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Designing and managing manufacturing networks – a survey of Swedish plants

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Abstract

The design and management of the manufacturing network for a firm is an important factor for its competitive position. By manufacturing network we mean the plant or plants of a manufacturing firm and the relationships with external suppliers. The way that these operate together is crucial for supporting the competition of the products in the marketplace. This paper presents the results of a survey of 106 Swedish manufacturing plants. We find that the markets and supply networks of Swedish plants are global, but there is a focus on Europe. The main reason for locating a plant in Sweden is proximity to skills and knowledge, and we find no pure low-cost plants. The overall level of site competence is very high. There are many significant differences between how internal and external suppliers are selected. The choice of internal suppliers, i.e. those suppliers in the manufacturing network that belong to the same firm, is to a large extent based on a single corporate decision reflecting quality and competence, while external suppliers are chosen based on quality, price, and delivery dependability considerations. All in all, this study provides a broad analysis of the manufacturing networks in which Swedish plants operate, and the roles of these plants.

Keywords: Empirical analysis; Operations management; Supply chain management; Survey research; Sweden.

1. Introduction

The competitive positions of manufacturing firms stem from the design of the entire manufacturing network, which needs to be in alignment with the market opportunities. In supply chain settings, some researchers argue that the competition in the future will be between supply chains rather than between individual companies. Still, the company is the legal entity, for which the results end up on the financial bottom line. Therefore, the company must build its strengths on its own manufacturing network and the surrounding industrial

structure. However, the literature contains few models that help managers to design and manage plant networks.

The design aspect is concerned with the configuration of the network. Issues of interest include for example: (i) where is the customer base?, (ii) where should plants be located; what is the rationale for a certain location?, and (iii) what types of suppliers are needed, and where should they be located? The management aspect is concerned with the coordination within the network, i.e. making the most of the elements in the structure. Issues of concern here include: (i) allocation of roles and resources among the plants; site competence and allocation of tasks between the local plant and those decisions that are taken centrally, (ii) managing the risks associated with the network, and (iii) aligning the elements to the task; managing performance relative the competitive priorities.

Sweden is a country that historically has been the home country of a large number of multinational companies, relative to the number of inhabitants. The manufacturing base in Sweden has been eroding somewhat in recent years, as a result of outsourcing initiatives. Some companies see this trend continuing in the coming years, while other companies are reversing such decisions and increasing the level of manufacturing in Sweden. In this perspective, two research questions are raised to help to increase the understanding of the manufacturing networks that include Swedish plants:

Research question 1: What do the manufacturing networks look like around Swedish plants?

Research question 2: What role do the Swedish plants have in the network?

In particular, we base this study on the concept of plant roles, suggested by Ferdows (1989, 1997), and the relationship between internal and external suppliers, to capture issues pertaining to outsourcing. Then, taking a broader view on manufacturing networks, some items were added into a questionnaire survey to more fully investigate network design and management aspects. This analysis is based on data from 106 Swedish manufacturing firms, capturing the plant level perspectives of designing and managing manufacturing networks in Swedish manufacturing firms. We report on the link to factors such as market and product characteristics, including qualifiers and order winners. The role of the plants in the network is and the principles for network design, including the reasons for location, are treated explicitly. We distinguish between internal and external suppliers and study the reasons for selecting a

specific type of supplier. Risk aspects concerning risk types and the ability to manage these risks are investigated. Finally, performance is studied in relation to the competitive priorities. Using the survey data, this paper gives an overview and analysis of aspects concerning the design and management of manufacturing networks containing Swedish plants. While the plants are located in Sweden, the markets that they serve and the suppliers that serve these plants are global.

In this paper we first present the related literature. Then, we present the research methodology. We present and discuss the results concerning the market, product, plant, supply, risk and performance. In the concluding sections we provide implications for research and practice.

