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A revisit and extension

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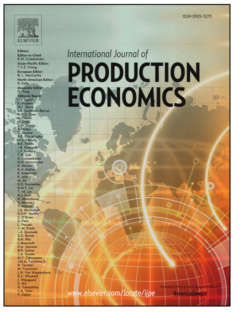

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The role of plants in manufacturing networks: a revisit and extension

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Abstract

Based on IMSS VI, this paper firstly revisits Ferdows' typology by simultaneously addressing multiple portfolios of its two dimensions, i.e. site competence and location advantage. It further complements this typology by developing a more objective, empirically derived taxonomy of plant role and accordingly proposes four new plant roles, i.e. Start Plant, Old School Plant, Expert Plant, and Replaceable Plant. These plant roles are different in terms of location advantages and site competences, as well as other characteristics, e.g. product, process, market, and location. Second, this paper extends our understandings on plant role by exploring the fit of a plant role with the differentiation of its management practices based on the developed taxonomy. It identifies three patterns regarding the fits between plant roles and their management practices and implies that plants that are strongly embedded in the manufacturing network are expected to play the high level of strategic role; plants with greater responsibility may sometimes correspond with less autonomy; plants in dilemma might have more motivation to coordinate with other plants and integrate with external customers; and plants managed in old styles might be more independent and thereby passive about coordination and integration with other partners. These results highlight that management practices need to be differentiated so that plants can pursue their roles effectively.

Keywords: Plant role**,** manufacturing network, revisit, extension

1. Introduction

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Since the 1980s, both global trade and foreign direct investment (FDI) have increased explosively (Cheng et al., 2015a). Within ten years, the foreign investment base has more than trebled (Friedman, 2006; Jacob and Strube, 2008). This development has resulted in the globalisation of markets and further led to the widespread restructuring of manufacturing companies and systems.

Being the single largest type of FDI in most countries (Ferdows, 1997a), manufacturing has inevitably become more international since the late 1980s. Along with deregulation, a converging world economy, rapid technical progress, and declining transaction costs, manufacturers actually benefited a lot from choosing globalisation (Ghoshal and Bartlett, 1990; Ferdows, 1997a). Therefore, during the last 30 years, manufacturing companies have attempted to disperse their plants geographically and coordinate them in a synergetic network (Ferdows, 1997a,b; Shi and Gregory, 1998). The role of manufacturing companies has accordingly shifted from supplying domestic markets with products, via supplying international markets through export, to supply international markets through local manufacturing (Cheng et al., 2015a). Manufacturing system concepts have also evolved from a focus on the plant to the one on the manufacturing network (Ferdows, 1989; Rudberg and Olhager, 2003; Cheng et al., 2015a; Cheng et al., 2016).

A manufacturing network is generally defined as a coordinated aggregation (network) of intra-firm plants/factories located in different places, underlining the need for a wide perspective covering geographic dispersion and interdependent coordination rather than the traditional focus on separated manufacturing sites (Ferdows, 1989; Shi and Gregory, 1998; and Rudberg and Olhager, 2003; Cheng et al., 2016). Thus, plants may be viewed as the basic construct and the integral part of a manufacturing network (Cheng et al, 2011), but it should also not be overlooked that the network consists of individual plants, sometimes with agendas of their own. In reality, different plants in the same network can actually differ in e.g., focus, age, autonomy, level of resources, investment, product allocation, location advantages, site competence and responsibility, and the level of creation, sharing, and absorption of innovations (Hayes and Schmenner 1978; Ferdows, 1997b; Vereecke et al, 2006). They are further recognised to have possibilities of playing different roles in

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the context of a manufacturing network (Ferdows, 1989, 1997b). The concept of plant roles was firstly proposed by Ferdows (1989, 1997b). It has been recognised and taken as the outset by much further research (Cheng et al., 2015a), because of its implications for managing different plant roles within a manufacturing network. Nevertheless, essentially being a typology that refers to conceptually derived interrelated sets of ideal types (Doty and Glick, 1994), the Ferdows model is not without flaws. More research is necessary to complement the model per se. Therefore, *the first research objective* of this paper is to revisit and complement the plant role model proposed by Ferdows (1989, 1997b), in order to address its limitations.

Furthermore, it is believed that there should be a fit between the way a plant is managed and the particular role it plays. If managers use similar approaches to manage plants with different strategic roles, the approaches may be compromised for all plants, or some plants may be managed inappropriately. In contrast, if managers know which management approaches need to be linked to specific plant roles, they can differentiate the management approaches within their network to match the roles of plants (Maritan et al., 2004). In other words, plants with different roles should have distinct management practices in place (Maritan et al., 2004). They are supposed to have different degrees of autonomy and integrate material flows, management skills, product/process development, or other knowledge with other plants in the same network, other functions in the firm, suppliers, and customers in different ways. The collaborations of a plant with these partners are normally referred as interplant coordination (with other plants), internal integration (with other functions), and external integration (with suppliers and customers) (Flynn et al., 2010; Zhao et al., 2008; Zhao et al., 2011; Schoenherr and Swink, 2012; Cheng et al., 2015a, 2016). Therefore, *the second research objective* of this paper is to extend our understandings on the plant role by identifying the specific differences in management approaches, in terms of plant autonomy, interplant coordination, internal integration and external integration, among plants operating in manufacturing networks but with different strategic roles.

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This paper is organised as follows. First, the related literature is reviewed, based on which research gaps, objectives, and hypotheses are further elaborated. This is followed by a description of the research design. The empirical analyses and the findings are then reported and discussed. Finally, this paper is concluded with the implications of the findings for both researchers and managers.

2. Literature review

2.1 History of studies on plant role

The concept of plant role was ambiguously addressed early in the history of P/OM study. For example, Hayes and Schmenner (1978) introduced the concept of product and process oriented organisations. The plants are given very different tasks depending on whether they are product or process oriented, which results in a differentiation of roles (Feldmann and Olhager, 2013). Nevertheless, regarding individual plants in a generic way, the early literature normally focused on plant level manufacturing strategy and primarily felt interested in the fit of business unit competitive strategy with plant characteristics (Maritan et al., 2004).

In the late 1970s, there was already a growing realisation among scholars of the need to manage not only the single factory, but also multi-plant organisations. However, at that time, manufacturing was fairly geographically concentrated even if markets became global. Therefore, the research was mainly concerned with plant location decisions and merely referred to the selection of the least costly site (Meijboom and Voordijk, 2003; Cheng and Johansen, 2014). Nevertheless, ever more research argued that cost evaluation seldom tells the complete story, nor does it always differ significantly enough to make a location choice strictly on its merit (Cheng et al., 2014). Thus, researchers and practitioners should look beyond the obvious in plant location and explore the strategic, intangible and qualitative features of a location that should be expected to contribute to the company’s competitiveness (Schmenner, 1979). Accordingly, much research has been conducted to identify the drivers for allocating manufacturing facilities in specific locations,

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allowing them to define roles that manufacturing facilities may be playing within a corporate network (Cheng et al., 2015a).

In the late 1980s, it became compulsory to address the increasing distribution of plants all over the world in the context of the internationalisation of companies and manufacturing. Accordingly, international manufacturing studies paid more attention to multi-plant discussions. In a study of Fortune 500 companies, Schmenner (1982) proposed four multi-plant manufacturing strategies, i.e. product plant strategy, process plant strategy, market area plant strategy, and general purpose plant strategy. He further indicated that all four manufacturing strategies of plants in multi-plant firms are influenced by the concept of plant focus (Feldmann and Olhager, 2013). Hayes and Wheelwright (1984) adopted the above typology, and further argued that a facility strategy requires choices regarding the size, location, and specialisation of individual facilities, and an understanding of the interaction of these decisions.

In the 1990s, much research gradually showed a growing consensus around the idea that a key for understanding the complexity of the global economy is the concept of the network (Coe et al., 2008). It further sought to extend existing manufacturing system concepts to underline the network characteristics of the new manufacturing system by linking manufacturing strategy concepts with views from international strategy (Cheng et al., 2015a). The concept of manufacturing network was accordingly proposed and new structured knowledge about manufacturing network was developed. As expected to contribute more to companies than merely low costs, plants were also recognised to have the possibility of playing different roles in manufacturing networks (Ferdows, 1989, 1997b).

2.2 Strategic roles of plants: Ferdows' model and related studies

The concept of plant roles was firstly introduced by Ferdows (1989, 1997b), but discussions on plant roles generally started from the roles of subsidiaries in multinationals (Bartlett and Ghoshal, 1989; Roth and Morrison, 1992; and Taggart, 1998). The contribution of Ferdows (1989, 1997b) is translating the strategic classifications of subsidiaries into a manufacturing classification of plants.

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His classification distinguishes plants on the basis of location advantage and plant competence. On the one hand, Ferdows defined location advantage as "the strategic reason for establishing and exploiting the plant" and identified three classes: access to low-cost production, access to skills and knowledge, and proximity to market. On the other hand, he referred site competence as "the extent of technical activities undertaken at the site" in his earlier work (Ferdows, 1989), but defined it in his more recent work as "the extent to which the following competencies are present in the plant: production, process technical maintenance, procurement, local logistics, production planning, product and process development and improvement, development of suppliers, the supply of global markets, and a global hub role for product and process knowledge" (Ferdows, 1997b). Using the two dimensions in a matrix, Ferdows further proposed six ideal types of plants, i.e. offshore, source, server, contributor, outpost, and lead-plant, among which a lead-plant assumes the ultimate role, being the global hub for product or process knowledge.

