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by

A. VEREECKE*
R. VAN DIERDONCK**
and
A. DE MEYER†

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* Assistant Professor, Vlerick Leuven Gent Management School, Belgium.

** Professor, Vlerick Leuven Gent Management School, Belgium.

† Akzo Nobel Fellow in Strategic Management, Professor of Technology Management & Asian Business, INSEAD, 1 Ayer Rajah Avenue, 138676 Singapore.

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A TYPOLOGY OF PLANTS IN GLOBAL MANUFACTURING NETWORKS

Authors:

Ann Vereecke (ann.vereecke@vlerick.be)
Roland Van Dierdonck
Vlerick Leuven Gent Management School (Belgium)
and Ghent University (Belgium)
Arnoud De Meyer(arnoud.de.meyer@insead.edu)
INSEAD (Singapore)
and Ghent University (Belgium)

ABSTRACT

The purpose of this paper is to propose a new, empirically derived typology of plants in the international manufacturing network of multinational companies.

In this research, network analysis has been used as a methodology for understanding the position of plants in international manufacturing networks. The focus has been primarily on the intangible know-how network, and secondarily on the physical, logistic network. Our analysis leads to four types of plants with different network roles. The plants differ in the extent to which they share innovations with the other plants, in the level of visits to and from the other plants, and in the level of communication with the other plants. Our analysis shows that the different types of plants play a different strategic role in the company, have a different focus and differ in age, autonomy and level of resources and investments. Also, the analysis suggests that the evolution of the plant depends to some extent on the network role of the plant. Finally, two scenarios for the development of a strong network role are identified.

Key words: international manufacturing, knowledge diffusion, categorisation of plants

1. INTRODUCTION

Already in 1964 Skinner warned “the time has come when we must begin to sharpen the management of international manufacturing operations” (Skinner 1964). As competition is globalizing and the complexity of the environment in which companies operate is increasing, managing an integrated international network has become an increasingly important task for manufacturing managers (Bartlett and Ghoshal 1989; Ferdows 1997a). However, despite the importance attached to it by both academics and practitioners, the field of international operations management is still at a relatively early stage of theory development (Roth et al. 1997) and could be enriched by insights from empirical research (Chakravarty et al. 1997).

In the field of international operations management, at least two categories of research can be distinguished (Chakravarty et al. 1997). The first category of research consists mainly of international comparisons. The basic question here is to what extent models and concepts in Production and Operations Management are applicable in different countries or regions. The second category studies the management of international networks of facilities, suppliers and markets. The basic question here is how to design and manage the flows of goods, people, technology and information in international networks (Chakravarty et al. 1997). Our research contributes to this second category of international operations research.

Competitiveness today is not solely based on the application of state-of-the-art management techniques in each of the individual plants, but also on the implementation of an integrative strategy on the network of plants (Ferdows 1997a). From a logistics perspective this requires the optimization of the company’s supply chain. From an organizational perspective it requires managing the creation and transfer of know-how in the network. Plants adopt a different role in these networks. As plants differ in product allocation and in focus, they play different roles in the supply chain (Hayes and Schmenner 1978). As they differ in the level of creation, sharing and absorption of innovations, they play different roles in the intangible network of know-how in the company (Ferdows 1997b). The purpose of our research has been to understand the different roles of plants in this know-how network. Based on rigorous and in-depth case research a new typology of plants has been derived. The plant types differ in the extent to which they share innovations with the other plants, in the level of visits to and from the other plants, and in the level of communication with the other plants. The analysis also shows that different roles in the know-how network coincide with different roles in the supply chain.

2 LITERATURE REVIEW

2.1 Operations in a multinational: a network perspective

Over the last two decades, research on the structure and organization of multinationals has shifted from a focus on the one-to-one headquarters-subsidiaries relationships towards a focus on managing a network of units (Kogut 1989). Ghoshal and Bartlett have claimed that the network approach "is particularly suited for the investigation of such differences in internal roles, relations, and tasks of different affiliated units (...) and of how internal co-ordination mechanisms might be differentiated to match the variety of sub-unit contexts" (Ghoshal and Bartlett 1990, p620).

In the management of these networks, the focus has often been on the flow of information. Doz, for example, states that differences in the mission of subsidiaries are reflected in the "pattern and intensity of information flows" (Doz and Prahalad 1991 p.160). In their more recent work Doz, Santos and Williamson argue that the success of some of the companies that recently internationalised successfully lays in their ability to "sense" information and know how and distribute it rapidly throughout the network (Doz et al. 2001).

The information flow is only one type of network relationship between the subsidiaries and headquarters, and among the subsidiaries. The physical flow of components, semi-finished goods or end products, financial flows, and "flows" of people moving around in the network are other types of network relationships (Bartlett and Ghoshal 1989).

This trend towards describing the multinational company as a network of units can also be observed in the manufacturing strategy literature. Work has been done, for example, in the description of the benefits and methods of the transfer of best practices across the manufacturing network. Chew, Bresnahan and Clark show that the improvement of the overall performance of multi-site companies depends on the local innovativeness of the plants as well as on the interplant transfer of these local innovations (Chew et al. 1990). Flaherty (1986; 1996) adds to this the importance of coordination. She argues that the coordination of international operations in a network can improve cost and delivery performance and enhance the learning from the experiences of units in the network

However, the systematic analysis of the relationship between the plants in the manufacturing network requires an appropriate methodology. Nohria claims that "if we are to take a network perspective seriously, it means adopting a different intellectual lens and discipline, gathering different kinds of data, learning new analytical and methodological techniques, and seeking explanations that are quite different from conventional ones" (Nohria 1992, p.8). Network analysis is a particularly powerful methodology for the description and analysis of the structure of networks and the position of the units in the network (Knoke and Kuklinski

1982). The next section describes the network relationships between the units in the manufacturing network from a conceptual perspective. The operationalization of these network relationships and the application of network analysis techniques are described in the Research Methodology section.