2. Related literature

The issues relevant to manufacturing networks are typically divided into two areas: configuration and coordination (Porter, 1985, 1986). The configuration aspect is concerned with the design of the network, such as the location of plants and their supply networks relative to the markets they serve. Porter (1985, 1986) distinguished between geographically concentrated and geographically dispersed networks. The coordination aspect is concerned with the management of a given network, primarily the level of coordination of activities in the network; cf. Porter (1985, 1986). The issues of configuration and coordination dominate the research agenda on manufacturing networks. Shi and Gregory (1998, 2005), Colotla et al. (2003), and Srai & Gregory (2008) viewed manufacturing networks as factory networks with matrix connections, where each node (plant) affects the other nodes and cannot be managed in isolation. Rudberg and Olhager (2003) analyzed manufacturing networks and supply chains from an operations strategy perspective. They related the manufacturing network to the decision categories of vertical integration and facilities, concerning both configuration and coordination. Some key aspects of the design and management of manufacturing networks are location, plant roles and competences, internal and external suppliers, risk management, and performance relative to competitive priorities. Next, we review the related literature on these issues.

2.1 Location

The literature on finding the best location for manufacturing plants in a network can be divided into two streams: mathematical approaches or factor assessments. Owen and Daskin

(1998) provide a review of mathematical programming models for the strategic facility location problem. They find that static and deterministic models dominate, whereas dynamic formulations can be useful for the difficult timing issues and stochastic formulations for capturing uncertainty in parameters such as forecast demand or distance values. Some of the most complex models reported in the literature have been implemented in practice and often on a large scale; see e.g. Digital (Arntzen et al., 1995), Hewlett-Packard (Lee and Billington, 1995), and Procter & Gamble (Camm et al., 1997). The decision support system is most often based on an optimization model; the objective function is typically monetary (profit, revenue or costs) to be minimized or maximized within the limits of a set of constraints.

The other stream of literature focuses on the aspects that are relevant for choosing the site location, selecting the site option that best fit the needs for the manufacturing plant. In the related literature, three key factors of strategic importance for site location have been identified: “access to low-cost production”, “proximity to market” and “access to skills and knowledge”; cf. Ferdows (1989, 1997), Fusco and Spring (2003), Meijboom and Voordijk (2003), and Maritan et al. (2004). To this list, Vereecke and Van Dierdonck (2002) added “socio-political climate” and “proximity to competition” as potential key factors influencing decisions concerning plant location, while MacCarthy and Atthirawong (2003) and Colotla et al. (2003) considered “proximity to raw material” and “cheap energy”. Yet other factors may be relevant depending upon the specific situation; see e.g. Badri et al. (1995) and Bhatnagar and Sohal (2005).

2.2 Plant roles and competences

Ferdows (1989, 1997) introduced the concept of plant roles within a manufacturing network. Even though such a network does not necessarily have to be global, the examples used in Ferdows (1997) are all taken from an international arena. The role of a factory contains two dimensions according to Ferdows; the strategic reason for the location of the plant (see section 2.1) and the competence level at the plant. He distinguished between high and low levels of site competence, concerning the scope of its current activities for which the plant has assumed responsibility: production, technical process maintenance, procurement and local logistics, process improvements, supplier development, process development, product improvements, product development, global market supply, and global hub for product or process knowledge. Ferdows identified six factory roles, which he labelled “offshore”, “outpost”, “server”, “source”, “lead”, and “contributor”. A “lead” factory assumes the

ultimate role, being the global hub for product or process knowledge. He acknowledged that some factories may combine two or more roles. For instance, a factory may be a server for a specific region and an offshore site for the production of certain components (1997, p.77). The model by Ferdows has been tested empirically by Vereecke and Van Dierdonck (2002) and Maritan et al. (2004). However, they only use a few of the competence areas in Ferdows (1997).