The Ferdows model has gained academic recognition and therefore become the springboard for much research, in which two streams can generally be recognised. The first stream of the existing studies tends to recognise the model as a useful framework for mapping, analysing, and evaluating the plant configuration and uses it to describe and categorise AS-IS (existing) plants (Vereecke and Van Dierdonck, 2002; Cheng et al., 2015a). For example, Mediavilla and his colleagues (Mediavilla and Errasti 2010; Mediavilla et al. 2015) explored the application of the model for the analysis of strategic plant roles in a manufacturing network. They extended the scope of the model by discussing a framework for deploying an improvement roadmap to facilitate a gradual upgrade of the strategic role of a plant within a network. Similarly, Cheng and his colleagues (Cheng et al., 2011 and Cheng et al., 2015b) used the model to map the evolution of plants, in order to further study the interaction between plants and networks as well as between production and R&D in their globalisation. The other examples include Fusco and Spring (2003), Meijboom and Voordijk (2003), Miltenburg (2009, 2015a, b), Scherrer and Deflorin (2017), among others. The second stream of the existing studies attempts to develop further understandings on the model. Vereecke

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and Van Dierdonck (2002) discussed and tested the model based on eight manufacturing companies headquartered in Western Europe from seven industries. They found some support for the model and proved it to be useful for the description and assessment of today's network of plants, but they also indicated that it is too limited to serve as a typology for new plants that might be added to the network and the perception of headquarters and of plant management concerning the plants' strategic role can be very different. Maritan et al. (2004) examined whether plants in a multinational manufacturing firm with different roles have different degrees of autonomy concerning planning, production, and control. Building on the Ferdows' model, they found that there was greater autonomy over planning decisions (long range production planning, production scheduling, quality standards, and maintenance policies and practices) for "source" versus "off-shore" plants, and for "lead" versus "outpost" plants. There also exist studies in this stream that attempt to develop further understandings specifically on the dimension of site competence. Meijboom and Vos (2004) introduced an instrument that enables the measurement of dynamics in the roles of plants in international networks, and provided a clear definition and more precise operationalisation of "site competence". Feldmann and his colleagues (Feldmann et al., 2009; Feldmann and Olhager, 2013) investigated the type and level of site competence and found that the areas of site competence can be grouped in a more detailed level than before in the related literature, characterised thematically as three bundles, i.e. production-related, supply chain-related, and development-related. They also indicated that competencies are not added individually, but successively in bundles over production, supply chain, and development. Table 1 is developed to summarise and compare previous research related to Ferdows' plant role model in terms of their research stream, focused dimension, and operationalisation of dimension.

Table 1: Previous research related to Ferdows' plant role model

Research stream	Study	Focused dimension and operationalisation
Use Ferdows' model to map, analyse, and categorise	Fusco and Spring (2003)	**Location advantage:** Cost, market, and knowledge **Site competence:** Not specified
	Meijboom and	**Location advantage:** Cost, market, and knowledge

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plants	Voordijk (2003)	**Site competence:** Not specified
	Miltenburg (2009, 2015a, b)	**Location advantage:** Cost, market, and knowledge **Site competence:** Operationalised in terms of the scope of activity and the level of capacity
	Mediavilla and Errasti (2010), Mediavilla et al. (2015)	**Location advantage:** Cost, market, and knowledge **Site competence:** Operationalised in terms of six main fields of analysis
	Cheng et al. (2011, 2015b)	**Location advantage:** Cost, market, knowledge, supplier, social policy, and competition **Site competence:** Not specified
	Scherrer and Deflorin (2017)	**Location advantage:** Market, supplier, knowledge, cost, and social political factor **Site competence:** Manufacturing capabilities, production related capabilities, and supply chain related capabilities
Develop understandings on Ferdows' model	Vereecke and Van Dierdonck (2002)	**Location advantage:** 15 drivers, but conclude that cost, market, and knowledge encompass the vast majority of plants **Site competence:** Not specified, instead develop a likert-scale to measure distinct levels of strategic role
	Maritan et al. (2004)	**Location advantage:** Cost, market, and knowledge **Site competence:** Level of technical activities at the site, in terms of original product design, product design changes, original process design and process design changes
Develop understandings on the dimension of site competence	Meijboom and Vos (2004)	**Site competence:** An instrument that includes 11 levels of site competence, ranging from production to creation of new processes and products for entire company
	Feldmann et al., 2009; Feldmann and Olhager, 2013	**Location advantage:** Cost, market, and knowledge **Site competence:** 9 levels of site competence, further classified into three bundles, i.e. production-related, supply chain-related, and development-related

2.3 Comments on the previous literature: the need of revisiting Ferdows' model

Judging by the number of papers that have attempted different kinds of plant categorisations, plant role is a highly relevant topic for both researchers and practitioners (Feldmann and Olhager, 2013). As illustrated in Cheng et al. (2015a), there has been a relatively stable publication rate over the years on this topic. The model presented by Ferdows has been successfully applied in the later research, and has thus been acknowledged as a key reference in the area. Essentially as a conceptual

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typology, the Ferdows model offers considerable benefits. The plant role types offer an interesting perspective on the international plant configuration (Vereecke and Van Dierdonck, 2002), while the typology as a whole provides insight into the more general relationships among lactation advantage, site competence, and plant role. It is also an important classification tool, which reduces the complexity of describing and evaluating plants in the context of an international manufacturing network to a clear set of analytical dimensions, and offers a yardstick against which individual cases can be studies and compared (Hotho, 2014). Accordingly, it was mostly used by the existing studies to map, analyse, and categorise the plant configuration, as illustrated in Table 1.

Nevertheless, because of its prior nature and frequent lack of specified empirical referents and cutoff points, the Ferdows typology is actually difficult to use empirically. The allocation of plants to types is often not clear-cut. In this case, some studies attempted to reconsider or further refine two dimensions of Ferdows' typology. With regard to location advantages of plants, Ferdows only included three of them in his model among all the categories that can be identified from the existing literature. Although his selection has not been empirically verified, there seems to be an agreement as illustrated in Table 1 that the three major location advantages are indeed access to low-cost labour, access to skills and knowledge, and proximity to market (Vereecke and Van Dierdonck, 2002; Feldmann and Olhager, 2013). Regarding site competences, Ferdows has provided two slightly different definitions, as described above. This however led to the lack of standardisation of scales for site competence, as the previous research has used different subsets to operationalise this dimension (Meijboom and Vos, 2004; Vereecke et al., 2006). Therefore, more attention was paid to develop further understandings on the dimension of site competence, as shown in Table 1.

Even though, the Ferdows typology still suffers from other issues. First, as the typology is derived inductively, it is hard to assess whether it is exhaustive and captures the full variety of plants found in the practice. As shown in Vereecke and Van Dierdonck (2002) and Cheng et al. (2011), in reality, there indeed exist plants that have high-level site competence, but take low cost manufacturing or market proximity as the primary location driver. These plants are obviously not

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reflected in Ferdows' typology. Without the systematical analysis of a wider range of possibilities, we might overlook more subtle but equally coherent and distinctive ways of plant configuration that could enrich the plant role types (Hotho, 2014). Second, the Ferdows typology identified six ideal plant role types. Although these types are abstract classifications rather than reflections of particular contexts, they are logically derived from studies of a relatively small number of cases. This raises the issue of whether these plant role types truly reflect universal patterns, or merely logical possibilities and the characteristics of representative cases (Marradi, 1990; Hotho, 2014). For example, one of the plant roles, i.e. outpost, seems to be empirically empty, since few instances can be identified in the practice (Vereecke and Van Dierdonck, 2002; Cheng et al., 2011; Cheng et al., 2015b). Finally, it has been almost two decades since Ferdows proposed his typology. However, except one study, i.e. Vereecke and Van Dierdonck (2002), little effort has been made to empirically test and update Ferdows' typology. The absence of large-scale empirical analysis makes it difficult to characterise and classify plants that are outside the scope of the existing studies. In other words, the typology does not provide enough variety to describe today's plants that may be added to the network, especially in light of economic, political, and technological development in last decades.

There are at least two ways around these typological limitations. The first is to accept a typology's limitations but recognise its analytical contribution. The second alternative is to complement typologies and inductively derived classification types with the construction of taxonomies (Hotho, 2014). Taxonomies are classifications of empirical cases that are often numerically or statistically derived. The purpose of taxonomies, unlike typologies, is not to define ideals, but rather to empirically classify organisations into comprehensive or mutually exclusive groups (Meyer et al., 1993; Boyer et al., 2000) that share common characteristics (de Jong and Marsili, 2006) and provide a multidimensional vision of the organisations studied (Bozarth and McDermott, 1998). Taxonomies are useful tools for exploring and assessing the extent to which existing types can be empirically identified. This may lead to the identification of new types or

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stimulate the refinement of conceptual typologies (Hotho, 2014). Considering the limitations of Ferdows' typology clarified above are all related to the lack of an empirical perspective, this paper aims to revisit and complement the plant role typology proposed Ferdows (1997b) by developing a more objective, empirically derived taxonomy. Specifically, this research builds on Ferdows' work by: (1) providing a taxonomy that is based on a statistical analysis of two dimensions of the model, rather than a subjective assignment of plants to groups; (2) providing a current assessment of plant roles; and (3) using a broader sample with more complete data. The first hypothesis is accordingly formulated as below:

Hypothesis 1 (H1): Plants can be classified into distinct groups based their location advantages and site competences.

Besides, as Ferdows (1997b) and some of the other existing studies (e.g. Schmenner, 1982 and Vereecke et al., 2006) suggested, plants with different roles are supposed to have many different characteristics. Therefore, in order to better understand the developed taxonomy of plant role types, this paper explores the other characteristics of plants in addition to location advantage and site competence. Specifically, it focuses on products produced by plant, processes held by plant, and markets served by plant. In fact, they are always considered as the basic characteristics of a plant not only in the traditional manufacturing strategy studies (Hayes and Wheelwright, 1979a,b), but also in the discussions related to multi-plant strategy and manufacturing network (Schmenner, 1982; Cheng et al., 2011).

