCs	45 plants and 55 DCs	8	Area chassis and final assembly manager (central), director of chassis and final assembly technology (central), two manufacturing technology managers (central), two managers of knockdown global operations (central), pilot plant manager (core plant), and central technology manager (core plant).
G	Automotive	X			X	X	8	45 plants and 55 DCs	4	Director of industrial engineering (core plant), production manager (core plant), technology manager (core plant), and director of manufacturing & engineering components (central).

To add to the insights derived from the interviews, documents were also studied, including records describing the network structure, the role of the core plant in the network, and other company-specific information. Further, informal discussions with managers and production engineers were held with respect to the concept of the core plant role and challenges encountered. Finally, several group meetings and workshops were held with all participating companies.

The transcribed interviews were transferred into a case study protocol for each case. Each interview was coded separately by two researchers according to the pre-set category prerequisites, capabilities, structure, identity, interaction, challenges, value created, and miscellaneous considerations. The coding results were compared and compiled together with other material, such as field notes and observations, to create a case study history. Similar entities were clustered and categorised. The categories were of a data-driven character, addressing different capabilities and prerequisites related to the core plant role. In the second step, a cross-case analysis with regard to the different capabilities and prerequisites identified was performed searching for patterns across the cases. As we did not find any substantial differences among the companies, there were no limitations regarding a subsequent analysis. Accordingly, the aim of the final step of the analysis was to more fully explore the capabilities and prerequisites identified in order to go beyond the first impression. This was accomplished by an iterative process of reading the empirical data and the theoretical framework.

4 Results of the empirical studies

Our findings indicate that a core plant needs to develop and maintain a wide range of capabilities to be able to deal with daily short-term issues at the subsidiaries, and contribute to long-term strategic development, which presupposes a number of things. Overall, similar prerequisites were highlighted among the core plants studied, although the specific terminology varied among the plants. The prerequisites identified can be categorised into the dimensions of people, organisation, and technology. This helps us to understand how the prerequisites are related and what can be affected and by whom.

4.1 Prerequisites – people dimension

The knowledge and experience possessed by the employees were considered as highly important core plant prerequisites for success. In each case, it was highlighted that the core plant role was fulfilled owing to the plant's unique production expertise and because it was responsible for competence transfer to the other plants in the manufacturing network. Specialist competence was required for the plant to be at the forefront of production development and general competence was needed for the plant to be a support function for the other plants in the network. Thus, not only manufacturing skills were considered necessary. For case C, its unique experiences and skills in simulation and virtual development made it the obvious core plant choice. For case E, the competence in quality, knowledge of economy and administrative aspects was highly valued. Social and communication skills were also considered important to be able to support the other plants in the network. The comprehensive set of skills was summarised in case A: "… social skills, language skills, but also be a little service-minded and at the same time as you usually need to have experience, you are a generalist, you do have the specialist role in the company …" Access to the resources and competence required was also considered as a prerequisite, i.e., to find and attract people with the skills required.

Another factor mentioned in all the cases that was needed to motivate core plant responsibility was the history of the plant. Several plants had been located at a specific site for a long time, often since the company started its business. The long history contributed to experience, confidence, and a feeling of ownership among employees, which is important. As stated by a respondent from case A, '… we have manufactured since 1850, here in the city, and this huge experience is an enormous strength'. The strength of the Swedish working mentality was another factor that was emphasised in several cases irrespective of whether the companies were Swedish-owned or not. The Swedish working mentality in terms of working in cross-functional teams and non-hierarchical organisations was considered important, and enabled the companies to solve complex problems and win valuable customer orders. For case B, for example, which was not a Swedish-founded company, the Swedish working mentality was emphasised as a strength: 'The Swedish attitude to work and teamwork is a great asset when we work with foreign colleagues and production transfers'.

4.2 Prerequisites – organisation dimension

In the organisational dimension, we include how the work is organised and structured, both formally and informally. The organisational dimension is linked to the system of individuals connected to achieve the defined goals of the network and includes rules, procedures, and cultural issues.

To act in a global manufacturing network requires an organisation where every plant is aware of its own role and that of the others, as well as functions that coordinate and support the plants on a global level. The methodologies used to support the network were differently designed between cases, but in all cases, the employees of the core plants were frequently sent to the subsidiaries to support them in specific tasks.