2.3 Internal and external suppliers

The literature that deals with the choice or relationship between internal and external suppliers can be categorized along four topical areas: make-or-buy decision making, outsourcing (see strategic sourcing, and supplier selection. All these are related to the fundamental question: What should be done in-house (by internal suppliers) and what should be done by external suppliers? This is the very core of make-or-buy decision-making; cf. Venkatesan (1992), Padillo and Diaby (1999), and Cánez et al. (2000). The outsourcing literature initially focused on the transferral of processes from internal sources to external sources, wherefore the direction of change was presumed; see e.g. Prahalad and Hamel (1990), Hamel and Prahalad (1994), and Quinn and Hilmer (1994). However, more recent literature on outsourcing has contrasted this move with insourcing, and some have even considered in- and outsourcing as alternatives similar to the choice between internal and external suppliers; see e.g. Lonsdale and Cox (2000), McIvor (2000), Sislian and Satir (2000), King (2001), Beaumont and Sohal (2004), and Baines et al. (2005). Most of the literature on strategic sourcing (e.g. Bozarth et al. 1998, Narasimhan and Das, 1999, and Kocabasoglu and Suresh, 2006), and supplier selection (e.g. Dickson 1966, Weber et al. 1991, Verma and Pullman 1998, Choi and Hartley 1996, and Dyer et al. 1998) focused on external suppliers, based on the assumption that the make-or-buy decision has already been made, wherefore the remaining selection is between alternative external suppliers. Another related area is transaction cost theory (Williamson, 1979, 1985), concerned with the cost associated with writing and monitoring a contract between a firm and an outside supplier – the costs associated with the transaction.

2.4 Risk management

Risk is an integral part in the manufacturing network design; see e.g. Bettis (1982), who suggested a model linking industry characteristics, strategy, risk and performance. Lately the interest in risk and risk management has increased further (Tang, 2006). The definition of risk that most authors agree upon is that risk is a combination of the probability of an event to

occur and its consequences (March and Shapira, 1987; Jüttner et al, 2003; Norrman and Jansson, 2004). Risk can be seen as a function of the company strategy and industry characteristics (Bettis, 1982). The industry characteristics include factors such as market characteristics, entry barriers, i.e. factors that individual organizations have little or no possibility to control or affect and instead only can react to. The strategy-component of risk however is a product of the company's internal decisions and organisation, such as investment intensity, R&D, value added etc. Since the company decides on these variables, they can also affect the probability and the impact of different risks. This type of categorisation, with one set of risk sources that cannot be affected and one that can, is supported in the literature on supply chain risks, see e.g. Jüttner et al. (2003) and Ritchie and Brindley (2007). Jüttner et al. (2003) extend this categorisation to include three categories: environmental risk, network-related risk and organizational risk. Environmental risks correspond well with the industry characteristics (cf. Bettis, 1982), but also include political and social factors. The other two categories in Jüttner et al. (2003) can be considered as two parts of the strategy component in Bettis (1982). Network-related risks include relational risks in the supply chain, e.g. opportunistic suppliers or insufficient cooperation, while organizational risks sources are internal risks resulting in e.g. machine failure or insufficient staff competence.

2.5 Competitive priorities and performance

The concept of competitive priorities is often used as a notation for both goals and objectives for manufacturing as well as requirements posed on the company from the marketplace; see e.g. Hayes and Wheelwright (1984), and Dangayach and Deshmukh (2001). The basic competitive priorities for manufacturing firms are usually considered to be quality, delivery, cost and flexibility; cf. e.g. Hill (2000). Hallgren and Olhager (2006) make a distinction between market requirements and manufacturing objectives; price and product range being market requirements, while cost efficiency and product mix flexibility are manufacturing objectives. In order to capture the way products compete in the marketplace different requirements can be given weights to represent relative priorities. Hill (2000) suggested apportioning 100 points among requirements, thereby creating competitive priorities. Delivery has two dimensions, speed and dependability, referring to short and reliable delivery lead times, respectively. Flexibility may have many dimensions; the three most common types of flexibility are volume, product mix, and design. Volume flexibility refers to the ability to change production volumes in response to varying demand levels, product mix flexibility is related to the ability to change quickly between products or product groups, and design

flexibility refers to the ability to manage product development and design requirements by the customer (cf. e.g. Olhager and West, 2002). After-sales service is also typically considered a basic competitive priority. The basic competitive priorities are also the main evaluation criteria for choosing suppliers (Huang and Keskar, 2007), as well as the main factors of operational performance (Narasimhan et al., 2006).

