Company-Specific Plant Role Models in International Manufacturing Networks – Empirical Evidence on the Design and Deployment

DISSERTATION
of the University of St.Gallen,
School of Management,
Economics, Law, Social Sciences,
International Affairs and Computer Science,
to obtain the title of
Doctor of Philosophy in Management

submitted by

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Dissertation no. 5381

Difo-Druck GmbH, Untersiemau 2024

The University of St.Gallen, School of Management, Economics, Law, Social Sciences, International Affairs and Computer Science, hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St.Gallen, October 16, 2023

The President:

Prof. Dr. Bernhard Ehrenzeller

VORWORT

Diese Dissertation entstand während meiner Tätigkeit als wissenschaftlicher Mitarbeiter am Institut für Technologiemanagement der Universität St.Gallen (ITEM-HSG) in den Jahren 2020 bis 2023. Die Aufgaben dieser Zeit prägten mich durch ihre Vielschichtigkeit: Als «Berater» hatte ich die Möglichkeit zahlreiche Industrieunternehmen und deren Management kennen zu lernen und dabei unsere Methoden der globalen Produktion in der Praxis umzusetzen. Als «Forscher» ging es weniger um Pragmatismus als um Präzision. Unter anderem um das Feilen an jedem einzelnen Satz ohne zu wissen, ob dies wohl das Paper wirklich ver(schlimm-)besserte. Schliesslich durfte ich als «Lehrassistent» die gewonnenen Erfahrungen an Studierende und Führungskräfte vermitteln. Die Themenfindung und Erstellung meiner Dissertation geht massgeblich auf die zuvor beschriebenen Tätigkeiten zurück, wofür ich allen involvierten Menschen – insbesondere den beteiligten Projekt- und Interviewpartnern – zu grossem Dank verpflichtet bin.

Mein Doktorvater, Professor Dr. Thomas Friedli, ermöglichte mir die Promotion in diesem vielseitigen Umfeld. Für seine Unterstützung, geprägt durch ein hohes Mass an Autonomie und Eigenverantwortung, möchte ich mich ganz herzlich bedanken. Ein weiterer Dank gilt Professor Dr. Klaus Möller, der mich in seiner höflich-konstruktiven und pragmatischen Art als Korreferent unterstützte. Ein besonderer Dank im akademischen Umfeld geht ausserdem an Marja Blomqvist aus Finnland. Mit ihrem grossem Erfahrungsschatz gab sie mir in zahlreichen Online-Calls stets detailliertes Feedback und bestärkte mich in meinen Vorhaben durch ihre ausgeprägte Motivationsfähigkeit.

Ein weiterer Dank geht an all meine «Mitstreiter» am Institut, welche mir während den letzten Jahren ans Herz gewachsen sind. In Erinnerung bleiben mehrtägige Projektreisen in teils abgelegene Stammsitz-Orte in Deutschland, die legendären Skiausfahrten in die Schweiz und nach Österreich sowie natürlich die leidenschaftlichen Diskussionen in der Kantine und an der Kaffeemaschine. Danke an Dominik Remling, Fabian Specht, Ferdinand Deitermann, Karl Schalm, Philipp Miedler, (Team GPROD) sowie Christoph Blum, Christoph Tienken, Daniel Wörner, Fabian Klinkner, Gian-Andri Steiger, Jessica Helbling, Lorenzo Pirrone, Manuel Wlcek, Matteo Bernasconi, Moritz Classen und Moritz Häussler. Hervorzuheben sind Benedikt Saretz und Mark Grothkopp, welche in laut Erzählungen teils anstrengenden Sessions, massgeblich zur Themenfindung und der Vollendung der Dissertation beitrugen. Ausserdem mein engster Kreis aus der Aachener Zeit, welcher mich erst zum Promotionsvorhaben motivierte: André Kottlewski, Felix Kuhn, Nils Wild, Sven Cremer, Thorben Ipers und Vera Ehlerding.