2.2 Network position of plants

The purpose of our research has been to understand the position of manufacturing units in international manufacturing networks. Our hypothesis is that distinct plants play different roles in these networks by having relationships of different type and intensity with the other plants and with headquarters. Bartlett and Ghoshal recognize four types of relationships between subsidiaries: physical goods, information, people and financial resources (Bartlett and Ghoshal 1989). The flow of financial resources in the strict sense of providing capital to subsidiaries is of lesser importance in our study of network relationships between plants, and will therefore not be discussed here. The three other types of relationships - goods, information and people- differ in their degree of tangibility. Our interest lies primarily in the intangible knowledge network of the multinational, which is explained in the next two sections , since we are exploring how the network of production facilities of the multinational may enhance the creation of strategic capabilities. The logistics organization of the multinational , which is reflected in the focus of the plants and in the tangible transfer of semi-finished goods through the network, is discussed in the description of the characteristics of the plant types.

The information network

Two types of information flows can be distinguished: the administrative information flow, and the knowledge flow (Gupta and Govindarajan 1991). In a manufacturing context, the *administrative information flows* consist of information on inventory levels, purchasing requirements, forecasts, production plans, etc. These information flows depend to a large extent on the degree of centralization of manufacturing tasks, such as planning, inventory management and procurement. More interesting from a manufacturing strategy perspective are the *knowledge flows*. It is commonly accepted that one of the main reasons for the existence of multinationals is the possibility to acquire, create and use technological assets across national boundaries (Dunning 1993, p. 290). Consequently, the ability to transfer innovations through the multinational's network is crucial for attaining competitive advantage. Three categories of innovation flows have been studied: the development and introduction of a new *product,* the development and introduction of a new *production process,* and the implementation of a new *management system* (Ghoshal and Bartlett 1988).

The people network

The flows of people in the manufacturing network may take different shapes. A typical example is the position of a manager having line or staff *responsibility in two or more plants*. This can be at the level of the plant manager, as well as the functional levels reporting to the plant manager. This type of relationship can be called "interlocking management", by analogy with the interlocking directorship, i.e. one person being member of the board of directors of two or more companies - see Gerlach (1992). Of equal importance are the "dispatched managers”, i.e. the managers who have been *transferred from one operating unit to another*, on a permanent or a temporary basis, by analogy with the dispatched director - see Gerlach (1992). A third shape of the flow of people refers to the day-to-day operations of the network.

These relations between units are realized through "coordinators", *managers traveling frequently between operating units* in order to share information and to accomplish co-operation between the units. The role of such coordinators has received a lot of attention in the organization literature. They are specific examples of what Galbraith and Mintzberg have defined as the "liaison devices" of an organization (Galbraith 1977; Mintzberg 1979).

A major advantage of these coordinators is the opportunity they create for personal contact between people in the organization. Ghoshal et al have shown that the relationship among subsidiary managers and the relationship between managers of subsidiaries and managers of headquarters have a significant influence on the frequency of the inter-subsidiary communication, and on the frequency of communication between the subsidiaries and headquarters (Ghoshal et al. 1991; Ghoshal et al. 1994). Communication plays an important role as a facilitator of the transfer of innovations in multinationals (Ghoshal and Bartlett 1988; Gupta and Govindarajan 1991).

We retain from this short discussion three variables that are particularly relevant for our study. Firstly, the flow of innovations between the units in the network. Secondly, the extent to which coordination exists in the network through managers traveling between the units. And thirdly, the frequency of communication between the units in the network.

Interlocking management has not been retained as such in the research, since it can be regarded as a special reason for frequent travels between the two plants involved. Dispatching has not been retained either, since we assume that this creates a tight relationship between the dispatching and the receiving unit only if the dispatched manager keeps in touch with his original unit. Measuring the communication between the two units then captures this.

3. RESEARCH METHODOLOGY

3.1 Case research

The research reported here is part of a larger research study on the international plant configuration. The research was exploratory, i.e. we wanted to understand the "*how*" and "*why*" of the international plant network. Thus case study research has been preferred over other research methodologies (Yin 1984).

In order to achieve precision and rigor, the methodological guidelines proposed by Eisenhardt (1989), Miles (1994) and Yin (1984) have been followed in the present study. Without being exhaustive, we mention that a strict research protocol has been designed, a questionnaire with both closed and open ended questions has been developed as guidance for the interviews, and both qualitative and quantitative data have been collected in a rigorous and structured way and have been analyzed in a systematic way. Several variables have been measured through multiple item measures. The reliability of these variables has been assessed by calculating the Cronbach alpha, and factor analysis has been used to reject or confirm the assumption that some theoretical constructs underlie the items (Carmines and Zeller 1979; DeVellis 1991).

In order to enhance construct validity multiple raters have been used. This tactic avoids the risk that data comes from a single respondent with a biased view or with limited access to information (Speier and Swink 1995; Boyer and Verma 1996b). The ICC or "Intra-Class Correlation" method has been used to assess the inter-rater reliability of the variables. The ICC index measures the variance of the scores of the raters within a plant, relative to the between-plant variance. Data on the ICC for all variables used in the analyses can be found in Appendix 1.