2.4 Comments on the previous literature: the need of extending Ferdows' model

Plants with different strategic roles are supposed to have different characteristics, which accordingly need to be managed in different ways. As mentioned in the introduction, in practice, if managers know which management approaches need to be associated with which plant roles, they

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can differentiate the management approaches within their networks to better manage plants with different strategic roles. However, the relationship between plant role and management approach is not addressed in Ferdows's model. Essentially as a theoretical typology, his framework is strong on its detailed discussion of plant types and roles, but a corresponding problem may be the absence of discussion of how plants might fit with particular management practices (Maritan et al., 2004). This absence may have led us to interpret Ferdows' framework as expecting advanced practices on all dimensions for Lead plants, which might however not be the case in the real world, as demonstrated in Vereecke and Van Dierdonck (2002), Cheng et al. (2011), and Cheng et al. (2015b). To bridge this gap, Maritan et al. (2004) focused on one aspect of management practices, i.e. the autonomy the plant has over three types of decisions, planning, production and control, and tested whether this autonomy systematically differs among plants with different roles. Nevertheless, this paper is the only one identified from the existing literature that examines the management practices that plants with different roles need to adopt. In other words, we actually do not know much about plants with different strategic roles, in terms of the ways they are managed. Therefore, based on the developed taxonomy of plant role, this paper also aims to extend our understanding on plant role by exploring the fit of a plant role with the differentiation of its management practices. Specifically, this paper chooses to examine not only decision autonomy, but also interplant coordination, internal integration, and external integration. Interplant coordination is defined as the question for a plant in a manufacturing network about how to link or integrate with other plants (Pontrandolfo and Okogbaa, 1999; Cheng et al., 2015a). The most important benefit that a plant belonging to a manufacturing network can obtain is to learn more about technology, customers, products or processes from other plants than it can learn by itself (Cheng et al., 2016). It may also gain advantages in cost or flexibility from collaborating with other plants in the same network that it cannot achieve if it is managed as a stand-alone entity (Maritan et al., 2004). Therefore, it is important to discuss plant role in the context of manufacturing network and investigate the relationship between plant role and interplant coordination. In addition to coordinate with other

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plants, a plant in a network is also supposed to acquire, share and consolidate strategic knowledge and information with internal and external partners, to achieve better alignment of objectives and business processes, coordination and fit (Swink et al., 2007; Cheng et al., 2016). Therefore, it is equally important to examine the relationship between plant role and internal/external integration. Internal integration refers to the degree to which a plant structures its intra-organisational practices, procedures and behaviours into collaborative, synchronised and manageable processes and systems across functions (Chen and Paulraj, 2004; Schoenherr and Swink, 2012). It breaks down functional barriers and facilitates information sharing and strategic cooperation between plant and internal functions, like product/process design, procurement, sales and distribution (Wong et al., 2011; Zhao et al., 2011). External integration refers to the degree to which a plant combines with its external partners to structure its inter-organisational strategies, practices, procedures and behaviours into collaborative and synchronised processes and systems (Chen and Paulraj, 2004; Flynn et al., 2010; Zhao et al., 2011). By definition, plants with different roles are supposed to have different degrees of engagements on product/process development and on supply chain management. Therefore, they are also expected to have different degrees of internal and external integration. Accordingly, the second hypothesis is formulated as:

Hypothesis 2 (H2): Plants with different strategic roles are different in terms of the degrees of their (a) decision autonomy, (b) interplant coordination, (c) internal integration, (d) external integration.

3. Research methodology

3.1 Sampling and data collection

This paper fulfils the proposed research objectives based on the data from the sixth International Manufacturing Strategy Survey (IMSS VI). Firstly established in 1992 by London Business School and Chalmers University of Technology, the IMSS is a global network of business schools and other research institutions that collaborate with each other as well as with manufacturing companies

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to develop a common survey instrument and data collection protocol for the global research of manufacturing and supply chain management.

The data used in this paper was collected from June 2013 to Jun 2014, with the final dataset released in September 2014. The sample was designed to reflect the population of manufacturing plants with more than 50 employees from ISIC 25-30 classifications, i.e. machinery, electronics, metal products, transport equipment and motor vehicles industrial sectors. Finally, 7,167 companies from 22 different countries were selected from public or private local databases and then contacted.

The original questionnaire was developed in English and later translated into local languages by national researchers who adopted double- and reverse-translation procedures (Vanpoucke et al., 2014). Before the official launch, the questionnaire has been extensively pre-tested by practitioners. Their active involvement ensured the high levels of relevance of the instruments and further made content validity carefully addressed (Wiengarten et al., 2014).

A common procedure was followed in each country in order to ensure that data was collection in the same way. The survey respondents were usually operations, production, supply chain or plant managers/directors, who were selected due to the knowledge and awareness they showed towards both operational and strategic decisions. 78.6% of the respondents have been working in their companies for more than five years. The local research teams normally approached the potential respondents through phone or email and sent them questionnaires by ordinary mail, fax or email after obtaining their participation agreements. At the end, 2586 questionnaires were delivered and, if needed, reminders were sent out after several weeks to increase response rates (Zhao et al., 2008). The quality of the returned questionnaires was reviewed at three stages. First, the local team checked for the quality of the responses on a case-by-case basis and often contacted the managers for missing data and for the accurate interpretation of the responses. Second, local research groups also controlled the gathered data for late respondent bias, company size, and industry. Finally, all the data was summarised into a unique database and was checked once again by the coordination team (at the Politecnico Di Milano) in terms of e.g. checking for input errors and outliers.

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After excluding the cases with much missing data or many errors, the final IMSS VI sample included 931 companies from 22 countries in Europe, the Americas and Asia, which represented a response rate of 36% (931/2586). Considering my goals as obtaining a large sample and keeping manufacturing practices relatively homogenous, IMSS VI offers an appropriate data set (Cheng et al., 2016). Furthermore, as plant role is usually discussed in the context of a manufacturing network, this paper specifically used a subset of the IMSS VI data, which consisted of 606 plants that identified themselves as one of the plants in a manufacturing network. This sample size is favourably comparable to the typical threshold recommended for empirical studies in operations management (Malhotra and Grover, 1998). The profile of the sample used in this paper is shown in Table 2.

Table 2: The profile of the sample used in this paper

Demographic dimension	Sample used in this paper: Plants that belonged to a manufacturing network	Number	Percentage (%)
Personnel employed in the companies that the plants belong to			
	Small Companies (<250 employees)	197	32.51
	Medium companies (between 250 and 500 employees)	122	20.13
	Large companies (>500 employees)	285	47.03
	Missing	2	0.33
	Total	606	100.00
Industrial sector			
25	Manufacture of fabricated metal products, except machinery and equipment	176	29.00
26	Manufacture of computer, electronic and optical products	83	13.70
27	Manufacture of electrical equipment	103	17.00
28	Manufacture of machinery and equipment not elsewhere classified	139	22.90
29	Manufacture of motor vehicles, trailers and semi-trailers	74	12.20
30	Manufacture of other transport equipment	31	5.10
	Total	606	100.00
Regions and countries			
	Europe	327	53.96
	Asia	207	34.16
	America	72	11.88
	Total	606	100.00
	Developed countries (Netherlands, Finland, Switzerland, Portugal, Spain, Italy, Taiwan, Belgium, Canada, Denmark, Germany, Norway, Sweden, Japan, USA)	394	65.02
	Developing countries (Romania, India, China, Hungary, Malaysia, Slovenia, Brazil)	212	34.98
	Total	606	100.00

3.2 Measures

This paper followed Ferdows' model to define plant role in terms of two dimensions, i.e. site competence and location advantage. First, as indicated in Section 2.3, Feldmann and his colleagues

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(Feldmann et al., 2009; Feldmann and Olhager, 2013) showed that site competences can be grouped into three bundles: production-related, supply chain-related, and development-related. These three bundles were further used in this paper to measure site competences, because of two reasons. One the one hand, they are generally acknowledged in the field of international operations and applied by much subsequent research (Thomas et al., 2015; Demeter, 2017; and Scherrer and Deflorin, 2017). On the other hand, they reduce the complexity of the discussions on site competence, which is helpful to improve the validity of data collected and further facilitate the corresponding analysis. In this paper, each bundle was gauged by observing the extent of specific activities that were carried out at the plant (Ferdows et al., 2016). Production bundle includes activities like basic production, process improvement, and technical maintenance. Supply chain bundle consists of activities like procurement, logistics, and supplier development. Development bundle includes activities like product improvement and introduction of new product and process technologies. Specific items in the survey asked for information about the presence of these activities at the plant. Second, a set of location advantages was provided to respondents. Nevertheless, as indicated in Section 2.3, it is generally agreed that the three major location advantages are indeed access to low-cost labour, access to skills and knowledge, and proximity to market (Vereecke and Van Dierdonck, 2002; Feldmann and Olhager, 2013). Therefore, the location advantages that the respondents rated were grouped into these three strategic reasons. Access to low-cost labour, raw materials, and energy comprised the first strategic reason, access to low-cost resources. The second reason, i.e. proximity to market, is comprised by proximity to important markets, as well as the abilities for rapid/reliable delivery, customisation, and fast service and support. Finally, access to skilled workers and managers and access to technological know-how comprise the last strategic reason, i.e. access to knowledge and skills. The respondents were asked to rate to what extent they recognise specific location advantages as the current advantages of their plants' locations. All the items listed in IMSS VI survey to measure site competence and location advantages are elaborated in Appendix 1 in more details.

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Furthermore, I identified items in the IMSS VI survey that correlated strongly with the characteristics of plants that I intended to test in this paper, i.e. products produced by plant, processes held by plant, and markets served by plant. All the relevant measurement items are also elaborated in Appendix 1 for details. For products produced by plant, the question about how the production of a product was distributed among the plants within the network was asked, where 1 is "Your product is produced only in your plant" and 5 is "Your product is produced at multiple plants within the network". For processes held by plant, I was interested in to what degree of processes the plant covers, where 1 represents "Your plant covers only some specific production steps" and 5 represents "Your plant covers the full production processes". For markets served by plant, the question whether "your plant serve just a specified surrounding geographic area/market" or "your plant serves the whole world/global market" was asked, where 1 represents the former and 5 represents the latter.

Differently, to operationalise the constructs related to management practices, i.e. decision autonomy, interplant coordination, internal integration, and external integration, I used multi-item, reflective rather than formative indicators (Bollen, 1989). The items for each construct were measured by using five-point Likert scales, where higher values indicated stronger autonomy, coordination and integration. They are also introduced in Appendix 1 in more details.