3. Research methodology

The study is based on a mail questionnaire survey. The questionnaire was designed and processed with respect to the guidelines and recommendations presented in Dillman (2000) and Forza (2002). The questionnaire was pre-tested by both industrialists and researchers with experience of survey research, resulting in a few changes in the phrasing of questions and a few additions of items; e.g. proximity to transport hubs as a factor for site location, and production planning as a site competence area. 563 Swedish manufacturing firms were contacted in 2007. The questionnaire was sent to all manufacturing plants in Sweden that have 200 or more employees at the site, and to members of PLAN (the Swedish society for supply chain management) in smaller companies. As noted in Forza (2002) it is not possible for a company or a plant itself to answer any questions; this has to be done by human respondents. Therefore, people working with manufacturing and logistics in manufacturing companies were contacted and asked to respond in the survey. After two reminders we received 106 useable responses, i.e. a response rate of 18.8 percent. The survey is carried out at the plant level, providing the plant perspective of the manufacturing network. The unit of analysis in this study is the main product line at a manufacturing plant. This unit of analysis helps to eliminate inconsistencies in responses, e.g. if several process choices are used within the same plant (Flynn et al., 1990).

3.1 Design of questionnaire

The questionnaire is concerned with market and product aspects, plant aspects, supplier aspects (distinguishing between internal and external suppliers), risk management and performance measures. Most questions are perceptual and use a seven-step Likert scale, except where a percentage distribution is required. By using perceptual Likert scales, response rates can be improved since the respondents can more easily give estimations and do not need to verify the exact value. The respondents were neither forced to communicate any sensitive performance information which may reduce the response rate. Past studies (see e.g. Vickery et

al. 1993, Klassen and Whybark 1999) have demonstrated that perceptual measures are useful for empirical research that relate to managerial evaluations. The full questionnaire can be obtained by the authors upon request.

3.2 Sample

The sample includes smaller, medium-sized as well as larger manufacturing plants, based on number of employees and sales turnover; see Table 1. All types of customer order decoupling point position are included in the sample; engineer-to-order, make-to-order, assemble-to-order, make-to-stock, and finally make and distribute to stock. The last position refers to holding finished goods inventory in the distribution system, beyond the plant inventory. All five generic process choices are represented in the sample. All these characteristics suggest that the responding firms in the sample are representative of the population of Swedish manufacturing firms. The respondents were all upper level managers related to production or logistics, and thus expectedly knowledgeable about the survey questions; cf. Table 1. The largest group of respondents was logistics/supply chain managers (32.6 percent of the responses), followed by production managers (30.1 percent), plant managers (6.0 percent) and presidents or vice presidents (3.6 percent). Other respondents include e.g. supply managers and logistics project leaders.

4. Results

The survey results are divided into two sections: design and management. Design is concerned with configuration and location of markets, plants, internal suppliers, and external suppliers, and the criteria for selecting internal versus external suppliers. Managerial issues are related to site competences, risk management, competitive priorities and plant performance.

4.1. Design aspects

4.1.1 Markets

The geographical distribution of markets was measured by letting the respondents assign share of sales they had in nine different regions, c.f. Table2. The Baltic region was included as a separate region since it in recent years has attracted attention as a near-shore low-cost region for internal or external suppliers to Swedish manufacturing firms. Table 2 shows that

Table 1. Firm characteristics.

Characteristic	Distribution
Number of employees:	
– 99	12.3 %
100 – 499	49.0 %
500 – 999	13.2 %
1000 –	25.5 %
Sales turnover (M€):	
– 9	6.3 %
10 – 49	35.4 %
50 – 99	18.8 %
100 –	39.6 %
Customer order decoupling point:	
Engineer to order	15.3 %
Make to order	34.3 %
Assemble to order	24.5 %
Make to order	15.6 %
Make and distribute to order	10.4 %
Process choice:	
Project manufacturing	4.4 %
Job shop	23.3 %
Flow shop	30.1 %
Line	26.1 %
Continuous processing	16.0 %
Respondents position:	
Logistics/Supply chain managers	32.6 %
Production managers	30.1 %
Plant managers	6.0 %
President/Vice president	3.6 %
Other	27.7 %

the major markets for Swedish firms are Sweden and Europe. The “weighted average” is the average of all the companies with presence in the specific region, i.e. having a share of sales > 0 %. The relative large difference between the overall average and the weighted average in some regions indicates that once a company is establishing itself on a market it is for a substantial share. Taking North America as an example, the overall average is 10.8 %. However only half of the companies (57) have markets in North America and the ones that do, have on average 18.9 % of their sales there. Of further interest is the relatively low share of sales found in Asia and other far-away regions. This means that factories based in Sweden mainly supply nearby markets, while markets in the Far East are either very small or supplied by other plants in the manufacturing networks than the Swedish ones.