3.2 Data collection

The case research has been carried out in eight manufacturing companies headquartered in Western Europe, in different industries: food products (2 companies), textile goods, plastic products, leather products, primary metal, fabricated metal and electrical goods. The companies had between 4 and 10 manufacturing plants. The primary selection criterion for the cases has been diversity, at the level of the company as well as the plant. At the company level it is important to have diversity in terms of the international environment in which the company operates, since one of the research objectives was to explore the link between the characteristics of the company's international environment and the plant configuration in the company. Consequently, the cases are distributed over the global, transnational and multinational environments, as defined by Bartlett and Ghoshal (1989). Diversity at the plant level has been obtained by selecting companies with a minimum of 4 plants, spread over a broad geographical region. The rationale being that with three plants or less, companies have few opportunities for differentiating the role and focus of their plants. A geographical spread of the plants (pan-European, or even global) was expected to result in a broad range of drivers for establishing the plant, and therefore also in a broad range of plant roles (Ferdows 1997b). The sample was limited to companies with their headquarters in Western Europe.

Data have been gathered at two levels of analysis: the plant and the company.

- Interviews have been conducted with the general manager and with manufacturing managers at headquarters. In total data has been collected on 59 manufacturing plants, through 37 interviews (with a total duration of approximately 120 hours). The number of interviews varied between 2 and 6 per case. A structured questionnaire with closed and open-ended questions has been used as a guide through the interviews.

- A second questionnaire has been sent to the plant managers and/or the manufacturing managers in the distinct production plants. 144 questionnaires have been sent to 54 out of the 59 plants (For five of the plants, headquarters asked us not to send a questionnaire to the plant managers). 83% of the questionnaires have been returned, from 50 plants. This implies that in total we have received data from the plant managers on 50 out of the 59 plants (85%). The number of questionnaires returned from the plants varied between 1 and 5 per plant.
- Information has also been obtained from desk research on company brochures, publications and company archives.

Fourty-five plants were located in Europe. The other 15 plants were located in East Asia and the Middle East, the USA and Canada, South Africa and Australia. The number of years the plant had been part of the company ranges between 0 and 50 years, with an average of 17 years. The number of employees in the plants ranges between 77 and 1,100 with an average of 340.

3.3 Operationalization of the network position of the plants

In describing the manufacturing network of a multinational company as an information and people network, the network units considered are all the plants and the group of managers in headquarters responsible for manufacturing (in this paper referred to as "headquarters"). As discussed earlier, the network relationships considered in this research are the flows of innovation, the use of coordinators and the communication between the units in the network.

The innovation transfers have been measured by asking managers in the plants (through the mail questionnaires) and in headquarters (through the interviews) to enumerate and describe the transfers of product, process and managerial innovations they know of over the past three years. A similar operationalization has been used by Ghoshal and Bartlett (Ghoshal and Bartlett 1988). The information that has been gathered from these different sources has been checked, complemented and corrected by at least one manager in headquarters.

The presence of coordinators has been operationalized as the extent to which people are traveling from one unit to another. This information on people flows has been collected through the mail questionnaire to the plants. The measurement is based on the tool used in the research by Ghoshal (1986). The respondents had to report the number of days they had spent, over the previous year, in headquarters and in each of the plants in the company's network.

One of the questionnaire items measures the communication between the managers in the plants and in headquarters. However, such self-reported answers may suffer from recollection problems. This problem is severe if the data collection method consists of an interview or questionnaire asking the respondent to name the persons he/she communicates with frequently. This approach has been used in early studies of communication networks in R&D laboratories (Allen 1977). An alternative approach is to provide a list of people, and to ask the respondent with whom on this list he/she has communicated, rather than letting the respondent name the people he communicated with (Knoke and Kuklinski 1982). This approach has been followed in our research. A score of 3, 2 and 1 has been given to daily, weekly and monthly communication respectively. Bartlett and Ghoshal have also preferred this scoring system (1989).

The primary network measure used in our research is the *centrality* of the plant in the network. If network relations are mutual (as is the case for the communication network), we measure centrality of the unit through its degree. The *degree of a unit* is defined as the proportion of other units with which a unit has a direct relationship (Knoke and Kuklinski 1982). If network relations are not mutual (as is the case for the flows of people and innovations), two degree measures are used: the unit's indegree and outdegree (Knoke and Kuklinski 1982). The *indegree of a unit* is defined as the proportion of relations received by the unit from all other units. The *outdegree of a unit* is defined as the proportion of relations from that unit to all other units.

Based on these definitions of centrality, the following network variables have been defined:

- the *communication centrality* of plant i captures the frequency of communication of the manufacturing staff of plant i with the manufacturing staff of the other units in the network
- the *innovation indegree* of the plant i captures the intensity of the innovation flow transferred (and implemented) from the other units to plant i
- the *innovation outdegree* captures the intensity of the innovation flow transferred (and implemented) from plant i to the other units
- the *people indegree* of the plant captures the number of days plant i has received visitors from the manufacturing staff team of the other plants
- the *people outdegree* of plant i captures the number of days manufacturing staff people of plant i have been visiting other plants in the plant configuration

In network analysis, the consequences of missing data are severe, since the lack of data from a single unit implies the lack of data on the N-1 possible relationships of this unit with the other units in the network. Estimates such as centrality can therefore be distorted if data are missing. Consequently, great care has been taken so as to maximize the response rate (Vereecke and Van Dierdonck 1999b).

3.3 Clustering of the data

To ensure the validity of the cluster solution, a two-stage procedure has been followed in clustering the data (Ketchen and Shook 1996). Ward's hierarchical clustering method has been used to define the number of clusters. This number of clusters has then been used as the parameter in the non-hierarchical K-means clustering method with Euclidian distance measure. K-means clustering is preferred over the hierarchical cluster methods for the development of the typology since it is an iterative partitioning method and thus is compensating for a poor initial partitioning of the cases. Since the units of measurement for the network relationships differ substantially and Euclidian distance is used as the distance measure in the cluster analysis, the variables have been standardized prior to the clustering (Aldenderfer and Blashfield 1984, p21).