The mandate and legitimacy to make decisions about production development and set the frames of what the processes should look like in the network were also stressed. An authority over the other plants in the network was considered as a prerequisite. A respondent in Case F describes the journey of acquiring legitimacy and mandate in the network: "The problem may be that the other factories have not really seen that [our plant] has this mandate. So it has been before. That's why we've been working hard to make sure that the other factories must first and foremost realise that [our plant] is a pilot plant, that's where we develop solutions, and so everyone has understood it, so to speak …"

In case B, there was a stated vision from top management regarding the breakdown of authority and mandate-related topics; however, more clarity on how this vision would be carried out in practice on the operational level was desired from the core plant. Structure and some guidelines were required in the current state to refine the efficiency in terms of management and production. In all cases, the importance of support from senior management and a willingness to work in the same direction was stressed. "… The important thing is that the other plants that are not pilot plants [core plants], that they understand the meaning of pilot plants [core plants] and that it is the local management that actually embraces that principle."

The closeness to functions was also stressed as a prerequisite. A close relation to R&D was considered highly important. For example, cases D, E, and G were chosen as core plants because they had a close relationship with R&D and also because R&D was located close to the core plant, and accordingly collaboration with operations was experienced to be easier. As mentioned in case B, "… what we have that benefits us, it is that we have our large design office down here, it is absolutely the largest development office in [the company] in the world. They are three kilometres from us."

The need to work with other functions and the subsidiaries was further underscored by the fact that core plants needed continuously integrate and create new knowledge to succeed in their role. The causes for changes could also come from outside of the network. As one informant in case D put it, "… I think that, by delivering to so many markets, we need to be good at what is especially for example for Asia, how is it currently in Africa in different countries, what is relevant to South America …" Further, it was emphasised that it was also important to learn from other plants in the network. Some plants within the network had developed detailed knowledge in a specific area, which could be of use to all other plants. It was important to share this knowledge with the core plant and to distribute it in the network. As one informant in Case B articulated, "Important to learn from the factory that is best and then share this knowledge to everyone in the network." Accordingly, another critical prerequisite was that the core plants were organised to learn from both within the network of manufacturing plants and also to integrate external knowledge.

An emphasised core plant prerequisite was to have sufficient resources and structures in place to fulfil the role of the core plant. As stated in case E, "… of course, the resources must be in place so you will have time to work with the questions. There must be an understanding that we have resources to work with issues that not only have to do with this site. There must be … financial means to possibly invest in things that may not be … what to say, may not benefit from the factory's operational KPIs here and right now."

Although the core plant did not need to be the plant with the highest volume, it was important for it to have knowledge, skills, and experience concerning serial production. Knowledge about serial production was important with respect to two areas. First, the knowledge developed from serial production was needed as it was considered a central input in future development projects. Second, without the knowledge of serial production it was not possible to support the subsidiaries in their daily issues and evaluate best practices that should be shared in the network.

As the core plants were at the forefront of production technology and process development, and were a support function for plants in the network, they were required to perform additional work compared to the other sites in the network. They were required to work more effectively to have good KPIs in serial production and also be excellent in generating new knowledge to be at the forefront of the network all the time. This means they needed to have an endless loop of improvement. Consequently, an ability to work effectively was demanded, which required structures, technologies, and work procedures. As stated in case G, "… on the net line, bottom line, we need to have fewer resources. We will work more efficiently and actually be able to work more rationally, that is, we can be fewer in the end …"

4.3 Prerequisites – technology dimension

Several of the core plants served as introduction plants and had the responsibility of launching new product models. They played roles in the earlier phases of production development until the testing and verification of the products before the products were launched on the market. The development of work procedures, IT tools, and common technologies used in the production network was also a core plant responsibility.

Being a plant with large facilities and having the convenience of a large variety of manufacturing technology was regarded as a prerequisite. In case G, the large size of the plant, together with its high production volumes, was one of the reasons it was chosen as a core plant. Because of its size, it had access to a development centre and was capable of global development. In case E, the respondents mentioned that they had a great influence on the other plants, because of the plant's size. Therefore, when the other facilities needed to improve something, the core plant could assist them with the proper resources.