First, in alignment with the literature and with respect to the present operations management context, autonomy in this paper was measured at the strategic and operational levels (Birkinshaw and Morrison, 1995; O'Donnell, 2000). Strategic autonomy was measured as the degree of a plant's autonomy in defining its own competitive strategy (Buckley and Ghauri, 2004; O'Donnell, 2000; and Taggart and Hood, 1999). Operational autonomy was based on Maritan et al. (2004), which classified 12 typical decision types of a plant into three categories, i.e. planning decisions (such as long range production planning, schedules, quality standards and maintenance policies and practices), production decisions (such as raw material sourcing, component sourcing and equipment sourcing), and control decisions (such as human resource policies for management and labour,

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choice of management systems). It further indicated that the level of autonomy in planning is particularly significant in explaining differences among plant roles, while the same does not hold for the level of autonomy in production and control, based on a large-scale global survey. The study is acknowledged in the field of international operations and adopted by much subsequent research (Golini et al., 2016; Scherrer and Deflorin, 2017). Therefore, operational autonomy in this paper was measured as the degree of freedom of the plant manager to decide on production planning.

Second, to reflect the definition of interplant coordination introduced in section 2.4, this study operationalised interplant coordination as current levels of implementation on five items: (1) information sharing with other plants (Rudberg and Olhager, 2003; Argoneto et al., 2008); (2) joint decision-making with other plants (Colotla et al., 2003; Argoneto et al., 2008); (3) innovation sharing/joint innovation with other plants (Ernst and Kim, 2002; Ferdows, 2006); (4) use of technology to support communication with other plants (Clemmons and Simon, 2001); and developing a comprehensive network performance management system (Colotla et al., 2003; Rudberg and West, 2008).

Third, I distinguished internal integration into the cross-functional integration activities of plants with development department and with purchasing and sales departments. In this paper, internal integration with development was measured by using responses to seven items in the survey, including (1) informal mechanisms; (2) design integration; (3) organisational integration; (4) technological integration; (5) integrating tools and techniques, (6) communication technologies; and (7) process standardisation. All these items are consistent with those used in the previous studies, e.g. Paashuis and Boer (1997), Koufteros et al. (2005), and Swink et al. (2007). Similarly, based on the previous research (e.g. Ellinger et al., 2000; Giménez and Ventura, 2005), the integration of plants with purchasing and sales was operationalised in terms of a four-item scale: (1) information sharing between manufacturing and purchasing; (2) joint decision-making between manufacturing and purchasing; (3) information sharing between manufacturing and sales; and (4) joint decision-making between manufacturing and sales.

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Fourth, external integration can further be collapsed into supplier and customer integration. Supplier integration is related to coordination and information sharing with critical suppliers that provide insights into suppliers' processes, capabilities and constraints. It is practiced in manufacturing plants to enable more effective planning and forecasting, product and process design and transaction management (Bowersox et al., 1999; Ragatz et al., 2002). Customer integration involves close collaboration and information-sharing activities with key customers that provide insights into market expectations and opportunities (Bowersox et al., 1999; Wong et al., 2011). It enables manufacturing plants to develop a better understanding of customers' preferences, and to build relationships with customers (Swink et al., 2007). Based on the previous research (e.g. Spekman, 1988; Ellinger et al., 2000; Frohlich and Westbrook, 2001; Flynn et al., 2010; Mazzola and Perrone, 2013), supplier and customer integration in this study were each operationalised through four items related to (1) sharing information with key suppliers/customers; (2) developing collaborating approaches with key suppliers/customers; (3) joint decision-making with key suppliers/customers; and (4) system coupling with key suppliers/customers.

Finally, I also included size of organisation and region plant is located to in the analysis. For organisation size, I used the logarithm of the total number of employees of the business unit in which the plant is placed (similar to Zhu and Sarkis, 2004; Peng et al., 2013). For region, I checked for differences across developing and developed countries.

3.3 Non-response bias, late-response bias and common method bias

Non-response bias and late-response bias were both controlled by the local research teams. To test for differences between respondents and non-respondents and between the early and late respondents, local researchers firstly tried to search for secondary data from the existing databases with information about all public firms in their countries. The accessible secondary data was then used to investigate whether respondents and non-respondents, as well as early and late respondents, were significantly different in size, industry, sale or other characteristics. If such databases were not

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available, non-response bias and late-response bias were then checked by using questionnaire items, such as size, industry, and operational performance. As a result, no significant non-response bias or late-response bias was reported in IMSS VI.

Common method bias (CMB) may be a concern for all studies that use data from a single source. It may be created because of common rater and item characteristic. The former might arise because of the respondents' perceived need to provide consistent or desirable answers and the latter because of social desirability or ambiguity in items. Addressing CMB must start at the research design phase and the most effective remedy is to be ex-ante smart about the issues by identifying what the measures of the predictor and criterion variables have in common and then eliminating or minimising them through the design of the study (Podsakoff et al., 2003; Guide and Ketokivi, 2015). Therefore, several techniques suggested in Podsakoff et al. (2003) were adopted at the research design phase of IMSS VI survey to minimise CMB during the data collection. First, the questions on different constructs were separated from each other. Specifically, the questions measuring the predictor and criterion variables were segmented into different sections of the questionnaire with counterbalanced order (Dobrzykowski et al., 2015; Cheng et al., 2016). Second, different scale anchors and formats were applied for items included in this study. Such procedural remedies reduce the likelihood of CMB by making it difficult for respondents to link the targeted measures together (Podsakoff et al., 2003). Third, the anonymity of both the respondents and the firms were explicitly maintained, eliminating incentives for socially favourable answers (Cheng et al., 2016). Finally, in order to reduce ambiguity, the questions related to all the constructs were made simple, specific, and concise. They also incorporated objective concepts and explanations for the ambiguous or unfamiliar items.

3.4 Measurement validation: the analyses of reliability and validity

A rigorous process was adopted to develop and validate the survey instrument by following the procedures suggested in previous empirical studies (Flynn et al., 2010; Zhao et al., 2011;

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Schoenherr and Swink, 2012). Prior to data collection, content validity was established based on the close collaboration between academics and industry professionals in the development of the measurement items and supported by previous literature, executive interviews and pilot tests. After the data collection, a series of analyses were performed to ensure the reliability and validity of the constructs.

First, the issue of missing data was addressed. Missing data can have two adverse effects in empirical surveys, namely (1) they reduce the statistical power of the analysis and (2) they may result in biased estimates (Roth et al., 1999). According to Littles MCAR test ($p<0.05$), the missing data in my dataset follows the pattern of Missing Completely At Random (MCAR). Following Tsikriktsis (2005), Multiple Imputation (MI) was adopted to deal with missing data.

The second issue was the reliability of measures for each construct. Reliability is an assessment of the degree of consistency between multiple measurements of a variable (Hair et al., 1998). The existing studies (e.g. Narasimhan and Jayaram, 1998; Flynn et al., 2010; Zhao et al., 2011) often used Cronbach's alpha to assess construct reliability. However, this coefficient alpha is based on the essentially tau-equivalent measurement model and the violation of the assumptions required for this model often results in coefficient alpha's underestimation of reliability (Graham, 2006). Therefore, instead of simply relying on "rule of thumb", i.e. Cronbach's alpha >0.70 (Nunnally, 1994), I chose to follow a two-step approach proposed by Graham (2006) to assess construct reliability:

1. Selecting an appropriate measurement model among the parallel model, the Tau-equivalent model, the essentially Tau-equivalent model and the congeneric model based on the model fit and the chi-square test on difference in fit between different models;
2. Estimating reliability based on the best possible model chosen from the first step, by squaring the implied correlation between the composite latent true variable and the composite observed variable.

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The results are shown in Table 3, which allow me to conclude that the reliability of constructs is established. It should also be noted that if in the first step, the Tau-equivalent model is chosen, the reliability calculated in the second step is actually Cronbach's alpha. Furthermore, I ran explorative factor analysis (EFA) to investigate unidimensionality of the scales. The results of EFA based on principal components analysis demonstrate construct unidimensionality by showing that all items have strong loadings on the constructs they are supposed to measure, and lower loadings on the constructs that they are not supposed to measure. Afterwards, I adopted confirmatory factor analysis (CFA) to further test unidimensionality and reliability. For conducting CFA, each measurement item was linked to its corresponding construct, and the covariance among the constructs was freely estimated. The model fit indices are $\chi 2(636)=1504.867$, GFI=0.885, AGFI=0.859, RMR=0.041, 90 percent confidence interval for RMSEA=(0.044, 0.051), NFI=0.883, RFI=0.864, IFI=0.929, NNFI=0.916, CFI=0.928, which indicate the acceptance of the model (Hu and Bentler, 1999). The CFA factor loadings are also listed in Table 3, which further demonstrate the construct unidimensionality as all items have strong loadings on the constructs they are supposed to measure. Besides, based on these loadings, average variance extracted (AVE) values and composite reliability (CR) values for all the constructs were calculated. As shown in Table 3, the CR values for all the constructs are higher than 0.70 (Hair et al., 2010). In this case, unidimensionality and reliability are further confirmed (Fornell and Larcker, 1981).

Finally, convergent validity and discriminant validity were tested again by using CFA. With the model fit indices shown above, the model is considered as acceptable (Hu and Bentler, 1999), indicating convergent validity (O'Leary-Kelly and Vokurka, 1998). Moreover, all the factor loadings shown in Table 3 are greater than 0.50, which also suggests convergent validity (Anderson and Gerbing, 1988; Wong et al., 2011; Wiengarten et al., 2014). The estimates for the AVE are also acceptable, although internal integration with development department falls slightly below the minimum of 0.50 (Fornell and Larcker, 1981; Flynn et al., 2010; Vanpoucke et al., 2014). Furthermore, in my CFA model, all the t-values are greater than 2.0, and each item's coefficient is

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greater than twice its standard error (Anderson and Gerbing, 1988; Flynn et al., 2010). All these suggest that the constructs achieve convergent validity. To assess discriminant validity, constrained CFA models were established for each possible pair of latent constructs. After setting the scale of measurement for each construct by fixing its variance at 1.0, these CFA models were used to assess discriminant validity for any pair of constructs by constraining the estimated correlation between the constructs to 1.0 and then performing a chi-square difference test on the model fit indices obtained for the constrained and unconstrained models (MacKenzie et al., 2011). As shown in Appendix 2, for each pair, significant differences of the $\chi 2$ statistics ($p<0.001$) between the constrained and unconstrained models can be observed, which in turn indicate high discriminant validity (Fornell and Larcker, 1981). Besides, following the suggestion of Voorhees et al. (2015), I also applied the approach proposed by Henseler et al. (2015) to further test discriminant validity. The heterotrait–monotrait ratios (HTMT) of the correlations between the constructs were calculated two by two. As all the HTMT values are less than 0.85, discriminant validity is further confirmed.