As suggested by Ketchen and Shook, the number of clusters has been determined through the use of multiple techniques.

- Upon visual inspection of the dendogram, we recognize a structure with four clusters.
- A 4-cluster classification accounts for 56% of the variance in the data. Disaggregation into 5, 6 and 7 clusters adds approximately 6% to the variance explained at each step. After 7 clusters the increases in R^2 are low (below 3%). This observation points at a classification into 4 or 7 clusters.
- The cubic clustering criterion (CCC) points at 9 clusters. However, tests have indicated that the CCC may suggest too many clusters (Milligan and Cooper 1985).

– We have used SAS to perform a number of the tests that have been put forward by Milligan and Cooper as most effective (Milligan 1996). The Pseudo F statistic, developed by Calinski and Harabasz (1974), has local peaks at 2 and 7 clusters. The Pseudo t^2 statistic, based on Duda and Hart (1973), indicates a clustering of the data in 2, 4 or 7 clusters.

We conclude that the different test routines point at a clustering into 2, 4 or 7 clusters. Since there is partial agreement among the test results, Milligan suggests to opt for the larger number, that is 7 (Milligan 1996). However, a classification into 7 clusters results in some very small clusters (including a cluster of 1 unit). As this is not acceptable, we have opted in the final analysis for a classification into 4 clusters.

4. EMPIRICAL RESULTS

4.1 A network typology of plants

The four clusters represent different positions of plants in the plant network of information and people. The average of the network variables in each of the clusters is represented graphically in Figure 1.

The typology of plants resulting from this cluster analysis is summarized in Table 1. We distinguish three levels for each of the variables: "low" for an average value below 0; medium in case for average level between 0 and 1; high for an average value above 1. These cut-off values are defined on the standardized variables.

Figure 1 Network clusters: graphical representation

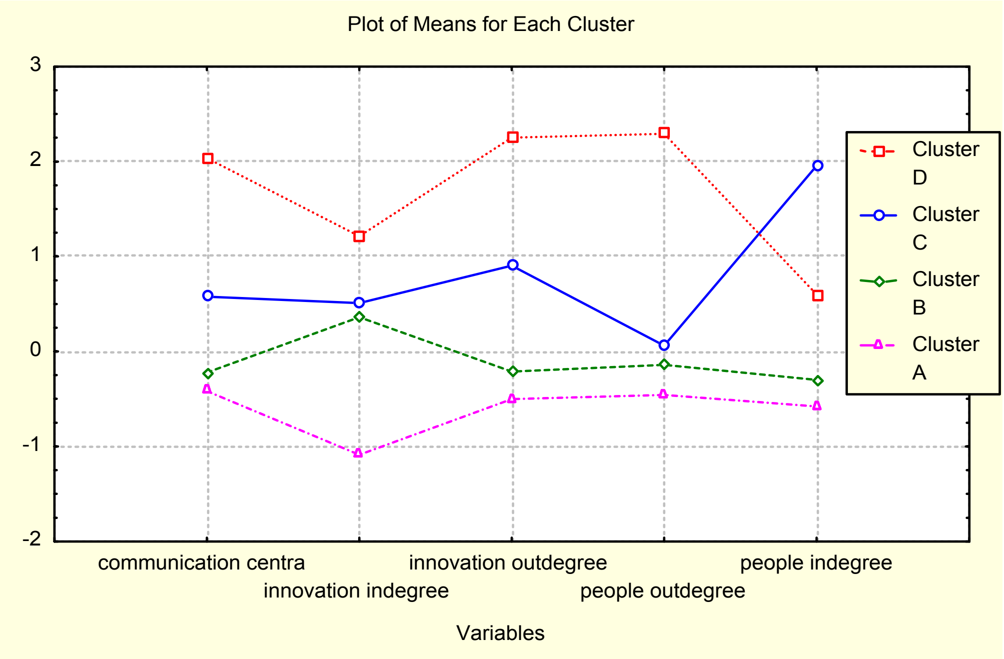


Table 1 Network typology of plants

	cluster A	cluster B	cluster C	cluster D
	"isolated"	"blueprint"	"host"	"glue for the network"
number of plants in cluster	11	26	8	4
communication centrality	low	low	medium	high
innovation indegree	low	medium	medium	high
innovation outdegree	low	low	medium	high
people indegree	low	low	high	medium
people outdegree	low	low	medium	high

Plants in cluster A occupy an "*isolated*" position in the plant network. Few innovations reach the plant, few innovations are transferred to other units, few manufacturing staff people come to visit such a plant, few manufacturing staff people from this plant go visit other plants, and there is little communication between the manufacturing staff people of this plant and the other manufacturing managers in the network.

A B-type plant picks up innovations from the network, but it returns significantly less innovations to the other units. The intake of innovations is not accompanied by a high inflow or outflow of people, nor by extensive communication with the manufacturing managers in the network. It looks like such a plant carries out innovations on the basis of a "*blueprint"* developed elsewhere, without much interference with the developing unit.

These two clusters thus consist of plants that are only weakly embedded in the manufacturing network. They represent the majority of plants in the sample.

The other two clusters, C and D, consist of plants that are true network players. A type C plant frequently exchanges innovations, both ways, with the other units. The picture that emerges is one of a "*host plant"*, since the manufacturing staff of the plant communicates fairly extensively with the other manufacturing managers, and the plant receives a lot of visitors from other plants.