Mein grösster Dank gilt meinen Eltern Angela und Ernst, meinen Geschwistern Marina und Julian und Grosseltern Helga, Gerda und Ivo. Sie unterstützten mich stets in meinem Lebensweg und gaben mir die Freiheit selbstbestimmt meinem Bildungsweg zu wählen.

St. Gallen, im November 2023 Jens Kaiser

ZUSAMMENFASSUNG

Unter Forschern ist die Bedeutung des Managements von Produktionsnetzwerken für den Wettbewerbsvorteil eines Unternehmens unstrittig. Jedoch scheinen Manager von der Komplexität des Netzwerkmanagements überfordert zu sein. Das Konzept der strategischen Standortrollen, ursprünglich eingeführt von Ferdows (1989), weist global verteilen Standorten klare Rollen zu und hilft somit die Komplexität zu beherrschen. Ferdows' Modell fehlt es jedoch an Detailtiefe, um die Rollen operativ umzusetzen. Folglich haben global operierende Produktionsunternehmen damit angefangen auf ihren Kontext abgestimmte Rollen zu gestalten und anzuwenden. Zu diesen «Real-World»-Rollen gibt es bisher jedoch kaum Forschung. Ziel dieser Arbeit ist es diese Forschungslücke zu füllen.

Drei Studien bilden die empirische Grundlage dieser Arbeit. Studie 1 untersucht den Inhalt von Standortrollenmodellen basierend auf einer Datenbank von 29 industriellen Modellen globaler Produktionsunternehmen. Als Ergebnis wird ein konzeptionelles Framework für Manager vorgeschlagen, die ihre eigenen Standortrollen konzipieren möchten. In Studie 2 wird der Prozess zur Gestaltung von Standortrollen untersucht. Die Multiple-Case Study von vier Produktionsnetzwerken zeigt, dass Standortrollen nur für bestimme Produktionsnetzwerke angewendet werden sollten. Werksleiter und benachbarte Funktionen wie F&E sollten eng in den Prozess der Standortrollenerstellung eingebunden werden. Studie 3 untersucht den Prozess der Einführung von Standortrollen anhand eines international tätigen Medizintechnikunternehmens in einer Single-Case Study. Die Studie integriert die Individualebene des Werksleiters, welcher massgeblich das Verhalten von Werken in einem Produktionsnetzwerk bestimmt. Die Ergebnisse implizieren, dass Netzwerkmanager Standortrollen für regelmässiges Werks-Roadmapping, rollenspezifisches Performance Management, und die globale Allokation von Produkten und Technologien nutzen sollten.

Die Ergebnisse der drei Studien werden in einer Schritt-für-Schritt-Anleitung für die Gestaltung und Anwendung von Standortrollenmodellen in der allgemeinen Diskussion der Arbeit zusammengefasst. Bei der Gestaltung sollten Netzwerkmanager (1) die Legacy von Standortrollen berücksichtigen, (2) Buy-in für Standortrollen erlangen, (3) den Inhalt des Modells definieren, und (4) Anwendungsfälle klären. Für die Anwendung sollten Netzwerkmanager (1) die Rollen einführen, (2) ihre Produktionsnetzwerke mithilfe der Rollen managen, (3) die Effekte im Netzwerk monitoren, und (4) die Architektur des Modells anpassen.

Nach Kenntnis des Autors ist dies die erste Arbeit, welche sich systematisch mit dem «unternehmensspezifischen» Teil von Standortrollen beschäftigt. Aufgrund des guten Zugangs zu industriellen Standortrollenmodellen konnten diese tiefgehend untersucht werden. Folglich konnten Forschungslücken wie eine zu starke Vereinfachung, die fehlende Netzwerkperspektive, und die fehlende Untersuchung von dynamischen Aspekten mit dieser Arbeit adressiert werden.