Table 3: The analyses of reliability and validity

Measurement items	Standardised factor loadings	Reliability based on Graham (2006)	AVE	Composite reliability (CR)
Autonomy		0.697	0.559	0.713
Strategic decision autonomy	0.633			
Production planning autonomy	0.847			
Internal integration with development department		0.872	0.490	0.870
Informal mechanisms	0.623			
Design integration	0.661			
Organisation integration	0.740			
Technological integration	0.711			
Integrating tools and techniques	0.742			
Communication technologies	0.674			
Process standardisation	0.741			
Internal integration with purchasing and sales departments		0.884	0.652	0.882
Sharing information with purchasing department	0.745			
Joint decision making with purchasing department	0.780			
Sharing information with sales department	0.846			
Joint decision making with sales department	0.854			
Supplier integration		0.848	0.596	0.855
Sharing information with key suppliers	0.771			
Developing collaborative approaches with key suppliers	0.831			
Joint decision making with key suppliers	0.792			
System Coupling with key suppliers	0.687			

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Customer integration		0.891	0.675	0.892
Sharing information with key customers	0.851			
Developing collaborative approaches with key customers	0.864			
Joint decision making with key customers	0.760			
System coupling with key customers	0.806			
Interplant coordination		0.876	0.589	0.878
Information sharing with other plants	0.804			
Joint decision making with other plants	0.757			
Knowledge sharing/joint innovation with other plants	0.746			
Use of technology to support interplant communication with other plants	0.755			
Developing comprehensive network performance management system	0.775			

3.5 Data analysis procedure

The values for latent variables (i.e. autonomy, internal integration with development department, internal integration with purchasing and sales departments, supplier integration, customer integration, and interplant coordination) were generated based on their corresponding measurement items by using “Data imputation” function in AMOS 23 with the regression imputation method. The generated dataset was then used for the further analyses conducted by SPSS 23. The analyses were fundamentally exploratory. This study firstly revisited and complemented the plant role typology proposed Ferdows (1997b) by simultaneously addressing site competence and location advantage and developing a more objective, empirically derived taxonomy. Then, it explored the other characteristics of plants in addition to location advantage and site competence, in order to better understand the developed taxonomy. Finally, this paper explored the fit of a plant role with the differentiation of its management practices, based on the developed taxonomy.

4. Revisiting the study of Ferdows (1997b)

4.1 Analyses and results

In order to revisit and complement the study of Ferdows (1997b), this paper developed a more objective, empirically derived taxonomy by performing a cluster analysis to classify plants into groups based on both of their site competences and location advantages. In fact, location advantage and site competence have always been the focus in the studies of plant role (Cheng et al., 2015a).

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Nevertheless, the existing research tended to discuss these two dimensions separately, although the original model indicated a potential dependency between them. Besides, Ferdows acknowledged that some plants might combine more location advantages and site competences and Vereecke and Van Dierdonck (2002) provided evidences for such an argument, but most of the existing studies still attached each plant with single location advantage and single site competence respectively to facilitate their analyses (Vereecke and Van Dierdonck, 2002; Maritan et al., 2004). To bridge these gaps, this paper chose to simultaneously address multiple portfolios of site competence and location advantage, when developing the taxonomy.

A two-step clustering procedure was used to minimise potential adverse effects of the large number of companies involved and the instability of hierarchical clustering algorithms. In the first step, I adopted Ward's hierarchical method of minimum variance (Everitt, 1981) to establish the number of clusters and profile the cluster centres. The changes in agglomeration coefficient indicated that a four-group solution was appropriate. Next, I used non-hierarchical cluster analysis based on the K-Means Cluster algorithm to fine-tune the results. I further compared the results of the hierarchical and non-hierarchical cluster analyses to examine the stability of the cluster solutions. Cluster profiles matched well across the methods, confirming that a four-cluster solution as shown in Table 4 was empirically appropriate and stable, rather than six clusters as suggested in Ferdows' typology. The first cluster of plants score relatively high on all six dimensions. In other words, they are responsible for all kinds of activities related to production, supply chain, and development, while enjoying the advantages of accessing to low cost resource, market, and knowledge and skills. Similarly, the second cluster of plants also score high on three site competences, but differently, they only score high on one of three location advantages, i.e. access to knowledge and skills. The third cluster of plants score high on production competence and relatively high on supply chain competence. Nevertheless, they surprisingly score low on access to low cost resource, but high on proximity to market and access to knowledge and skills. The last cluster of plants only score high on production competence out of six dimensions.

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Table 4: Cluster analysis based on site competence and location advantage

	Cluster A (N=198)	Cluster B (N=142)	Cluster C (N=94)	Cluster D (N=172)
Production	4.64	4.88	4.82	3.89
Supply chain	4.44	4.72	3.74	3.04
Development	4.23	4.78	2.97	2.77
Low cost resource	3.89	1.72	1.75	3.21
Proximity to market	4.20	3.08	4.46	3.12
Knowledge and skills	4.16	3.88	4.30	3.21

In order to develop further understandings about these four clusters of plants, I explored the differentiation of their characteristics. Specifically, I focused on products produced by plant, processes held by plant, markets served by plant, organisation size, and region plant is located. Based on the results of cluster analysis shown in Table 4, one-way ANOVA and the multiple comparison LSD test were performed to check if the first four plant characteristics exhibited significant differences among four different clusters of plants. Nevertheless, due to the heterogeneity of variances, some of the results had to be further validated by Kruskal-Wallis test and explained according to Tamhane comparison test. As shown in Table 5, the plants in different clusters are significantly different from each other in terms of their products ($P<0.01$ based on one-way ANOVA), processes ($P<0.001$ based on a Kruskal-Wallis test), and markets ($P<0.001$ based on a Kruskal-Wallis test), but not in terms of their organisation size ($P>0.05$ based on one-way ANOVA). More specifically, according to the multiple comparison LSD test, the plants in Cluster B tend to have more products only produced by them, compared to the plants in Clusters A and D. Meanwhile, according to Tamhane comparison test, the plants in Cluster B on the one hand tend to cover more production processes than the plants in the other three clusters, followed by the plants in Cluster A, whereas the plants in Cluster D relatively hold only some specific production steps. On the other hand, the plants in Cluster B also tend to serve more markets, compared to the plants in Clusters C and D that focus more on specified markets.

Table 5: Plant characteristics by cluster: results of ANOVA and Kruskal-Wallis test

		Cluster A	Cluster B	Cluster C	Cluster D	ANOVA
Products produced by plant		(2)	(1, 4)		(2)	P<0.01
	Mean	3.22	2.43	2.91	3.23	
	S.D.	1.52	1.47	1.48	3.45	
Processes		(2, 4**)	(1, 3, 4**)	(2**)	(1, 2**)	P<0.001*

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held by plant	Mean	4.03	4.37	3.73	3.48	
	S.D.	1.09	1.09	1.39	1.15	
Markets served by plant			(3, 4**)	(2**)	(2**)	P<0.001*
	Mean	3.90	4.17	3.46	3.53	
	S.D.	1.24	1.20	1.51	2.01	
Organisation size						P>0.05
	Mean	6.57	6.26	6.62	6.31	
	S.D.	1.85	1.68	1.68	1.75	

1. P-values with * are derived from Kruskal-Wallis test, while other p-values are derived from one-way ANOVAs.
2. Numbers in brackets with ** indicate other groups significantly different from the cluster in the Tamhane test (P<0.05), while other numbers in brackets indicate other groups significantly different from the cluster in the multiple comparison LSD test (P<0.05).

Differently, I performed a Chi-square test to examine whether the plants in four clusters are different in terms of the regions they are located. Table 6 shows the distribution of plants by four clusters and their regions. A Chi-square test of this distribution reveals a significant (P<0.001) difference regarding region between four clusters of plants. A cross-tabulation of the actual and expected counts of cluster memberships across region further indicated that the plants in Clusters B, C, and D are generally over-represented in the developed regions, except the plants in Cluster A.

Table 6: Distribution of plants in different clusters by region

Region	Cluster A	Cluster B	Cluster C	Cluster D	Total
Developed region	105	108	75	106	394
Developing region	93	34	19	66	212
Total	198	142	94	172	606

4.2 Discussions

Instead of attaching a plant with single location advantage and single site competence respectively, this research revisits the plant role typology proposed by Ferdows (1997b) by simultaneously addressing multiple portfolios of these two dimensions and allowing plants to combine more site competences and location advantages. It further complements the study of Ferdows (1997b) by developing an empirical taxonomy of plant role, which suggests classifying plants into four clusters. Each cluster of plants might play a unique role. H1 is thereby supported. Based on the analyses above, the characteristics of the plants in four clusters can be summarised in Table 7 and further discussed below.