The type D plants differ from the type C plants in two aspects: Firstly, the level of communication centrality and the outflow of innovations are even higher in the type D than in the type C plants (significantly different at $p=10\%$ for communication centrality and at $p=5\%$ for innovation outflow). Secondly, the major flow of visitors is in the opposite direction. Whereas in type C plants the inflow of visitors is significantly higher than the outflow ($p<1\%$), in type D plants the outflow is higher than the inflow ($p<5\%$).

Given the high level of network relations for a type D plant, we have labeled these plants as "*glue for the network*".

4.2 Cluster validation

Analysis of variance on the variables used to generate the cluster solution is frequently used to test the validity of the cluster analysis solution. The test results are summarized in Table 2.

Table 2 Analysis of Variance on 4-means cluster solution

	F	p-level
communication centrality	12,18	0.000006
innovation indegree	17,38	0.000000
innovation outdegree	21,69	0.000000
people indegree	47,81	0.000000
people outdegree	14,76	0.000001

However, we do not want to overemphasize the value of this analysis of variance. Since the clustering method attempts to minimize variance within the clusters, it is logical that the F-test is significant (Aldenderfer and Blashfield 1984, p65). External criteria analysis is more appropriate. Such analysis is based on statistical tests on variables that have not been used to generate the cluster solution, and yet are relevant (Aldenderfer and Blashfield 1984; Milligan and Cooper 1985).

A concept that is strongly related to the typology discussed here, is the concept of the "strategic role" of the plant. Building on the work done by Ferdows (1989) we define the importance of the strategic role of the plant as the extent to which the plant contributes to the other units in the manufacturing network (Vereecke and Van Dierdonck 1999a). We have measured the importance of the strategic role of the plant on a 9-point Likert scale, describing plants which have as their main goal "to get the products produced" at the lowest extreme, to plants that are a "center of excellence, and serve as a partner of headquarters in building strategic capabilities in the manufacturing function” at the highest extreme. Given our definition, the importance of the strategic role of the plants in cluster D should be high. The importance of the strategic role of the plants in clusters A and B, on the other hand, should be low, since these plants make little contributions to the plant network. The plants in cluster C are expected to play a strategic role of medium importance. The average and median of the importance of strategic roles are shown in Table 3. We should note here that for the importance of the strategic role, as well as for most of the plant characteristics that will be discussed later, the assumption of normality is violated. For those variables the non-parametric alternatives to the ANOVA, the Kruskall-Wallis and Median Tests have been used.

The Kruskal-Wallis test indicates a significant difference in the the of strategic role between the clusters (p<10%). The Median Test and Mann-Whitney U-Test confirm that the difference in strategic role follows the hypothesized pattern.

Table 3 Importance of strategic role of the plants

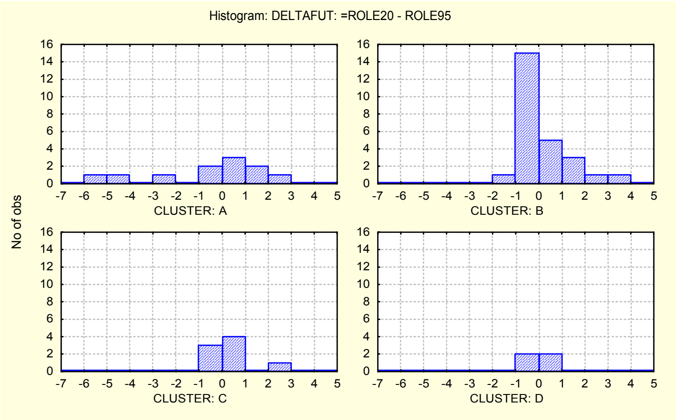
	Valid N	Mean	Median	Median Test: number observed-expected below median
Cluster A	11	4.80	4.67	-0.39
Cluster B	26	4.52	4.69	1.73
Cluster C	8	5.76	6.44	-0.08
Cluster D	4	7.97	8.10	-2.04

4.3 Future strategic role of the plant

We have discussed the relationship between the network position of the plant and the importance of the strategic role played by the plant. Our research also provides information on the expected changes in the strategic role of the plant. The interviewees were asked to estimate the importance of the strategic role of the plant as they expect it to be in 5 years, on the 9-point Likert scale described above. Figure 2 shows the histogram of the expected change in importance of the strategic role, for each of the four clusters. We can see that in each of the clusters positive as well as negative changes are expected, which explains why on average little change is observed. However, what is interesting in these histograms is that

- whereas in clusters C and D only a few marginal increases are expected (up to +1, with one exception), several increases are expected in clusters A and B. The increases go as high as +2.7 (on a 9-point scale) in A and +4.0 in B
- whereas in clusters C and D a few marginal decreases are expected (up to -1 on a 9-point scale), most of the plants in B are expected to decrease in strategic role. In cluster A, the expected decreases for some of the plants are fairly dramatic: decreases are expected up to –5.5.

**Figure 2	Expected change in strategic role by network type**



This suggests that the plants which occupy an integrated position in the network (clusters C and D) are fairly stable in terms of the importance of the strategic role they play in the company. Some of the A and B plants are expected to experience an important increase in strategic role. Given the relationship that we observed between the role of the plant and its network position, it is fair to expect that these plants will probably be moving from clusters A or B towards cluster C or D. Some of the other plants in clusters A and B, on the other hand, are expected to experience a decrease in strategic role. It is clear that these two clusters of non-integrated plants are less stable than the two clusters of integrated plants.