The development of a common production platform that should be utilised later on in the production process, was one example of structure in case G. Their solution would facilitate the other production plants and would be a future solution. In case B, the entire network shared the same CAD software. In case F, the core plant had a budget to improve processes and development, because its research and development department received research funds, which also included money allocated to production development.

Our interviewees argued that to secure full benefits at this high maturity level, which the core plants possess, changeable production technology is a prerequisite in order to meet the variations in volumes and product models and variants that often need to be dealt with. To easily integrate new production technology into the system was also regarded as important and required a certain level of changeability within the system.

Increased technology development is achieved through physical test areas. For example in Case F they had their own test facilities and a budget for testing new technologies and experimenting with new ways of production. The test area allows employees to test and verify new production technology, processes and methods, i.e., core plants can facilitate the development of new technologies from R&D to introduction ready. Further, the test area has been an important meeting place for different functions and from different entities. Accordingly, it increased the awareness and understanding of the different needs of the core plant and led to a higher acceptance of the developed solutions at the subsidiaries as they were actively involved. As it was put in case F, "…this is an introduction area according to me and when you have such an area you have a huge responsibility. … this test area is about taking responsibility to ensure that we can develop, verify and validate and accomplish a complete solution."

5 Discussion and conclusions

The core plant role is identified as critical to the overall success of global manufacturing companies as well as to the long term survival of these plants (Meijboom and Voordijk, 2003; Vereecke et al., 2006). Existing research has focused on the overall capabilities and competences required at the core plant, while research on the managing of the core plant role from an operations perspective is still limited. Further, research has been carried out on the contribution of site capabilities to the network targets (Thomas et al., 2015), but there is an absence of studies focusing on the core plant role and how this role can be maintained over time. Therefore, the purpose of our article was to describe prerequisites by which core plant capabilities can be created. Our findings are particularly relevant in light of growing managerial and theoretical interest in understanding the determinants for efficiently managing the core plant role from an operations perspective. The findings are relevant to operation managers, plant managers, and others interested in developing and maintaining core plant excellence.

Our findings have highlighted that the studied core plants had multiple prerequisites at their plants which supported their work as excellent core plants. These prerequisites clearly differentiated the core plants from the subsidiaries in the network. Moreover, our results show that critical core plant prerequisites are influenced by

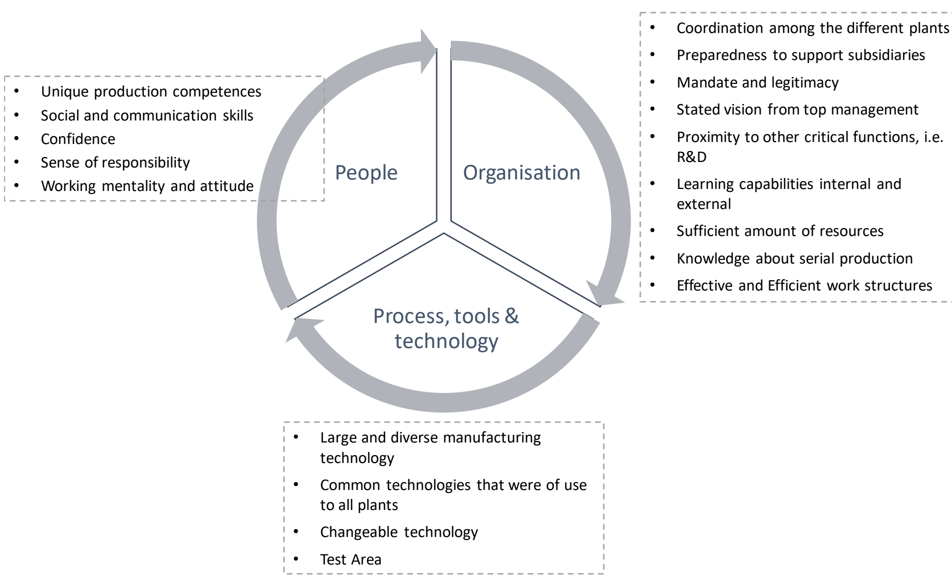
1 human

2 organisational

3 process and technological aspects.