Table 7: The characteristics of the plants in four clusters

	Cluster A	Cluster B	Cluster C	Cluster D

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Location advantage	Access to low cost resource, market, and knowledge and skills	Access to knowledge and skills	Access to market and knowledge and skills	None
Site competence	Responsible for activities related to production, supply chain, and development	Responsible for activities related to production, supply chain, and development	Responsible for activities related to production and (to a certain degree) supply chain	Responsible for activities related to production
Products produced by plant	Products produced at multiple plants	More products only produced by plant	More products only produced by plant	Products produced at multiple plants
Processes held by plant	Full production processes	Full production processes	Some specific production steps	Some specific production steps
Markets served by plant	Global market	Global market	Specified markets	Specified markets
Region	In either developed or developing regions	In developed regions	In developed regions	In developed regions

Plants in Cluster A can be located in either developed or developing regions. They normally have full-scale site competences and are responsible for the activities related to production, supply chain, and development, while having the access to all three kinds of location advantages. Their products might be produced at multiple plants, but they generally cover full production processes and serve global markets. Based on these characteristics, two cases are identified and provided in Appendix 3 as the example of plants in Cluster A. As demonstrated by these cases, the A cluster is an intriguing category for plant managers and plants in this cluster are typically plants that act as a main production base, an important market server, and a pilot plant for new products. Regarded as the "engine" or "centre of excellence", these plants are truly lead-plants and indeed like stars in their manufacturing networks. Therefore, I label them as "*Star Plant*".

Plants in Cluster B are comparable to the Start Plant on all site competence dimensions, but they do not have the access to low cost resources and markets. They tend to be located more in developed regions. Similar to plants in Cluster A, they also cover full production processes and serve global markets, but, differently, they have more products only produced by them. These

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plants are indeed important for companies and can also be seen as competence centres, as they have full-scale site competences, have products only produced by them, and supply broad markets. A case plant is also identified according to these characteristics and provided in Appendix 3 to facilitate the understandings on plants in Cluster B. As demonstrated by the case, plants in Cluster B are expected to be the only "mother plant", the earliest plant in their manufacturing networks, located close to headquarters. These plants seem to build on heritage and gain their experience from the past operations. In other words, they are more like "*Old School Plant*", compared to the plants in Cluster A. Nevertheless, it is interesting to notice that the Old School Plant might also be closed down as demonstrated by the case in Appendix 3 due to strategic considerations.

Cluster C consists of plants that are in an awkward situation. They have the access to markets and knowledge and skills, but they are mainly responsible for production activities, as well as some supply chain activities. They also tend to be located more in developed regions, but different from plants in Cluster B, they cover only some specific production steps and serve specified markets. Taking all these characteristics into consideration, plants in Cluster C might be highly specialised ones focusing on specific types of products, processes, or markets. They might be quite successful at being experts in what they do. Hence, I label them as the "*Expert Plant*". A case is similarly given in Appendix 3 in order to facilitate the understandings on this category of plants. With the access to market and knowledge and skills, these plants might have the chance to further develop their site competences especially in the context of backsourcing (Kinkel, 2012) or reshoring (Ellram et al., 2013; Gray et al., 2017). Some Western manufacturers are bringing manufacturing back home (Ketokivi et al., 2017), but this trend is not without uncertainty, as plants need time to develop and their development can be easily influenced by many temporal considerations (Ketokivi et al., 2017).

Plants in Cluster D seem to be weakest. On the one hand, they do not have the access to any of location advantages; on the other hand, they only have the site competence related to production. Compared to plants in Clusters A and B, their products are produced at multiple plants. Besides, they cover only some specific production steps and serve specified markets. In other words, they

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might not have any competitive advantages and can be easily replaced as demonstrated by the cases in Appendix 3. Accordingly, they are labelled as "*Replaceable Plant*".

These four new plant roles suggest that the portfolios of site competences and location advantages of a plant can be much more complicated than what is described in Ferdows (1997b). In practice, there seldom exist plants attached with single location advantage and single site competence respectively. In other words, six plant roles in Ferdows' typology are indeed logical possibilities, rather than reflecting empirical patterns. In this case, derived from the statistical analysis of a large scale of sample with more complete data, the four new plant roles complement the Ferdows typology by adding more empirical, coherent, and distinctive ways of plant configuration. According to Ferdows' definition, both Star Plant and Old School Plant can be viewed as Lead Plant, but they are different in terms of their development. As the "mother plant", Old School Plant might be a result of the past and it might build up its competences on heritage. Nevertheless, its future is not guaranteed. It might still be closed down if it does not demonstrate its sustainable importance for the company it belongs to. Start Plant actually goes beyond just Lead Plant, since it also has the access to low cost resource and market. It can join the company more recently and gradually develop under the strategic guidance, as shown by the case "*Star Plant in developing country: a Chinese plant in Company A*" in Appendix 3. It can also be the "mother plant" of the company it belongs to, as shown by the case "*Star Plant in developed country: a Danish plant in Company A*". Similar to Source and Contributor in the Ferdows' typology, Expert Plant might not have full-scale site competence, but it represents the other kind of plant that can survive due to its location advantages as well as its speciality in terms of products, processes, or markets. Finally, Replaceable Plant suggests that, in the practice, there indeed exist plants that might not have any unique location advantage and site competence and, therefore, can be easily replaced. Together with Ferdows' typology, these four new plant roles provide enough variety to describe and assess today's plants that might be outside the scope of the previous studies.

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5. Extending the study of Ferdows (1997b)

5.1 Analyses and results

Based on the new taxonomy with four new plant roles, this paper further extended our understandings on plant role by exploring the fit of a plant role with the differentiation of its management practices. Specifically, this paper investigated the interrelationships of plant role with six management practices, i.e. decision autonomy, interplant coordination, internal integration with development department, internal integration with purchasing and sales departments, supplier integration, and customer integration. Again, one-way ANOVA and multiple comparison LSD test were performed based on the results of cluster analysis for plant role (Table 4) to check whether six management practices exhibited significant differences among the plants in four clusters. Similarly, some of the results were validated by Kruskal-Wallis test and explained according to Tamhane comparison test, if facing the heterogeneity of variances.

Table 8: Management practices by cluster: results of ANOVA and Kruskal-Wallis test

		Cluster A	Cluster B	Cluster C	Cluster D	ANOVA
Decision autonomy		(b**)	(a, c, d**)	(b**)	(b**)	P<0.001*
	Mean	1.72	1.15	1.60	1.78	
	S.D.	0.78	0.69	0.73	0.57	
Interplant coordination		(b, c, d**)	(a, d**)	(a**)	(a, b**)	P<0.001*
	Mean	3.87	3.11	3.42	3.40	
	S.D.	0.85	0.86	0.88	0.72	
Internal integration with development		(b, c, d)	(a)	(a)	(a)	P<0.001
	Mean	3.76	3.14	3.33	3.28	
	S.D.	0.73	0.72	0.75	0.71	
Internal integration with purchasing and sales		(b, c, d)	(a)	(a)	(a)	P<0.001
	Mean	3.10	2.71	2.70	2.64	
	S.D.	0.59	0.65	0.65	0.65	
Supplier integration		(b, c, d)	(a)	(a)	(a)	P<0.001
	Mean	3.37	2.88	2.96	2.97	
	S.D.	0.70	0.65	0.67	0.75	
Customer integration		(b, c, d)	(a, d)	(a)	(a, b)	P<0.001
	Mean	3.70	2.94	3.09	3.26	
	S.D.	0.92	0.86	0.99	0.92	

1. P-values with * are derived from Kruskal-Wallis test, while other p-values are derived from one-way ANOVAs.
2. Numbers in brackets with ** indicate other groups significantly different from the cluster in the Tamhane test (P<0.05), while other numbers in brackets indicate other groups significantly different from the cluster in the multiple comparison LSD test (P<0.05).

As shown in Table 8, the plants with different roles are significantly different from each other in terms of the degrees of their decision autonomy and interplant coordination (P<0.001 based on Kruskal-Wallis test), as well as their internal integration with development, internal integration with

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purchasing and sales, supplier integration, and customer integration ($P<0.001$ based on one-way ANOVA). More specifically, according to the Tamhane comparison test, the plants in Cluster B tend to have higher level of decision autonomy compared to plants in other clusters. Meanwhile, the plants in Cluster A coordinate more with other plants in the same network, while the plants in Cluster B coordinate less. According to the multiple comparison LSD test, the plants in Cluster A have higher degrees of internal integration and supplier integration than other three types of plants. They also integrate more with their customers, while the plants in Cluster B integrate less.

5.2 Discussions

The results shown in Table 8 reveal that plants in different clusters are indeed different in terms of the degrees of their decision autonomy, interplant coordination, internal integration, and external integration. Therefore, H2 is also supported. In other words, different management practices fit different strategic plant roles. The notion of differentiated fit is useful to help understand the operations and management of plants that are part of a network (Maritan et al., 2004) and three patterns of differentiated fit can be identified from results shown in Table 8, which will be further discussed below.

The first pattern can be observed when addressing decision autonomy. It is not contrary to my expectations that Old School Plants in Cluster B have more decision autonomy than other types of plants, as they are expected to be the only "mother plant", the earliest plant in the network. Besides, as I will elaborate below, these plants do not have much interaction with other plants, internal functions, and external partners, making them focus more on their internal operations and thereby ask for more decision autonomy. In contrast, it is beyond my expectations that Star Plants in Cluster A do not have more decision autonomy than Expert Plants and Replaceable Plants. To some extent, this can also be explained by the higher degree of interaction that Star Plants have with other plants, internal functions, and external partners. Working as an interface between external partners and other plants in the same network, Star Plants may receive too much information and too many

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requirements from other plants, and they needs to further communicate with external partners to make sure the demands of other plants can be satisfied. In other words, the need for a Star Plant to coordinate activities across the internal network and the external context may mean it suffers from an information-inflow overload (Tran et al., 2010) and has less freedom in making independent decisions for its own operations.