An example illustrates our point. Two of the “blueprint” plants in the sample have been closed since we started the case research. We don’t want to infer here the plants in the “isolated” or “blueprint” clusters are on the waiting list for closure. The examples of plants with a positive expectation in strategic role would certainly contradict this point. Our hypothesis is that the plants in these two clusters are in a variable position, and that this variability may lead towards an increase as well as a decrease in terms of the importance of the role the plant plays in tomorrow's network. These plants seem to provide flexibility in the network.

4.4 Characteristics of the plant types

In order to better understand the network typology of plants, the four types of plants have been compared on a set of plant characteristics. We have analysed:

- the *age* of the plant (the number of years the plant has been part of the company)
- the *size* of the plants (expressed in number of employees)
- the *focus* of the plant (Hayes and Schmenner 1978; Collins et al. 1989):
  - product focus: the extent to which the plant focuses on a narrow portion of the company's product range
  - market focus: the extent to which the plant focuses on a narrow portion of the geographical market served by the company
- the *supplier/user relationship* with other plants in the network: the extent to which a plant supplies components or semi-finished goods to or uses components or semi-finished goods from another plant in the network. It has been measured as the centrality (outdegree and indegree) of the plant in the physical network of goods. The outdegree of plant i captures the portion of plants in the plant configuration, to which plant i supplies components or semi-finished goods. The indegree of the plant i, analogously, captures the portion of plants in the plant configuration, from which plant i receives components or semi-finished goods.
- the *level of investment*: A list of 14 potential investments has been included in the questionnaries. The ICC exceeds 0.60 , which is the cut- off value suggested by Boyer and Verma (Boyer and Verma 1996a) for all but one items (See Appendix 1). For the item

"investments in materials and/or capacity planning" the ICC reaches 0.57. However, since this is very close to the cut-off level, the item has been retained in the analyses. From this list of 14 items three types of investment have been identified through factor analysis:

  - investments in the *production process*, that is in setup time reduction, plant automation, process analysis, productivity improvement and throughput time reduction (Cronbach alpha of the resulting factor = 0.77);
  - investments in *planning*, that is in material and/or capacity planning and just in time systems (Cronbach alpha of the resulting factor = 0.79);
  - investments in *managerial improvement* programs, that is in statistical process control, supplier partnerships, total quality management and employee participation programs (Cronbach alpha of the resulting factor = 0.73);
  - investments in *new product development.*

- the *autonomy* of the plant. Both strategic autonomy and operational autonomy have been measured through questionnaires administered in the plants. A similar approach has been followed by Ghoshal (Ghoshal 1986; Bartlett and Ghoshal 1989) and by De Bodinat (1975). The ICC reaches the cut-off level of 0.60 for all items (See Appendix 1). Two dimensions of strategic autonomy have been identified, through factor analysis:

  - strategic autonomy in decisions concerning the operations of the plant, that is the decision to develop a new product or to introduce a new planning system and the selection of a new supplier (Cronbach alpha of the resulting factor = 0.81);
  - strategic autonomy in decisions concerning the design of the plant, that is the decision to develop a new production process and the choice of a new technology (Cronbach alpha of the resulting factor = 0.85);

  Two dimensions of operational autonomy have been identified, through factor analysis:

  - operational logistics autonomy, that is in developing a production plan, placing purchasing orders, managing inventories (Cronbach alpha of the resulting factor = 0.84);
  - operational autonomy in design and engineering, that is in developing new products and processes (Cronbach alpha of the resulting factor = 0.88).
- the *level of capabilities* in the plant. Three types of capabilities are distinguished: the level of technical resources, the capabilities to develop new products, and managerial capabilities. They have been measured in the headquarters interviews, through a 1-9 Likert scale. The ICC-value of 0.60 was reached for the new product development and managerial capabilities, but not for the level of technical resources (ICC=0.34). (See Appendix 1) Consequently, the level of technical resources has been omitted from the analyses. The Cronbach alpha for the factor consisting of the remaining two variables was 0.85.
- the *performance* of the plant. Performance has been measured relative to the target set for the plant. Performance data has been obtained from a list of 9 performance items, included in the questionnaire sent to the plant management teams. Since this performance data is self-reported, it is important to have data from multiple respondents per plant, and to evaluate the inter-rater reliability. All but 2 performance items exceeded the ICC-value of 0.60. In the remaining list of 7 performance items, two dimensions of performance have been identified, through factor analysis (See Appendix 1):
  - performance on time measures, that is performance relative to the target set for manufacturing throughput time, delivery lead time and on-time delivery to customers (Cronbach alpha of the resulting factor = 0.85)

- performance on cost and quality measures, that is performance relative to the target set for unit production cost, productivity of direct workers, defect rates, and overall product quality (Cronbach alpha of the resulting factor = 0.83).

The results of the (mostly non-parametric) comparisons of the four clusters on these variables are listed in Table 4. The significant differences are summarized in Table 5.