4.1.2 Plant locations

The plant itself was the focal point of the survey. We investigated the reasons for location as it is perceived currently. Based on the related literature and the pre-test round with

industrialists and researchers we included eight factors that could be strategic reasons for the location of a particular plant; see Table 3. The plant location factors were captured using a seven-point Likert scale ranging from “unimportant” (1) to “of the utmost importance” (7) as a strategic reason for plant location.

Table 2. Geographic distribution of markets.

Market	Overall average	Number of plants in sample	Weighted average with respect to presence
Sweden	33.8 %	94	35.9 %
Baltic region	1.5 %	32	4.7 %
Other Europe	36.4 %	90	40.4 %
North America	10.8 %	57	18.9 %
India	1.0 %	27	3.6 %
China	2.5 %	35	7.0 %
Other Asia	8.0 %	55	14.5 %
Other	5.5 %	48	11.4 %
Total	100.0 %	-	-

Table 3. Reasons for geographical plant location.

Reason for location	Mean	Std.dev.	Median	Mode
Proximity to skills and knowledge	4.08	1.84	4	4
Proximity to transport hubs	3.70	1.60	4	4
Proximity to market	3.38	1.76	3	4
Socio-political climate	3.00	1.63	3	4
Proximity to cheap labour	2.84	1.47	2	2
Proximity to cheap energy	2.70	1.54	2	2
Proximity to raw materials	2.48	1.54	2	2
Proximity to competition	1.69	0.94	1	1

Proximity to skills and knowledge is the primary reason for plant location. This is in line with expectations, since Sweden is a high-cost country and has experienced a gradual shift towards higher end products in the manufacturing industry. Proximity to transport hubs comes second, which can be motivated by the relative low density of the population in Sweden and long transportation distances. Proximity to markets is the third major reason, which corresponds to that Sweden is the major market for Swedish plants, c.f. Table 2. The other potential reasons for site location are of lesser importance. Judging by the relatively low averages in Table 3, it seems likely that companies have only one major reason for the site location.

4.1.3 Supplier locations and selection criteria

The structure of the manufacturing network includes the supply network. The survey was concerned with both internal and external suppliers, to be able to investigate the extent of similarities and differences between them. We checked for geographical distribution and the criteria for choosing suppliers of both types. The geographical distribution of the supply networks is focused around Europe, including Sweden, and North America; cf. Table 4. The concentration of suppliers close to home is higher than compared to the distribution of markets. This is particularly true for internal suppliers, with 89.2 % of internal suppliers in Europe. The external supply base is somewhat more widespread, since 10.1 % of the suppliers are located outside Europe and North America.

Table 4. Geographical distribution of internal and external suppliers (all 95 plants that responded to this question have external suppliers, while 58 of these also have internal suppliers).

Geographical distribution of suppliers	Internal (N=58)			External (N=95)		
	Number of plants in sample	Average	Weighted average w.r.t. presence	Number of plants in sample	Average	Weighted average w.r.t. presence
Sweden	42	47.3 %	65.3 %	92	53.2 %	54.9 %
Baltic Region	6	5.7 %	54.7 %	30	2.7 %	8.6 %
Other Europe	36	36.2 %	58.4 %	88	29.8 %	32.1 %
North America	11	7.6 %	39.9 %	38	4.3 %	10.7 %
India	5	1.9 %	21.8 %	36	4.2 %	11.1 %
China	1	0.0 %	2.0 %	14	0.5 %	3.5 %
Other Asia	2	0.4 %	11.0 %	28	2.7 %	9.0 %
Other	2	0.9 %	26.5 %	19	2.7 %	13.5 %
Total	-	100.0 %	-	-	100.0 %	-