ABSTRACT

Scholars generally recognize that managing international manufacturing networks (IMNs) is crucial for a firm's competitive advantage. However, managers seem overwhelmed with this complex management task, causing many firms to fail to benefit from their IMNs fully. The concept of strategic plant roles – first introduced by Ferdows (1989) – helps to overcome this complexity by assigning targeted roles to globally dispersed plants. Yet, Ferdows's model lacks the right level of detail to make it operational. Consequently, multinational corporations (MNCs) have ventured to design and deploy their own plant roles – fitting their specific contextual conditions. However, hardly any research exploring these "real-world" roles can be found in the literature. Filling this gap is the purpose of this thesis.

Three studies build the empirical base of this thesis. Study 1 investigates the content of plant role models; it uses a database of 29 MNCs' models. As a result, a conceptual framework is suggested for managers aiming to build their own plant roles. Study 2 explores dynamics related to plant role models. The multiple-case study of four IMNs using plant role models reveals important principles when creating and deploying plant roles. Results indicate that plant roles should only be applied for specific (sub-) networks. Plant leaders and adjacent functions such as R&D should get closely involved in the role-creation process. Last, study 3 explores the plant role introduction process at an internationally operating medical technology company in a single-case study. The study systematically integrates the individual level of plant leaders as key decision-makers who determine a plant's conduct in IMNs. The findings indicate that network managers should use plant roles for regular plant roadmap building, role-specific performance management, and the global allocation of products and technologies.

The three studies' findings are synthesized in a step-by-step guide for designing and deploying plant roles in the general discussion of the thesis. When designing plant roles, network managers need to (1) embrace the plant role legacy, (2) get buy-in for plant role creation, (3) define the content of the model, and (4) clarify use cases. For its deployment, network managers need to (1) roll out the roles, (2) manage their IMNs by means of the roles, (3) monitor network effects, and (4) adapt the architecture of the model.

To the author's knowledge, this is the first thesis systematically exploring the "company-specific" part of plant roles. Given the unique access to industrial plant role models, this thesis thoroughly explores how companies build their own versions. Hence, shortcomings of plant role articles in IMN literature – such as oversimplification, missing network perspective, and missing investigation of related dynamics – could be addressed by this thesis.

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LIST OF ABBREVIATIONS

APAC	Asia Pacific
AS	Alternative Search
AUT	Austria
BU	Business Unit
CEO	Chief Executive Officer
cf.	confer
CFO	Chief Financial Officer
CH	Switzerland
Comp.	Competence
COO	Chief Operating Officer
CRM	Customer Relationship Management
DL	Direct Labor
e.g.	exempli gratia (for example)
Embedd.	Embeddedness
EMEA	Europe, the Middle East, and Africa
ERP	Enterprise Resource Planning
et al.	et alii (and others)
F&E	Forschung und Entwicklung
FTE	Full Time Equivalent
GER	Germany
HQ	Headquarters
HR	Human Resources
i.e.	id est
IMN	International Manufacturing Network
IP	Intellectual Property
ITEM	Institute of Technology Management
JP	Japan
KPI	Key Performance Indicator
Man.	Manufacturing
MNC	Multinational Corporation
MRQ	Main Research Question
NA	North America
OU	Operating Unit
P&L	Profit and Loss Statement

P/OM	Production/Operations Management
QFD	Quality Function Deployment
R&D	Research and Development
RG	Research Gap
SCA	South and Central America
SEA	Southeast Asia
SKU	Stock Keeping Unit
SRQ	Sub-Research Question
SVP	Senior Vice President
Tech.	Technology
UNCTAD	United Nations Conference on Trade and Development
US	United States of America
VP	Vice President
WEU	Western Europe

1 Introduction

In my experience, the benefit of setting specific roles for plants, regardless of how they are specifically defined or labeled, is to treat them differently and adjust how they are managed – e.g., investments, KPIs, and linkages to other plants and functions. If we take that view, many companies are paying more attention to setting their own plant roles.