Table 4 **Statistics on plant characteristics by cluster**

variable		Mean / *median* A	B	C	D	difference between clusters
age	number of years plant is part of company	11.1	16.8	30.6	19.7	the plants in cluster C are significantly older than the plants in clusters A and B. ($p < 5\%$)
size	number of employees*	*154*	*240*	*362*	*533*	not significant
	number of workers*	*111*	*165*	*251*	*308*	not significant
	number of salaried workers*	*43*	*43*	*126*	*226*	not significant
	number of manufacturing staff people*	*13*	*21*	*41*	*40*	not significant
market focus	proportion of market range supplied by the plant*	*0.18*	*0.63*	*0.90*	*0.89*	plants in cluster A are strongly market focused, whereas the plants in cluster C and D typically supply a broad market (Kruskal-Wallis Anova with $p < 5\%$ and Mann Whitney U-test)
product focus	Proportion of product range*	*0.15*	*0.22*	*0.30*	*0.38*	not significant
supplier/user relationship	Outdegree*	*0*	*0*	*0*	*0.47*	outflow of components and semi-finished goods is low for the plants in cluster A and is high for the plants in cluster D. (Kruskal-Wallis Anova with $p < 5\%$ and Mann Whitney U-test)
	Indegree*	*0*	*0.11*	*0.22*	*0.42*	inflow of components and semi-finished goods is low for the plants in cluster A and is high for the plants in cluster C and D. (Kruskal-Wallis Anova with $p <5\%$ and Mann Whitney U-test)
operational autonomy	Logistics	6.2	6.9	6.4	5.8	not significant
	Development & engineering	4.4	4.8	5.8	6.2	not significant
strategic autonomy	operations of the plant	4.1	5.2	5.1	5.4	not significant
	design of the plant	3.7	4.8	5.7	6.3	the level of strategic autonomy in plant design in cluster A is significantly lower than in clusters B, C and D ($p<5\%$). Plants in cluster D have a significantly higher level of strategic autonomy in plant design than A ($p<5\%$) and than B ($p<10\%$).

investment	process investment	5.5	5.3	5.1	6.8	the level of process investment in the plants in cluster D exceeds the level in the three other clusters significantly (p<5% for B-D and for C-D; p<10% for A-D)
	investment in planning	4.4	4.9	4.6	6.3	Plants in cluster D invest significantly more in planning systems than plants in cluster A (p<10%). They also invest more in planning systems than plants in clusters B and C, although with low significance (p=12%)
	managerial investment	6.5	4.9	4.9	5.7	Plants in cluster A invest significantly more in managerial improvement programs than plants in clusters B and C (p<5%).
	new product investment	4.9	5.2	5.7	7.0	not significant
plant capabilities	level of resources	6.4	5.3	6.4	7.5	The level of capabilities in cluster B is significantly lower than in cluster A (p<10%), C (p<10%) and D (p<5%).
performance relative to target	time performance	1.0	0.72	0.84	0.82	not significant
	cost & quality performance*	*1.0*	*0.63*	*0.02*	*0.69*	not significant

remark: Variable for which the assumption of normality is rejected are marked with *.

For those variables the median value is mentioned (in italic). For the other variables the mean value is mentioned.

Table 5 Summary of plant characteristics by cluster

cluster A	– relatively young – market focused – little inflow and outflow of components and semi-finished goods – relatively low level of strategic autonomy in plant design – relatively high level of managerial investment
cluster B	– relatively young – relatively low level of managerial investment – relatively low level of capabilities
cluster C	– relatively old – broad market – high inflow of components and semi-finished goods – relatively low level of managerial investment
Cluster D	– high outflow and outflow of components and semi-finished goods – relatively high level of strategic autonomy in plant design – relatively high level of process investment – relatively high level of investment in planning systems

5. DISCUSSION

Some general lessons can be drawn from the plant typology and the characteristics of the four types of plants.

Firstly, the plants providing innovations to the manufacturing network, the "host" plants and the "glue" plants, are at the same time receivers of innovations from other units in the network. Apparently, transferring know-how is beneficial, not only for the receiver, but also for the provider. An explanation may be that the quality of the relationship between two units is a major factor in the exchange of innovations, or as Szulanski has put it “the relationship serves as a conduit for knowledge” (Szulanski 1996). Once such a relationship has been established, it works in both directions. This observation indicates that a protective attitude towards knowledge, trying to keep it inside the plant in order to prevent other plants in the network to improve, is counterproductive in the long run.

Secondly, the analyses show that there is a strong link between the position of the plant in the intangible network of ideas and in the tangible network of goods. The “isolated” plant, which is not actively taking part in the network of ideas is also isolated in the physical sense: we observed very little flows of components or semi-finished goods from these plants to the other plants in the network, and vice versa. The network players (type C and D) on the other hand are typically suppliers to the other plants (in the case of cluster D) or customers of the other plants (in the case of cluster C) for components or semi-finished goods. Kobrin, who argued that "the two most important intrafirm flows are products and technology, and the latter is often embodied in the former", has also observed this link between know-how and physical flows (Kobrin 1991, p19). Our research suggests that the product is not only a carrier of technological product and process innovation, but also of managerial innovations.

Thirdly, we conclude that the two types of network players, ie. the plants in clusters C and D, have a very different character. The plants in cluster C are typically fairly old, they supply a broad market, and they are characterized by a low level of managerial investment. It is striking that out of the eight C-plants, four are the “original plant”, the earliest plant in the network, located close to headquarters. Type D-plants are characterized by investments and autonomy. Only one of the D-plants is an “original” plant. These observations suggest that there are two different scenario’s for the development of plants operating as network players in the international plant configuration. The first scenario, which leads to a C-type plant, builds on the heritage of the plant. The network relationships exist because the plant has been in the network for a very long time. We hypothesize that, because of its age and because of the broad market it supplies, the plant has gained a lot of experience, which explains why the plant is seen as an important source of innovative ideas by other plants. The plant seems to undergo this scenario as the network evolves over time. The scenario that emerges from the characteristics of the type D-plants is more dynamic. These plants build capabilities through investments, under a relatively high level of autonomy. Such plants are actively building network relationships by sending manufacturing staff to other plants and through extensive communication.

Building network relations takes time. The average age of the networked plants (type C and D) is 28 years, whereas the average age of the two more isolated types of plants (type A and B) is only 15 years. The difference in age between these two groups is significant ($p<1\%$). Networks apparently develop over a long period of time.