We also checked the criteria on which suppliers are selected. The respondents were asked to rate the importance of fourteen different criteria for choosing suppliers, using a seven-point Likert scale, ranging from “low importance” to “decisive importance”. The result is presented in Table 5. Two clear conclusions can be drawn from the comparison between internal and external supplier selection. First the decision to use an internal supplier is based on very few criteria (as opposed to the selection of external suppliers); many criteria have received either a very high (7) or a very low score (1). Second, there is a significant difference in how internal and external suppliers are selected. “Corporate decision” is used significantly higher (at the 0.01 level) for internal suppliers, while all other criteria rank higher for selecting external suppliers. This indicates that the choice of an internal supplier is to a large extent based on a single corporate decision, to some extent reflecting quality and competence. Many of the other issues are even significantly more important in the choice of external supplier,

indicating that external suppliers experience a multi-criteria selection process. Here, quality, price and delivery dependability are the top three criteria; all with a significant difference at the 0.01 level. A Wilcoxon signed rank test was used for testing the differences between criteria for selecting internal and external suppliers, for the 58 companies that had both internal and external suppliers. Thus, this result shows that in order to choose an external supplier a wide range of high-performing competences are required. In contrast, the choice of an internal supplier is to a large extent based on the fact that the plant and its capacity is already in the network, and that plant performance in terms of quality, cost, delivery, etc, is assumed to be adequate.

Table 5. Criteria for selecting internal and external suppliers.

Criteria	Internal				External			
	Mean	Std.dev.	Med.	Mode	Mean	Std.dev.	Med.	Mode
Corporate decision**	5.66	1.83	6	7	4.02	1.96	4	4
Quality (conformance to spec's)**	4.55	2.20	5	6	6.00	1.05	6	6
Exploit competence	4.53	2.23	5	6	4.65	1.53	5	6
Delivery dependability **	4.11	2.08	4	1	5.37	1.26	6	6
Volume flexibility**	3.81	1.91	4	5	4.54	1.36	5	4
Price**	3.76	2.06	4	1	5.51	1.12	6	6
Delivery speed *	3.64	1.92	4	1	4.29	1.47	4	4
Design flexibility *	3.25	1.97	3	1	3.69	1.57	4	4
Geographical proximity	3.22	2.07	2	1	3.33	1.51	3	3
Product mix flexibility	3.14	1.89	3	1	3.44	1.44	3	4
Logistical solution**	2.89	1.79	3	1	3.91	1.67	4	4
Size of company**	2.84	1.80	2	1	3.87	1.33	4	4
After-sales service*	2.52	1.73	2	1	3.21	1.70	3	2
Geographical coverage **	2.47	1.74	2	1	3.16	1.57	3	2

* The difference between internal and external suppliers is significant at the 0.05 level,
** The difference is significant at the 0.01 level.

4.2. Management aspects

4.2.1 Plant competence

In addition to plant location, we investigated the competences and responsibilities of the plant. Based on the related literature (primarily Ferdows 1989, 1997) and the pre-test round with industrialists and researchers we included eleven competence areas, for which responsibility could be assigned to the plant or held centrally in the network; cf. Table 6. The plant competences were captured using a seven-point Likert scale ranging from “no local responsibility” (1) to “full local responsibility” (7). The result is shown in Table 6.

Table 6. Competences and responsibilities at the plant.

Area of plant responsibility	Mean	Std.dev.	Median	Mode
Production	6.64	0.97	7	7
Production planning	6.44	1.16	7	7
Technical maintenance	6.25	1.40	7	7
Process development	5.83	1.54	6	7
Logistics	5.56	1.58	6	7
Introduction of new process technologies	5.37	1.84	6	7
Sourcing	5.28	1.99	6	7
Supplier development	4.64	2.07	5	7
Supply of global markets	4.29	2.42	5	7
Introduction of new product technologies	4.25	2.33	4	7
Product development	4.20	2.18	4	7

Overall, plants seem to possess many competences with local responsibility, indicating that plants typically have high strategic roles, such as “source”, “lead”, and “contributor” plants, using the terminology by Ferdows (1989, 1997). Twenty-one plants in the sample had the maximum score on all competences, i.e. an average of 7.0. The competence areas having the highest score for local responsibility were production, production planning and technical maintenance. Even though product development had the lowest average score, full responsibility (=7) was still the most frequent answer. All measures of central tendency indicate that the average plant at least share the responsibility or have full local responsibility concerning all competence areas.