Kasra Ferdows[1]

With over 1,000 citations on Google Scholar[2], Kasra Ferdows's Harvard Business Review article "Making the Most of Foreign Factories" (Ferdows, 1997b) can be regarded as the most influential article on international manufacturing networks (IMNs). At the same time, it marks the "springboard" (Cheng & Farooq, 2018, p. 17) of the scholarly discussion on the roles of manufacturing plants. Since then, multiple articles have evolved around Ferdows's (1997b) article, both confirming and exploring his suggested roles.

Ferdows's quote above, cited from an e-mail exchange in 2022, implies that multinational corporations (MNCs) come up with their own versions of plant roles – coined *company-specific plant roles*. A trend that our institute also experienced in multiple industry and research projects. However, hardly any article that analyzes "real-world" plant roles used by companies can be found in the literature. Filling this gap is the purpose of this thesis.

The following section sets out the background and relevance of this thesis. Subsequently, the research design is introduced. This chapter closes with an overview of the structure of the thesis.

1.1 Background and Relevance

1.1.1 Practical Relevance

In recent decades, foreign direct investment and international trade have increased "explosively" (Cheng, Farooq, & Johansen, 2015, p. 392). As a result, global manufacturing is today a rule rather than an exception (Ferdows, 2018; Olhager & Feldmann, 2022, p. 242). Only in 2021, the manufacturing sector generated about US$ 16 trillion value added worldwide, which accounts for 17% of the world's gross domestic product (Worldbank, 2023). About one-third of the global trade in services and goods is generated within MNCs (UNCTAD, 2018), highlighting the relevance of their related IMNs.

Hence, managing and designing such a *manufacturing network* is of crucial importance to creating and maintaining a competitive advantage (Cheng et al., 2011; Hayes et al., 2005;

[1] Ferdows (personal communication, October 1, 2022).

[2] At the time of writing, the article had 1,121 citations on Google Scholar.

Miltenburg, 2015a; Olhager & Feldmann, 2022; Shi & Gregory, 1998) as it has a considerable impact on the future performance and profitability of MNCs (Bartlett & Ghoshal, 1989; Cheng, Farooq, & Johansen, 2015; Ferdows, 1997a; Hayter, 1997). However, many firms still fail to fully benefit from their manufacturing networks' advantages[3] (Abele et al., 2008; Friedli et al., 2014). One of the main reasons may be that decision-makers are confronted with an "arduous list of independent variables to consider" (Ferdows, 2018, p. 394), often resulting in unmanageable complexity.

A suitable way to deal with the high number of variables is to develop conceptual frameworks that enable decision-makers to "delayer" their complex issues into a set of smaller ones (Ferdows, 2018, p. 399). As such, the concept of *strategic plant roles* helps practitioners to put a strategic perspective on their IMNs and manage the complex interaction between the plant and network level in an integrated way. The concept of plant roles was first introduced by Ferdows (1989, 1997b); it holds that not all plants in a manufacturing network have to follow the same strategy (Olhager & Feldmann, 2022). Instead, plants can take on different roles, such as the lead for a specific technology or marketeer for a particular market, to gain advantages for the overall manufacturing network's success.

The results of the benchmarking study "Managing Global Production Networks"[4] (Friedli et al., 2020) indicate that the concept of plant roles has already been widely adopted in the industry. As shown in Figure 1, two-thirds of the asked network managers indicated that they apply a plant role model within their IMN. Looking at the successful practice companies[5], even 11 out of 14 (i.e., 79%) apply a plant role model.

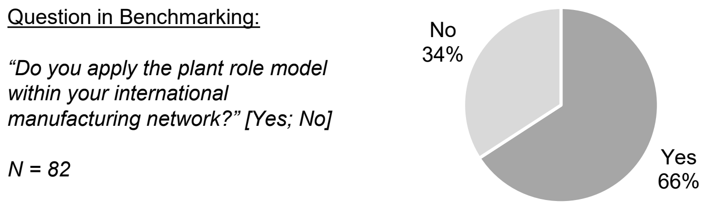

Figure 1: Application of plant role models[6] in the industry (adapted from Friedli et al., 2020)

[3] Based on survey results, Meyer and Jacob (2008, p. 140) suggest a total landed costs saving potential of 20 to more than 40% due to manufacturing network optimization. The authors name McKinsey/PTW (ProNet analysis) as source.