Thus, our findings show that the human, technology, and organisation (HTO) concept is also relevant to understanding the highly complex work of the core plant. A conclusion is that prerequisites related to all three HTO aspects need to be addressed by the core plant. First, the people working at the core plant influence the outcome of the core plant, i.e., not only their skills and knowledge, but also their willingness and openness to work together with and for subsidiaries. Second, the outcome of the core plant is influenced not only by how the work of the core plant is formally organised with the subsidiaries, the headquarters, and other critical functions, but also by the core plants informal authority and the role taken to interconnect activities between different sites and their internal development work. Finally, the performance of the core plant is also influenced by its ability to have a playground with up-to-date technology where new technologies, processes, and methods can be tested and developed so that they are ready for implementation in serial production.

Figure 1 Summary of the identified prerequisites



Although the majority of prerequisites are related to the organisational aspects, all three dimensions are critical and interrelated, and all need to be in place to develop core plant excellence. It is critical to have an organisation that is able to fulfil its global responsibilities and still support the core plant work, individuals with the right skills and competences, and the technology that supports the work (see Figure 1). One possible explanation with regard to the few identified technological aspects could be that the studied core plants have largely focused on technological issues; thus, human and organisational aspects have lagged behind. Accordingly, human and organisational activities should be given a higher priority in the studied core plants, and managers have to carefully elaborate and clarify the development of prerequisites that have a qualitative factor even though these can be difficult to follow-up and measure. However, having deep knowledge about production technology is a critical prerequisite to be able to work with production. Moreover, if the core plant does not have the required knowledge about production technology, it appears it would be difficult to transfer it in the network and help subsidiaries in their development.

The core plants that are proficient at warranting these prerequisites are likely to enjoy long term benefits. Although earlier research has shown how subsidiaries in the network evolve and change their roles towards becoming more strategic plants (Cheng et al., 2011), the identified qualitative prerequisites may constitute a tacit, non-imitable component of the core plant. The real value of the core plant is not only its advanced production technology, as this can be implemented at any site, but also the intellectual capital embedded within its processes which has evolved over a considerable amount of time and is deeply related to the culture, mind-set, and mentality at the core plant. Thus, a critical prerequisite is that managers specifically need to assure that critical competences will not disappear from the core plant through reorganisations or changes in management, for example. It becomes clear that prerequisites related to human, technology, and organisation aspects are dependent on each other, and all need to be in place.

Our findings further underline the importance of the knowledge and expertise collected at the core plant. The need to have people with several competences and deep knowledge at the core plant is not new (Feldman and Olhager, 2013; Ferdows, 1997), but our findings show that it is not enough to only possess specialist knowledge at the core plant from an operations perspective. To be able to take on core plant responsibilities, it was necessary to have knowledge about the local prerequisites and regulations, be able to work cross-functionally, have good communication skills, manage cultural differences, and handle many interfaces within and external to the plant. Moreover, it was found that operations managers at the core plant needed to continuously work for an increased understanding and awareness of the implications of the core plant at the shop floor and to the top management. At the shop floor, it was critical to create an urgency to become a role model for all plants in the network but also the need to be 'neutral', i.e., the core plant cannot only protect its interests and should be able to see hubs as partners and not as competitors. The lobbying of top-management was critical because the core plants required additional resources and often had higher costs because they needed to address many problems that occur at the early stages of the introduction of new production technologies and processes, which also could result in lower performance. As a consequence, our findings imply that operations managers need to communicate the benefits achieved by the core plant concept. A key challenge here is to have suitable core plant KPIs and measures that can quantify the core plant values.

Finally, our results imply that there are several prerequisites which are difficult to control by the core plant but which could be supported by information from senior management. To facilitate effective and efficient enactment of the core plant role, sufficient senior management is usually important. Specifically, senior management plays a key role in creating the mandate and legitimacy of the core plant, promoting the core plant in the network, and also providing the core plant with the needed resources and governance. Further, some of the prerequisites identified are related to the business environment.

6 Limitations and suggestions for future research

As with any study, there are limitations associated with this study. The empirical data collected is limited to seven global manufacturing companies which all have their core plant in Sweden and which are part of the manufacturing industry. Accordingly, it is important to be careful when generalising the findings to other manufacturing companies working in different contexts to the ones studied. However, it should be possible to extend some implications to other companies working in the manufacturing industry as the selected companies were different with regard to serial production, operations activities carried out at the core plant, the size of the network, the formalisation of the core plant role, and geographical proximity to other functions, such as R&D, and the headquarters. If the number of cases studied is relatively small, it is preferable to choose cases that highlight differences (Pettigrew, 1990) as common patterns that emerge from great variation are of particular interest (Patton, 2002). Accordingly, a critical focus of this research was whether similar prerequisites could be found despite the contextual differences between the studied plants.