The Second pattern can be observed when examining the differentiation of interplant coordination and customer integration among four newly proposed plant roles. As expected, Star Plants in Cluster A have higher degrees of interplant coordination and customer integration than other types of plants. It is also consistent with my expectations that Old School Plants in Cluster B have lower degrees of interplant coordination and customer integration. These plants seem to focus more on their internal operations and are thereby more passive about coordination with other plants and integration with external customers, although they also have more competences on sites. To some extent, they are similar to "hosting network player" in the classification of Vereecke et al. (2006). These plants might have been in the network for a very long time. This is also why they are called Old School Plants. Because of their ages, the broad markets they supply, or even their easy access to headquarters, they have gained a lot of experience and gradually developed their site competences. They do not depend on the other organisations for maintaining or improving their manufacturing capabilities and are accordingly passive to coordinate and integrate with others. In fact, I suspect that the future perspectives of Old School Plants depend on their altitudes towards coordination and integration with other organisations. Accordingly, their future can be predicted to be in two opposite directions, as demonstrated by the cases in Appendix 3. Old School Plants that are strongly embedded in the manufacturing network, such as the Danish plant in Company A, are expected to further grow in strategic importance and are assumed to evolve to be Start Plants. Others are expected to become less important and may even disappear from the manufacturing network, like the German plant in Company B. Nevertheless, it is surprising to observe that Replaceable Plants in Cluster D have significantly higher degree of interplant coordination and

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customer integration than Old School Plants. A possible explanation may be that in case of e.g. overcapacity and cost cutting, the Replaceable Plants are a welcome candidate for disinvestment or closure, since they do not have the access to any of location advantages and only have the site competence related to production. In order to avoid becoming less important or even disappearing from the manufacturing network, they have more motivation than Old School Plants to coordinate with other plants in the same network and to integrate with external customers.

The third pattern can be observed when discussing the differentiation of internal integration with both development and purchasing/sales and supplier integration among four new plant roles. With more site competences, Star Plants are also expected to have higher degrees of internal integration and supplier integration. To some extent, these plants are similar to "active network player" proposed in the classification of Vereecke et al. (2006). They are actively building their network relationships through more coordination and integration with other plants, internal functions, and external partners. It is their enthusiasm, their site competences, and their abundant access to location advantages that make them an important and active network player.

6. Conclusions

6.1 Theoretical contributions

This paper mainly focuses on plant in a manufacturing network and seeks to fill the voids in this area. It revisits and complements the plant role typology proposed by Ferdows (1997b), and further extends the current understandings on plant role by identifying the specific differences in management practices among plants with different strategic roles. Its theoretical contributions are thereby twofold.

First, this paper identifies three limitations of the plant role typology of Ferdows (1997b). It also notices that most of the existing studies still attached each plant with single location advantage and single site competence respectively, although it has been theoretically and empirically found some plants might combine more location advantages and site competences. In this case, this paper

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revisits Ferdows' typology by simultaneously addressing multiple portfolios of the two dimensions of the typology, i.e. site competences and location advantages. It further complements this typology by developing a more objective, empirically derived taxonomy of plant role and accordingly proposes four new plant roles, which are Star Plant, Old School Plant, Expert Plant, and Replaceable Plant. These plant roles are not only different in terms of location advantages and site competences, but also different in terms of other characteristics, such as the products they produce, the processes they hold, the markets they serve, and the regions they are located. Five case examples are also provided to facilitate further understandings on four new plant roles.

Second, this paper enriches the literature by exploring the fits between plant roles and their management practices based on the developed taxonomy with four new plant roles. Three patterns are identified and further discussed in detail. The results imply that plants that are strongly embedded in the manufacturing network are expected to play the high level of strategic role; plants with greater responsibility may sometimes correspond with less autonomy; plants in dilemma might have more motivation to coordinate with other plants and integrate with external customers; and plants managed in old styles might be more independent and thereby passive about coordination and integration with other organisations. These results highlight the importance of understanding not only what strategic role each plant in a manufacturing network plays, but also how management practices might need to be differentiated so that the plants can pursue their roles effectively.

6.2 Managerial implications

In terms of managerial implications, this paper advances the understandings of plant managers, as well as managers who are responsible for global operations. The first managerial implication is related to the newly proposed taxonomy of plant role. The taxonomy implies that it is important for plants to be strongly embedded in the manufacturing network and hold unique specialisation. Together with the Ferdows typology, this taxonomy can be used as a "toolbox" for drawing a map of plants in manufacturing networks, which allows managers to classify their plants. An evaluation

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of this map may help them in understanding their plant roles and identifying possible gaps or unbalances.

The second managerial implication is derived from the discussions on the fits between plant roles and their management practices. The Star Plants are indeed the stars in their manufacturing network, but their managers may be in a dilemma at the same time. With higher levels of internal integration, external integration, and interplant coordination, they often give more to others than they receive from them, which might cost them resources more than the benefits they might receive. Nevertheless, as beneficial to the firm, their involvement in integration and coordination is essential. Therefore, managers who are responsible for global operations should pay attention to remove disincentives for increasing integration and coordination for these plants, especially when some of them might be less willing to do so. Meanwhile, the Old School Plants seem to be a result of the past and they are not active in working together with others. However, considering their full-scale site competences, it is important to stimulate them to have more integration and coordination with internal functions, plants in the same network, and external partners. The managers of these plants also need to acknowledge the danger of a protective attitude towards integration and coordination. The isolated position of their plants might result in a difference in view between plant managers and company managers about the strategic future of the plants. If an Old School Plant continues to be isolated to other partners, it might become less important and may even disappear from the manufacturing network, as illustrated by the German plant in Company B in Appendix 3. Instead, if it actively engage into integration with internal functions and external partners and coordination with plants in the same network, like the Danish plant in Company A in Appendix 3, it might grow to be a Star Plant. Regarding the Expert Plants, they have the potential to be further developed. In order to support their further development, managers who are responsible for global operations have to identify which plants in the manufacturing network have the potential, and then provide supports to foster these plants. Integrating more with internal functions and external partners and coordinating more with other plants in the same network might facilitate Expert plants

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to cultivate their site competences and enhance their strategic importance. Last, for Replaceable Plants, they are certainly in a dangerous zone. It is understandable that these plants would like to coordinate more with other plants in the same network and integrate more with their customers in order to escape from the dangerous zone. Nevertheless, their coordination and integration behaviours might at the same time create the redundancy of information flows in the manufacturing network, as which might be unnecessary especially considering the lower strategic importance of these plants. Therefore, control over management practices in terms of integration and coordination should not be left solely to plant managers. Instead, specific persons who can proactively manage the integration and coordination of plants with internal and external entities are needed at the company's headquarters.

6.3 Limitations and future research

This research has certain limitations, which present opportunities for future research. First, the data used in this study were only collected from plants. Future research can broaden its scope by collecting data from all other stakeholders in a manufacturing network, such as headquarters, suppliers, and customers. Second, this paper aims to investigate the role of plants in manufacturing networks. However, a network perspective is not explicitly reflected in the paper, although the analysis of this paper was based on 606 plants that identified themselves as one of the plants in a manufacturing network. In this case, future research is needed to take a network perspective in better understanding the roles of individual plants. Third, this paper relied on cross-sectional data. As plant roles and some of the management practices are actually developed over time, it will be fruitful for future studies to examine the evolution of plant roles as well as their relationships with management practices over a longitudinal period. Fourth, the measures used in this paper (such as site competence, interplant coordination, internal and external integration) could be better. For example, as indicated by Mazzola and Perrone (2013), inter-firm dimensions in terms of minority equity alliances or outsourcing contracts can influence the clustering of operational objectives.

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Although briefly reflected in the measures of external integration used by this paper, these dimensions need to be considered in a more explicit manner in the future research. Fifth, this paper has proposed some explanations to its empirical findings, but more research is still needed to fully understand the mechanisms behind them. More interviews with companies are necessary to validate the empirical findings of this paper and enrich our understandings on the roles of plants in manufacturing networks. I hope future research will mitigate these problems and further complement this research.

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Appendix 1: Measurement items

Site competence: To what extent is your plant responsible for the following activities?

	No responsibility			**Full responsibility**	
Production (e.g., production, process improvement, technical maintenance)	1	2	3	4	5
Supply Chain (e.g., procurement, logistics, supplier development)	1	2	3	4	5
Development (e.g., Product improvement, Introduction of new product or process technologies)	1	2	3	4	5
Serving as a hub for product / process knowledge (e.g. showroom for good practice, sending out experts to share knowledge)	1	2	3	4	5

Location advantage: To what extent do you agree with the following statements about the current advantages of your plant's location?

	Strongly disagree			**Strongly agree**	
Your current advantage is to access to low cost resources (labour, materials,	1	2	3	4	5

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energy)					
Your current advantage is the proximity to market (rapid/reliable delivery, customization, fast service and support)	1	2	3	4	5
Your current advantage is to access to knowledge and skills (skilled workers and managers, technological know-how)	1	2	3	4	5
Currently you have no advantage	1	2	3	4	5

Products produced by plant, processes held by plant, markets served by plant

Your product is produced only in your plant	1	2	3	4	5	Your product is produced at multiple plants within the network
Your plant serves just a specified surrounding geographic area/market	1	2	3	4	5	Your plant serves the whole world / global market
Your plant covers only some specific production steps (the others are performed by other plants in the network)	1	2	3	4	5	Your plant covers the full production process

Autonomy

You can make your own strategic decisions	1	2	3	4	5	The strategy is set by another plant in the network or an international division
This plant is autonomous in defining the production plan	1	2	3	4	5	Production plans are coordinated by another plant or an international division

Internal integration with development department

	Current level of implementation				
	None				**High**
Informal mechanisms, such as direct, face-to-face communication, informal discussions, ad-hoc meetings	1	2	3	4	5
Design integration between product development and manufacturing through e.g. platform design, standardization and modularization, design for manufacturing, design for assembly	1	2	3	4	5
Organizational integration between product development and manufacturing through e.g. cross-functional teams, job rotation, co-location, role combination, secondment and co-ordinating managers	1	2	3	4	5
Technological integration between product development and manufacturing through e.g. CAD-CAM, CAPP, CAE, Product Lifecycle Management	1	2	3	4	5
Integrating tools and techniques, such as Failure Mode and Effect Analysis, Quality Function Deployment, and Rapid Prototyping	1	2	3	4	5
Communication technologies such as teleconferencing, web-meetings, intranet and social media	1	2	3	4	5
Forms of process standardization, such as a stage-gate process, design reviews and performance management	1	2	3	4	5