[4] The benchmarking study was conducted between May and July 2020, participants hold positions such as COO, Head of Manufacturing, Head of Global Operations etc. The companies were mainly headquartered in German-speaking countries and came from various industries. Further results of the benchmarking study were published in Kaiser and Remling (2021).

[5] Based on specific criteria, the 14 best participants were classified as successful practice companies.

[6] In the original benchmarking study, we asked for the application of "site role concepts" in "global production networks". To improve readability, the terminology has been adapted to the one used in this thesis.

The benchmarking numbers show the topic's overall relevance in the industry. However, they do not explain how such models are designed and deployed. In practice, these models may only have informal character without a clear description of related policies and without communicating the roles to the affected plants or the plant leaders. Potential misalignment between central functions and the local behavior of plants may be the consequence. To support this proposition, several statements from practitioners are listed in Table 1. The statements were gathered from projects the author was involved in at the Institute of Technology Management (ITEM) from 2020 to 2022.

Table 1: Statements from practitioners

#	Statement	Position, Company
1	*The site is set up as a low-cost site but actively tries to tie in high-complex products: which is creating friction in the organization.*	Global Supply Chain Strategy Team, Medical device manufacturer
2	*To get better performance results, the plant manager tries to increase the product mix to fully load his plant capacity. However, he should load the plant by increasing the volume, not the mix.*	Manufacturing Director of a Business Unit (BU), Packaging equipment manufacturer
3	*Every plant wants to do that product, but we have to fight against that.*	BU Director, Medical device & pharmaceuticals manufacturer
4	*The plants want to migrate toward the lead factory, but we do not want the plants to do that.*	Vice President (VP) Manufacturing, Medical device manufacturer
5	*There is a misfit between site missions and the respective incentives*	Plant Leader & Regions Head, Medical device & pharmaceuticals manufacturer

The statements show that central functions have specific expectations about the behavior of the plants. For example, they implicitly assign them roles such as *low-cost* or *high-volume and low-mix sites* (cf. Table 1, statements 1, 2). However, the plants often seem not to know their missions, or their behavior is primarily driven by performance or incentive systems (cf. Table 1, statements 2, 5) that contradict the behavior expected from central functions.

Hence, this thesis aims to elaborate strategies to improve the interaction between plant- and network-level since this is an integral part of a successful IMN (Colotla et al., 2003; Olhager & Feldmann, 2022). It will do so by helping manufacturing firms define and manage their individual plants' roles appropriately.

1.1.2 Theoretical Relevance

Research about IMNs has its origin in the disciplines of *production/operations management* (P/OM) and *manufacturing engineering* (Shi & Gregory, 2005, p. 622). Following the globalization of the manufacturing base in the late 1980s and 1990s (Rudberg & Olhager, 2003), scholars became aware that there is a growing need to manage *multi-plant* *networks* instead of single factories (Cheng, Farooq, & Johansen, 2015). Dominated by the topic of *plant location decisions* in the 1980s and 1990s (e.g., Aikens, 1985; Meijboom & Vos, 1997; Vos, 1991), scholars gradually shifted their focus from the plant to the network level of *configuration* (e.g., Miltenburg, 2009; Shi & Gregory, 1998) and *coordination* (e.g., Deflorin et al., 2012; Ferdows, 2006). Although the phenomenon of IMNs has attracted considerable attention from scholars in the past decades, Ferdows argues that related literature has not kept up with the growing complexity in practice (Ferdows, 2021). He, therefore, calls for more research in this field; moreover, he suggests expanding to methodologies (e.g., case-based research, action research) that better fit the high number of variables in an IMN context (Ferdows, 2018).