4.2.2 Risk management

The section on risk and risk management included ten risk factors (see Table 7) based on the related literature, focusing on what risks the plants faced and to what degree they were handling the risks. Risks were rated on a seven-point Likert scale ranging from “no risk” (=1) to “very large risk” (=7) and the ability to manage them from “very poor” (=1) to “completely managed” (=7). The top three individual risks were (i) capacity risk (the risk of having the wrong level of capacity with respect to demand), (ii) market risk (the risk that demand changes in a way that the company cannot adapt to) and (iii) supplier risk (the risk that the suppliers cannot follow the technological development). Figure 1 shows the perceived risks, and the ability of the plant to manage these risks.

Table 7. Risk factors.

	Perceived risk level				Ability to manage risk			
	Mean	Std.dev.	Median	Mode	Mean	Std.dev.	Median	Mode
Capacity risk	4.64	1.43	5	6	4.68	1.31	5	5
Market risk	4.61	1.29	5	5	4.66	1.21	5	4
Supplier risk	4.07	1.33	4	5	4.32	1.29	4	4
Competence risk	3.93	1.46	4	4	4.50	1.18	5	5
Customer risk	3.88	1.38	4	4	4.70	1.25	5	5
Product development risk	3.78	1.61	4	2	4.62	1.18	5	5
Technology risk	3.52	1.62	3	2	4.68	1.27	5	6
Inventory risk	3.23	1.74	3	2	4.76	1.48	5	6
Political risk	3.19	1.59	3	4	4.47	1.42	4	4
Financial risk	2.90	1.44	3	2	5.31	1.31	6	6

The expectation was that high risk would be matched by high ability to manage the corresponding risk, i.e. that the important risk areas receive strong management attention. However, this is not the case. Figure 1 shows a scatter diagram of all plants; each plant is positioned based on its average score on perceived risk and the average level of its ability to manage these risks. There is a distinct downward slope (significant on the 0.01 level), indicating that firms that perceive low levels of risks are able to manage them, while firms that perceive great risks are not as able to manage those risks. One interpretation is that risks that can be managed are not perceived as problematic. Another interpretation is that risk management is an area that can be improved for some companies, i.e. those companies that experience high levels of risks and are poor at managing these risks.

Figure 1. Ability to manage risk vs. perceived risk level.

4.2.3 Competitive priorities and plant performance

In order to map the competitive priorities each respondent rated eight different competitive priorities on a seven-point Likert scale, ranging from “low importance” to “decisive importance” with respect to the relevance as an order-winning criterion. The results are presented in Table 8 and show that many criteria are important for winning orders. Quality comes out as the highest ranking order winner, with both the highest mean and lowest variance. Price is surprisingly low on the list; tied for fifth place. This result can at least partially be explained by that plants in Sweden, with high labor costs, have to find alternative means of competing, thus focusing to a larger extent on quality, product characteristics and delivery dependability.

Table 8. Competitive priorities and plant performance.

	Competitive priorities				Performance			
	Mean	Std.dev.	Median	Mode	Mean	Std.dev.	Median	Mode
Quality (conformance to spec's)	6.12	0.88	6	6	5.33	1.02	5	6
Delivery dependability	5.43	1.07	6	6	5.02	1.15	5	6
Product mix flexibility	4.75	1.64	5	6	5.19	1.20	5	6
Delivery speed	4.57	1.39	4	4	4.79	1.11	5	4
Price (Cost efficiency)	4.57	1.41	5	4	4.57	1.14	5	5
Volume flexibility	4.49	1.49	5	6	5.13	1.10	5	4
After-sales service	4.40	1.76	5	6	4.83	1.16	4,5	4
Design flexibility	3.85	1.41	4	4	4.88	1.25	5	4

Operational performance was mapped similarly as the competitive priorities. The respondents were asked to rate their performance in comparison to competitors on a scale from “much worse” (=1) to “much better” (=7). The overall performance, according to the responses, is quite a bit above average. The mean, median and mode are all at least at the mid-point in the scale; the mean and the median are even close to five on the seven-point scale. This can partially be explained by that high performing firms in general have a higher tendency to participate in research projects than low performing firms, according to our own experience. The top three performance categories are quality, product mix flexibility and volume flexibility. There are no statistically significant differences between any of the performance measures. The difference between the highest ranking measure and the lowest ranking measure is less than one.