Although research on plant roles provides valuable insights into the competences required at the core plant, only parts of the existing research can be used to understand how the core plant role can be managed from an operations perspective. More research is needed to better understand the specific conditions of organising and managing the core plant role from an operations perspective. The selection of respondents from the managing level might have affected the strong focus on prerequisites linked to humans and organisation. If, for example, production technicians or receivers at the subsidiaries had been included in the study, the focus might have been different. Thus, the critical prerequisites identified in this exploratory study need to be validated further by including more perspectives and linked to core plant capabilities. Further, in this paper prerequisites by which core plant capabilities can be created were described. The findings showed that prerequisites were influences by human, technology and organisation. Further studies of prerequisites can therefore be done from an HTO perspective based on models by e.g., Davis et al. (2014) or Porras and Robertson (1992). Finally, the results of study provide support for the importance of the core plant role, but also highlight the need for increased systematisation of core plant practices from an operations perspective, as the existing knowledge is still limited.

References

Bartlett, C.A. and Ghoshal, S. (1998) *Managing Across Borders: The Transnational Solution*, 2nd ed., Harvard Business School Press, Boston, MA.

Bengtsson, L. and Berggren, C. (2008) 'The integrator's new advantage – the reassessment of outsourcing and production competence in a global telecom firm', *European Management Journal*, Vol. 26, No. 5, pp.314–324.

Bengtsson, L., Niss, C. and Von Haartman, R. (2010) ‘’Combining master and apprentice roles: potential for learning in distributed manufacturing networks’, *Creativity and Innovation Management*, Vol. 19 No. 4, pp.417–427.

Brass, D.J., Galaskiewicz, J., Greve, H.R. and Tsai, W. (2004) ‘Taking stock of networks and organizations: a multilevel perspective’, *Academy of Management Journal*, Vol. 47 No. 6, pp.795–817.

Cheng, Y., Farooq, S. and Johansen, J. (2011) ‘Manufacturing network evolution: a manufacturing plant perspective ‘, *International Journal of Operations & Production Management*, Vol. 31, No. 12, pp.1311–1331.

Cheng, Y., Farooq, S. and Johansen, J. (2015) ‘International manufacturing network: past, present, and future’, *International Journal of Operations & Production Management*, Vol. 35, No. 3, pp.392–429.

Colotla, I., Shi, Y. and Gregory, M.J. (2003) ‘Operation and performance of international manufacturing networks’, *International Journal of Operations & Production Management*, Vol. 23, No. 10, pp.1184–1206.

Davis, M.C., Challenger, R., Jayewardene, D.N. and Clegg, C.W. (2014) ‘Advancing socio-technical systems thinking: a call for bravery’, *Applied Ergonomics*, Vol. 45, No. 2, pp.171–180.

Edmondson, A.C. and McManus, S.E. (2007) ‘Methodological fit in management field research’, *Academy of Management Review*, Vol. 32, No. 4, pp.1155–1179.

Enright, M.J. and Subramanian, V. (2007) ‘An organizing framework for MNC subsidiary typologies’, *Management International Review*, Vol. 47, No. 6, pp.895–924.

Feldmann, A. and Olhager, J. (2013) ‘Plant roles: site competence bundles and their relationships with site location factors and performance’, *International Journal of Operations & Production Management*, Vol. 33, No. 6, pp.722–744.

Feldmann, A., Olhager, J., Fleet, D. and Shi, Y. (2013) ‘Linking networks and plant roles: the impact of changing a plant role’, *International Journal of Production Research*, Vol. 51, No. 19, pp.5696–5710.

Ferdows, K. (1997) ‘Making the most of foreign factories’, *Harvard Business Review*, Vol. 75, No. 2, pp.73–88.

Jarillo, J.C. and Martíanez, J.I. (1990) ‘Different roles for subsidiaries: the case of multinational corporations in Spain’, *Strategic Management Journal*, Vol. 11, No. 7, pp.501–512.