Using the number of publications as an indicator, plant roles are highly relevant for both practitioners and researchers (A. Feldmann & Olhager, 2013). The topic originated from the research on the *strategic roles of subsidiaries* in MNCs (e.g., Bartlett & Ghoshal, 1986, 1989; Jarillo & Martíanez, 1990; Roth & Morrison, 1992). Ferdows (1989, 1997b), however, was the first researcher to translate the classifications of subsidiaries into a classification of manufacturing plants (Cheng & Farooq, 2018). He proposed two dimensions to conceptualize the roles of plants: the *strategic reason for the plant* (i.e., access to low-cost manufacturing, access to skills and knowledge, and proximity to market) and the *site competence* (e.g., related to production, supply chain, and development activities) (Ferdows 1989, 1997b). Ferdows's model has been widely recognized in academia (Cheng & Farooq, 2018). However, it has also been a starting point for discussions about its *applicability* (e.g., Cheng et al., 2011; Cheng, Johansen, & Hu, 2015; Fusco & Spring, 2003; Mediavilla et al., 2015; Miltenburg, 2009, 2015a, 2015b) and its *conceptualization* (e.g., Maritan et al., 2004; Vereecke & van Dierdonck, 2002), partly resulting in *new plant role models* (e.g., Blomqvist & Turkulainen, 2019; Vereecke et al., 2006).

Although research about plant roles is abundant in IMN literature, the models are usually based on a limited number of dimensions with restrained variety (Cheng & Farooq, 2018; Vereecke & van Dierdonck, 2002). Consequently, it is hard to deploy the models in real-world settings (Mediavilla et al., 2015). Furthermore, there is only limited knowledge about the interplay of plant roles on a network level (Blomqvist & Turkulainen, 2019). Lastly, previous research assumes universalistic application of plant role models, neglecting that firms might design their own versions of a plant role model; from now on called *company-specific plant role model*.

Thus, the thesis at hand aims to contribute to the field of plant roles in IMNs in the following ways: A new perspective to the existing literature is proposed by looking at plant role models from a *company-contingent* perspective. This includes looking at models of plant roles existent in firms (e.g., with four distinct roles) rather than focusing on single plant roles such as the lead plant (Deflorin et al., 2012). Moreover, Ferdows's (2018) call for more *case-study research* is followed.

1.2 Research Design

1.2.1 Research Questions

Based on the outlined practical and theoretical relevance, the purpose of this thesis is derived – exploring the phenomenon of company-specific plant role models. The main research question (MRQ) and the underlying sub-research questions (SRQs) can be developed, respectively. Table 2 summarizes them.

Table 2: Research questions of the thesis

MRQ	How to design and deploy company-specific plant role models in IMNs?
SRQ1	What is the content of company-specific plant role models?
SRQ2	How are company-specific plant role models created and deployed?
SRQ3	What is the effect of company-specific plant role models on network capabilities?
SRQ4	How can network management introduce company-specific plant role models?

SRQ1 focuses on the *content* of company-specific plant role models. It investigates questions such as how many roles such models have, how the roles are differentiated, or which measures are taken for the different roles. SRQ2 explores the *dynamics* of plant role models. Are the models created top-down or bottom-up? Who is involved in the creation process? What measures are taken to steer the plant roles? SRQ3 investigates the effect of the introduction of plant role models on *network capabilities*. It first examines which network capabilities are affected the most before establishing explanations. Last, SRQ4 aims to guide network managers in *introducing* plant role models in their own organizations. Each SRQ adds to answering the overarching MRQ – *How to design and deploy company-specific plant role models in IMNs*.

Some of the terms used in the research questions need further elaboration: the term *plant role model*[7] has been borrowed from Cheng and Farooq (2018). The authors use the term to refer to the original model proposed by Ferdows (1989, 1997b). This research investigates how companies design and deploy their own version of the original plant role model. Hence, the term *company-specific* is added as a prefix to plant role models. Company-specific is not to be mixed with the term "company-wide". That means even if a plant role model only covers one BU or division of a company, the term company-specific will still be considered applicable.