In terms of performance, no significant difference is observed between the clusters. Reaching the target on cost, quality or time measures doesn't appear more or less difficult in the distinct clusters. This suggests that there is not a unique optimal network position for a plant. Rather, the network position of the plant should be regarded from a contingency perspective.

Finally, the analyses suggest that the future perspectives of the plant depend on the plant's network position. Plants that are strongly embedded in the production network are expected to maintain the high level of strategic role they are already playing in the network. The future of plants in rather isolated positions has been predicted to be in two opposite directions: some plants are expected to grow in strategic importance, and are assumed to develop network relationships; others are expected to become less important, and may even disappear from the manufacturing network. A possible explanation may be that, in case of over-capacity and cost cutting, an "isolated" or "blueprint" plant is a welcome candidate for disinvestment or closure. Closing such a plant implies a reduction of overall capacity, which is exactly what is aimed at. It does not imply, however, an important reduction in know-how transfers, since these plants do not contribute considerably to the other plants in the network.

Overall, this leads us to believe that in managing international networks of plants, managers can balance long-term know-how development and medium-term flexibility. In approving investments in the network relationships they allow some of the plants to play an active role in the creation and diffusion of know-how in the network, thus creating long-term competitive advantage. The other plants provide the manager with strategic flexibility. Their role in the network can be adapted in the medium term, according to the changing needs of the business. The good news is that the creation of a portfolio of plants in order to pursue strategic flexibility does not seem to have a negative impact on the performance per se. Given the small number of plants in each of the clusters, this conclusion requires verification on a larger sample.

6. LIMITATIONS AND FUTURE RESEARCH

An important limitation of the research is the focus on the intra-company network relationships. While we acknowledge that inter-company network relationships are important in creating sustainable competitive advantage, we have limited our research to the network relationships between units of the same company. Whether the "host" and "network glue" plants are also tightly embedded in the external, inter-company network remains to be studied.

Secondly, our research describes the strategic role played by plants in international plant networks. It identifies those plants that develop know-how and capabilities and that transfer this know-how to the other plants in the network. The research doesn't explain how this know-how is developed, nor does it describe the mechanisms used for the diffusion of this know-how and their effectiveness. This is also an area of future research.

Also, we did not make any assertions about the relationship between the portfolio of plants in terms of their network type and the performance of the company. We hypothesize that the optimal portfolio of plants is contingent on the company's competitive environment. However, this needs to be studied.

As mentioned in the Methodology section, this paper is based on case research. While one of the major advantages of case research is the depth of the information that can be collected, its major disadvantage is the limitation in sample size, and therefore the potential limitation in external validity. However, we are convinced that the careful selection of the cases from a diversity of industries improves the external validity of the work.

The cases have been limited to companies headquartered in Western Europe, to avoid cultural differences between the cases. Whether the conclusions still hold in multinationals headquartered in other continents is unexplored and can be subject to future research.

Finally, the research focuses on manufacturing companies only. Whether a similar typology can be developed for service companies remains to be explored.

7. CONCLUSION

In the research, network analysis has been used as a methodology for understanding the position of plants in international manufacturing networks. The focus has been primarily on the intangible know-how network, and secondarily on the physical, logistic network. A typology of plants in a manufacturing network has resulted from the research. Four types of plants, with a different strategic role, different characteristics, and different perspectives for the future have emerged.

The current research suggests that two scenarios for attaining an integrated network position exist: a scenario built on heritage, and a dynamic, bottom-up scenario. Future research should bring more insights into the dynamics of the network position of plants.

Appendix 1 Inter-rater reliability scores on perceptual measures

construct	factor	item	ICC
strategic role today			0.85
strategic role 5 y ahead			0.83
operational autonomy	*logistics*	developing a Master Production Schedule	0.81
		developing material and capacity plans	0.78
		developing the shop floor schedule	0.70
		developing sales forecasts	0.89
		placing purchasing orders	0.80
		managing inventories	0.70
	development & engineering	developing new products	0.74
		making changes to existing products	0.77
		developing new production processes	0.78
		making changes to existing production processes	0.79
strategic autonomy	*operations of the plant*	the decision to develop a new product	0.69
		the decision to make changes to an existing product design	0.76
		the selection of a new supplier	0.77
		the decision to introduce a new planning and control system	0.80
		the choice of standards, goals and performance measures for quality management	0.70
	design of the plant	the decision to develop a new production process	0.76
		the decision to make changes to an existing production process	0.78
		the choice of technology	0.73
investment	*process investment*	setup time reduction	0.67
		plant automation	0.73
		process analysis	0.73
		productivity improvement	0.75
		throughput time reduction	0.85

	investment in planning	material and/or capacity planning	0.57
		just in time systems	0.72
	managerial investment	statistical process control	0.87
		supplier partnerships	0.81
		total quality management	0.89
		employee participation programs	0.76
	new product investment	new product development	0.77
plant capabilities	*level of resources*	capabilities in developing new products	0.66
		managerial capabilities	0.62
	not included in the analyses	*level of technical resources*	*0.34*
performance relative to target	*time performance*	manufacturing throughput time (from start until finish of production)	0.61
		service level (on-time delivery to customers)	0.75
		delivery lead time (from customer's order until delivery)	0.60
	cost & quality performance	average defect rates at the end of manufacturing	0.75
		average unit production costs for a typical product	0.80
		productivity of direct production workers	0.78
		overall product quality as perceived by the customers	0.69
	not included in the analyses	*rate of new product introduction*	*0.47*
	not included in the analyses	*equipment setup time*	*0.54*

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