A comparison between performance measures and competitive priorities (as a measure of importance) shows whether the plants are performing well on the issues that are important from a competitive point of view. This relationship is illustrated in Figure 2.

Figure 2. Competitive priorities versus performance

The trend line shows that there is a positive relationship between importance and performance, indicating that firms in general are good at what they perceive as important. The figure also includes a dotted line, where the levels of plant performance and competitive priorities are equal. The position of a factor relative to this line (in addition to the trend line) indicates the balance between the importance and the performance of that factor. If the factor is above both lines, then performance is relatively lower than what importance would suggest. Furthermore, a position below both lines indicates that performance is better compared to importance. Quality and delivery dependability are areas where plants are under-performing. Since these factors are the top two competitive priorities, overall plant performance would most likely benefit considerably by improvements in quality and delivery dependability. Price (cost efficiency) and delivery speed are balanced, while plants are relatively over-performing on all three types of flexibility as well as after-sales services. The relationship between cost efficiency versus flexibility suggests that while cost performance is at par with expectations relative to the competitive priorities, plants are more flexible than needed.

5. Conclusions

In this paper we have investigated how manufacturing networks are designed and managed, related to the market characteristics, the distribution and roles of plants, the selection of internal and external suppliers, risk management, and operational performance, based on a survey of 106 Swedish manufacturing plants. The design aspects are concerned with markets, plant location, and internal as well as external suppliers, while the management aspects are concerned with plant roles and site competence, risk management, and aligning performance to the competitive priorities. We focused on two research questions, concerned with the manufacturing networks around Swedish plants, and the roles of Swedish plants in the network.

In addressing the first research question, we find that the markets of Swedish plants are global and that the supply network is global, such that both internal suppliers and external suppliers are located globally. We find that quality and price issues are treated quite differently. Quality is perceived as a high priority for competing in the market, for plant location and roles, and for both internal and external suppliers. Thus, there is a strong alignment concerning quality, which is confirmed by the fact that quality is the performance factor with the highest rating. As for price, the products do not compete on price in the market, the plants do not have a low-cost focus, but cost is a very important criterion for choosing external suppliers. This supports the perception of cost as a major factor for outsourcing parts of the manufacturing network, and most likely for items for which cost is important.

The second research question was concerned with the role of Swedish plants. We find that the primary reasons for having a plant in Sweden are proximity to skills and knowledge, followed by proximity to transport hubs and the market. Swedish plants have a high level of competence in general, supporting proximity to skills and knowledge as the main location selection criterion. The home market is the major market for the products manufactured at Swedish plants (33.8 %), almost as important as the rest of Europe (37.9 %), supporting proximity to transport and the market as major reasons for plant location. Cost related issues are rated much lower, in line with that no pure low-cost oriented plants were found in the sample.

The companies that have a good ability to manage risks perceive the risks to be lower than the companies that have a poor ability to manage risks. This suggests that risk management has a positive impact on the presence of risks in general. Better risk management is likely to improve the performance for those companies that perceive significant risks and exhibit poor risk management skills. Even though the site competence in other areas is very high in general for Swedish plants, risk management is an area where the competence level could improve.

A limitation of this study is that it focuses on Swedish manufacturing plants. The results are therefore constrained to the investigation of the role of Swedish plants in manufacturing networks and their perspectives on market and supplier aspects. We therefore encourage other researchers to do similar research in other countries, to be able to understand similarities and differences between countries. Even though this study focuses on Swedish manufacturing networks, the results are most likely representative of many western countries. The design and management of the manufacturing network including the external suppliers has to be aligned to the market characteristics and take the particular products into consideration.

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