This thesis about company-specific plant role models distinguishes the design and

[7] Other terms for *model* that can be found in literature are *framework* (e.g., Blomqvist and Turkulainen (2019) , A. Feldmann and Olhager (2019)) or *typology* (e.g., Vereecke and van Dierdonck (2002), Thomas et al. (2015)). This research does not differentiate between these terms.

deployment (cf. Table 2). The term *design* refers to the *content* and *structure* of plant role models. The latter two terms are borrowed from Netland (2012), who uses them in the context of corporate lean production systems. Similar to lean production systems, the *content* of plant role models is often formalized in a document. It comprises several plant roles, their potential relationship to each other, and dimensions such as the product and market scope. The *structure* of plant role models refers to the organizational and technical structure to deploy the content of the plant role model (cf. Netland, 2012). The organizational structure may include a dedicated network management team that supports the plants in deploying the plant roles. The technical structure may consist of intranet pages supporting the communication between central functions and the plants (cf. Netland, 2012).

The *process* of how the plant role model is deployed in the IMN is denoted by the term *deploy*. The process includes a variety of organizational mechanisms such as incentive systems, performance management systems, resource management, sending technical experts to plants, and assessments of existing plants' competencies (cf. Netland, 2012).

1.2.2 Research Ideology and Approach

To understand how the design of the thesis is chosen, it is important to articulate the author's philosophical view and belief system – the *research ideology* (Strang, 2015). Following a *qualitative research approach*, the author thinks that meaning is created by engaging with participants and interpreting numbers and behaviors into facts (Strang, 2015). Consequently, a pragmatic worldview with elements of constructivism is adopted. *Pragmatism* means that the researcher focuses on the research problem instead of the methods (Creswell, 2014). The thesis uses multiple data sources such as a literature review, documents, interviews, workshops, and observations from meetings to address the research problem. However – as reflected in the *constructivist* worldview – knowledge in this thesis is mainly generated inductively by socially interacting with experts to gather their subjective views (Creswell, 2014) and extract perspectives, information, and experience. Interviewing experts is a component of the thesis' second, third, and fourth sub-research questions.

In line with the St.Gallen tradition in management, this research is positioned in the area of business administration as an application-oriented social science (H. Ulrich, 1982; P. Ulrich & Hill, 1976). As opposed to fundamental sciences, problems in applied sciences occur in a practical context that affects practitioners in their daily business (H. Ulrich, 1984). Therefore, research outcomes should solve concrete, practical problems (H. Ulrich, 1984). Hence, the researcher focuses on analyzing alternatives for action to affect the social system "company" (P. Ulrich & Hill, 1976). This research aims to affect the social system "company" by providing network managers with new knowledge and models to appropriately align the network and plant level within IMNs. To cope with a system inherent to high levels of detail and dynamic complexity, such as an IMN (Ferdows, 2018), the author chose the research to follow an iterative learning process as proposed by

Kubicek (1977).

As shown in Figure 2, the researcher starts with a first theoretical understanding that they use to address research questions to practice (Gassmann, 1999). Then, data are collected, critically reflected, abstracted, and used to generate new insight and extend the existing knowledge base (Gassmann, 1999). This process may give ground to new research questions, which kick off a new cycle within the iterative learning process (Gassmann, 1999). Following this process enabled the author to understand the inquired research topic deeply.