Internal integration with purchasing and sales departments

	Current level of implementation				
	None				**High**
Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level)	1	2	3	4	5
Joint decision making with purchasing department (about sales forecast, production plans and stock level)	1	2	3	4	5
Sharing information with sales department (about sales forecast, production plans, production progress and stock level)	1	2	3	4	5
Joint decision making with sales department (about sales forecast, production plans and stock level)	1	2	3	4	5

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Supplier integration

	Current level of implementation				
	None				High
Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	1	2	3	4	5
Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements)	1	2	3	4	5
Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control)	1	2	3	4	5
System coupling with key suppliers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	1	2	3	4	5

Customer integration

	Current level of implementation				
	None				High
Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	1	2	3	4	5
Developing collaborative approaches with key customers (e.g. risk/revenue sharing, long-term agreements)	1	2	3	4	5
Joint decision making with key customers (about product design/modifications, process design/modifications, quality improvement and cost control)	1	2	3	4	5
System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	1	2	3	4	5

Interplant coordination

	Current level of implementation				
	None				High
Improve information sharing for the coordination of the flow of goods between your plant and other plants of the network (e.g. through exchange information on inventories, deliveries, production plans, etc.)	1	2	3	4	5
Improve joint decision making to define production plans and allocate production in collaboration with other plants in the network (e.g. through shared procedures, shared forecasts)	1	2	3	4	5
Improve innovation sharing / joint innovation with other plants (through knowledge dissemination and exchange of employees inside the network)	1	2	3	4	5
Improve the use of technology to support communication with other plants of the network (e.g. ERP integration, shared databases, social networks)	1	2	3	4	5
Developing a comprehensive network performance management system (e.g. based on cost, quality, speed, flexibility, innovation, service level)	1	2	3	4	5

Appendix 2: Discriminant validity test

Measurement construct	Unconstrained model		Constrained model		
Autonomy	χ^2	df	χ^2	df	$\Delta\chi^2$
Internal integration with development department	122.112	26	264.956	27	142.844***
Internal integration with purchasing and sales departments	150.884	8	366.386	9	215.502***
Supplier integration	38.115	8	171.291	9	133.176***
Customer integration	18.668	8	121.280	9	102.612***
Interplant coordination	82.155	13	181.317	14	99.162***
Internal integration with development department					
Internal integration with purchasing and sales departments	273.689	43	404.656	44	130.967***

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Supplier integration	216.360	43	299.013	44	82.653***
Customer integration	152.578	43	199.202	44	46.624***
Interplant coordination	224.597	53	282.006	54	57.409***
Internal integration with purchasing and sales departments					
Supplier integration	214.375	19	332.596	20	118.221***
Customer integration	167.486	19	282.678	20	115.192***
Interplant coordination	270.879	26	388.094	27	117.215***
Supplier integration					
Customer integration	93.091	19	139.026	20	45.935***
Interplant coordination	136.868	26	218.682	27	81.814***
Customer integration					
Interplant coordination	107.146	26	138.473	27	31.327***

P<0.001

Appendix 3: Case examples of four new plant roles

Star Plant in developing country: a Chinese plant in Company A

Company A is a Danish multinational enterprise working in water supply products and solutions, within which it holds a market leader position. With 14 production and 45 sales companies in 41 countries, its international base is strong.

Company A started its operations in China in 1990s, mainly due to the attractiveness of low cost labour and the Chinese market. In 1995, the decision was made to build a plant in Suzhou. Starting with the production of simple products, the plant gradually expanded its capacity. When it considerably improved its quality level and started to be profitable, the plant was given more responsibilities. Accordingly, a development centre was established and co-located with the Chinese plant for the purpose of obtaining “design for manufacturability” and creating closer integration between development activities and manufacturing operations. It started from recruiting talented engineers in China and went through three waves during its growth: making simple things, supporting local production, and developing new products. Under the support of the development centre, the Chinese plant delivered two newly adapted products in 2011 and launched a totally new solo-heating product in 2012 for both the Chinese and the global markets. Finally, in 2009, a technology centre (built as a technological platform that focuses on production technologies and processes) was established and co-located with the Chinese plant. It mainly specialised in tool and

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automation equipment and functioned as a base for developing and supplying new automatic assembly lines to all the Asian plants.

Today, the Chinese plant has around 700 employees and is the third largest plant in Company A. Its incentive seems turning to be proximity to the second largest and fastest growing market in order to support the long-term vision and strategy for “China as the second home market”. However, there are still obvious obstacles to achieving the company’s desired market potential in China. Despite its efforts to eradicate counterfeiting, one of the biggest challenges still faced by the company is the issue of intellectual property (IP) rights. Therefore, the Chinese plant still obtains complex parts from the parent facility in Denmark or from other plants around the world.

Star Plant in developed country: a Danish plant in Company A

Company A started its production in Denmark in 1945. The company has rapidly evolved into an international manufacturer in the past decades, but the role of its mother Danish plant is still important. First, employing 4000 people, the Danish plant is the largest in the company. As a socially responsible company, it is Company A’s duty to support and safeguard the interests of local people. Second, as one of the managers at the company remarked, because Germany is still one of the biggest markets for the company, it makes sense to keep the production close to one of the company’s largest consumer markets. Third, the Danish plant has some of the most advanced facilities needed for pump development and manufacturing. More importantly, because of IP issues, the company has not been able to transfer some of its competencies in the Danish plant to other overseas plants.

With over 70-year experience, the Danish plant can produce all the varieties of products with high quality for the global markets. Due to high degree of automation, it is not that expensive to produce in Denmark. Sometimes, it is even cheaper to produce in Denmark in terms of productivity and total cost. Furthermore, the company follows “Centrally driven, global approach with a local presence” as the principle for organising new product development. Co-locating with a

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development centre, the Danish plant develops and delivers new products for the global markets, under the supports from other development centres in Hungary and China. Meanwhile, the Danish plant is also co-located with a technology centre. Although the Danish technology centre has lost some capabilities in the last years, it still serves as the main engine with around 110 engineers, which designs production equipment, including testers and tools, for all the plants under the supports from the Danish plant. Therefore, the Danish plant continues to retain an important role.

Old School Plant: a German plant in Company B

Company B is a leading compressor manufacturer with more than 50 years of experience in the three market segments of household, light commercial and mobile. It used to be a strategic business unit (SBU) of a Danish MNE but was acquired by a German holding company in 2010.

The company started its operations in Germany in 1956 with the establishment of both headquarters and production facility. The German plant had remained the only one within the company until 1993, when another plant was founded in Slovenia for cost reduction. In 2002, a new plant was established in Slovakia, which, together with the Slovenian site, produced mainly household products specifically for the European market. Nevertheless, the German plant was always considered as the main production base and the competence centre. Another major move was made in 2007, when the company decided to establish a Chinese plant. In fact, the Chinese plant was built to take over all the production responsibilities of the German site. Although designed to meet certain specifications from the start, it still took time for the Chinese site to gradually build up its capabilities. During the development of the Chinese plant, the German plant was still the important production base for Company B, which developed and produced most of products for the global market. Some of the products were only produced in the German plant, due to the requirements of specific capabilities. Nevertheless, the Chinese plant grew quite fast under the support of the headquarters. One year later, it expanded from a totally green field to a full-scale production site releasing 100,000 compressors. Correspondingly, all the production activities were

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transferred to China and the German plant was shut down in 2009. Today, only an R&D centre is kept in Germany along with the headquarters, which only employs around 100 engineers and merely focuses on basic technology study (BTS) and NPD. These two tasks have not been transferred because the Chinese site is not yet sufficiently capable, and tacit knowledge is accumulated from past operations, embedded within the German R&D organisation and thereby not easily transferred.

Expert Plant: an American plant in Company C

Company C is a Danish pharmaceutical company with research centres and production facilities in seven countries.

Company C started its manufacturing operations in US in 1994 and established its first American manufacturing plant in 1996. Nevertheless, the American plant was not co-located with any research centre. In Company C, the production can be released to manufacturing plants only when the products have gone through strict preclinical and clinical trials globally. During the preclinical and clinical development phases, the preliminary and final production processes, specifications, and analytical control methods are also decided by the chemistry, manufacturing and control (CMC) supply within the R&D function, which are normally highly standardised and automated.

In order to meet the fast-growing demands of the American markets, the American plant was further expanded three times in 2004, 2007, and 2010, respectively, by building new assembly lines and increasing capacities. In 2010, a large formulation and filling plant was constructed on this site with a US$ 400 million investment. In the following years, the site gradually started to produce more mainstream products for the entire American markets. Today, it is producing six different products and is also responsible for product packaging and distribution. These products are adapted according to the local regulations and only produced in the American plant.

Replaceable Plant: Northwest European plants in Company D

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With 1,400 employees and an annual turnover of euro 307 million, company D is a global energy company with a focus on providing better energy efficiency to customers. The company has eight plants in Europe and sells its products (pipes, joints and fittings) in 28 countries.

Company D started its operations in Denmark in 1970 and was successful with heavy growth at the beginning. In the 1970s and 1980s, two local Danish plants were taken over. Afterwards, at the end of the 1980s, Company D acquired its first foreign plant in Sweden, which produced only a part of straight pipes and some pre-fabricated fittings at the beginning of its operations. This acquisition was followed by the purchase of a German plant in 1988 and a Finnish plant in 1990, which were responsible for producing a full range of products for their local markets with the purpose of increasing regional market shares. After the Berlin wall fell in 1989, a new market opened in Central and Eastern Europe. Because of lower costs and the potential for local sales, two plants were opened in Poland in the 1990s, mainly for producing pipes and fittings, whereas joints still were delivered from Northwest European plants.

However, from the beginning of the present millennium, the demand for pipes in Europe was generally in decline. Therefore, the German plant was firstly closed down. More recently, because of the global financial crisis, more plants were closed down. All their productions were moved to Poland to realise the purpose of adjusting the capacities of the network. Other plants, for example one in Sweden and the other in Finland, were kept but the ranges and volumes of products produced within them were adjusted. Nevertheless, in the future, they might also be replaced.

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