Johansen, J. and Riis, J.O. (2005) ‘The interactive firm – towards a new paradigm: a framework for the strategic positioning of the industrial company of the future’, *International Journal of Operations & Production Management*, Vol. 25, No. 2, pp.202–216.

Maritan, C.A., Brush, T.H. and Karnani, A.G. (2004) ‘Plant roles and decision autonomy in multinational plant networks’, *Journal of Operations Management*, Vol. 22 No. 5, pp.489–503.

Meijboom, B. and Voordijk, H. (2003) ‘International operations and location decisions: a firm level approach’, *Tijdschrift voor Economische en Sociale Geografie*, Vol. 94 No. 4, pp.463–476.

Meijboom, B. and Vos, B. (2004) ‘Site competence dynamics in international manufacturing networks: instrument development and a test in Eastern European factories’, *Journal of Purchasing and Supply Management*, Vol. 10, No. 3, pp.127–136.

Miltenburg, J. (2009) ‘Setting manufacturing strategy for a company’s international manufacturing network’, *International Journal of Production Research*, Vol. 47, No. 22, pp.6179–6203.

Pashaei, S. and Olhager, J. (2017) ‘The impact of product architecture on global operations network design’, *Journal of Manufacturing Technology Management*, Vol. 28, No. 3, pp.353–370.

Patton, M.Q. (2002) *Qualitative Research & Evaluation Methods*, 3rd ed., Sage, London.

Pettigrew, A.M. (1990) ‘Longitudinal field research on change: theory and practice’, *Organization Science*, Vol. 1, No. 3, pp.267–292.

Porras, J.I. and Robertson, P.J. (1992) 'Organizational development: theory, practice, and research', in Dunnette, M.D. and Hough, L.M. (Eds.): *Handbook of Industrial and Organizational Psychology*, pp.719–822, Consulting Psychologists Press, Palo Alto, CA.

Riis, J.O., Johansen, J., Vejrum Waehrens, B. and Englyst, L. (2007) 'Strategic roles of manufacturing', *Journal of Manufacturing Technology Management*, Vol. 18. No. 8, pp.933–948.

Rudberg, M. and Olhager, J. (2003) 'Manufacturing networks and supply chains: an operations strategy perspective', *Omega*, Vol. 31, No. 1, pp.29–39.

Shi, Y. and Gregory, M. (1998) 'International manufacturing networks – to develop global competitive capabilities', *Journal of Operations Management*, Vol. 16, Nos. 2–3, pp.195–214.

Simon, S., Näher, U. and Lauritzen, M.D. (2008) 'R&D: aligning the interface with production', in Abele, E., Meyer, T., Näher, U., Strube, G. and Sykes, R. (Eds.): *Global Production: A Handbook for Strategy and Implementation*, pp.350–371, Springer, Berlin.

Slepniov, D., Vejrum Waehrens, B. and Jørgensen, C. (2010) 'Global operations networks in motion: Managing configurations and capabilities', *Operations Management Research*, Vol. 3, Nos. 3–4, pp.107–116.

Srai, J.S. and Christodoulou, P. (2014) *Capturing Value from Global Networks: Strategic Approaches to Configuring International Production, Supply and Service Operations*, University of Cambridge, Cambridge, UK.

Thomas, S., Scherrer-Rathje, M., Fischl, M. and Friedli, T. (2015) 'Linking network targets and site capabilities: A conceptual framework to determine site contributions to strategic manufacturing network targets', *International Journal of Operations & Production Management*, Vol. 35, No. 12, pp.1710–1734.

Vereecke, A. and Van Dierdonck, R. (2002) 'The strategic role of the plant: testing Ferdows's model', *International Journal of Operations & Production Management*, Vol. 22, No. 5, pp.492–514.

Vereecke, A., Van Dierdonck, R. and De Meyer, A. (2006) 'A typology of plants in global manufacturing networks', *Management Science*, Vol. 52, No. 11, pp.1737–1750.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002) 'Case research in operations management', *International Journal of Operations & Production Management*, Vol. 22, No. 2, pp.195–219.

Yin, R.K. (2009) *Case Study Research: Design and Methods*, 4th ed., SAGE, Thousand Oaks, CA.