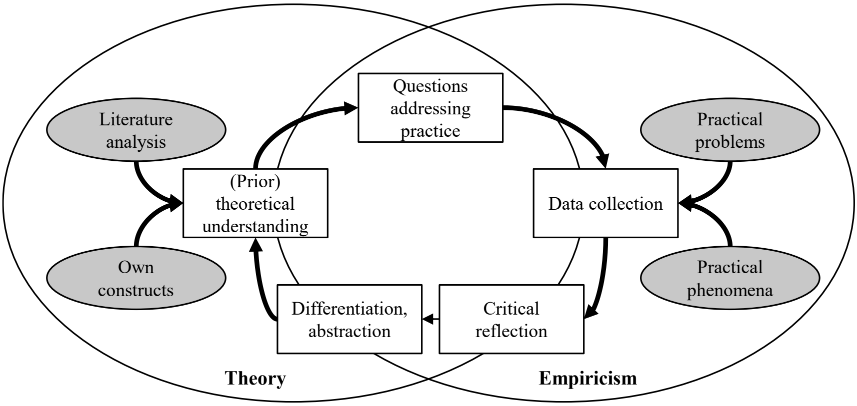

Figure 2: Research as an iterative learning process (adapted from Gassmann, 1997, p. 22)[8]

1.2.3 Research Theory

As a set of interrelated concepts, definitions, and propositions, *research theories* can contribute to explaining and predicting research phenomena (D. R. Cooper & Schindler, 2014, p. 62). This research chooses contingency theory as the primary theoretical lens to view organizations and the phenomenon of company-specific plant role models. Contingency theory supports the key assumption of this research – that companies develop their own versions of plant role models (i.e., company-contingent)

Contingency theory emerged in the 1960s (Fiedler, 1964) as a result of criticism of the classical *universalistic theories* (Donaldson, 2001) that assume "one-best-way" and the superiority of some principles over others (Voss, 1995). The basic idea of contingency theory holds that the situation and context impact the structure of the organization as well as the behavior of its members (Kieser & Walgenbach, 2010). Firms that fit their organizational structure to their situation (i.e., contingencies) will have higher efficiency results (Donaldson, 2001). Contingencies include both external factors (e.g., environmental

[8]Gassmann (1997) refers to Kubicek (1977, p. 14) and Tomczak (1992, p. 84).

uncertainty) and internal factors (e.g., organizational size or strategy) (Donaldson, 2001). In the P/OM discipline, scholars have paid close attention to contingency theory over the last decades, shifting their interest "from the justification of the value of those [best] practices to the understanding of the contextual conditions under which they are effective" (Sousa & Voss, 2008, p. 697).

Doz and Prahalad's (1991) classification of theories for managing MNCs helps distinguish the relevance of contingency theory from other organizational theories. As shown in Figure 3, theories based on transaction costs or organizational learning are relevant for developing midrange constructs and/or theories. Contingency theory, however, fits this thesis' context: empirical research on a (manufacturing) network level.

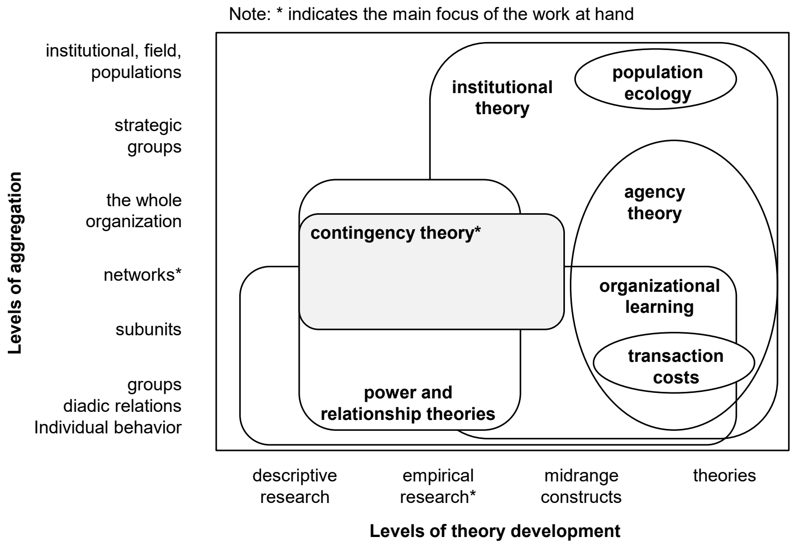

Figure 3: Theoretical positioning of the thesis (adapted from Doz & Prahalad, 1991, p. 156)

Two main arguments further justify the relevance of contingency theory for this research. First, the theory must be applicable to IMNs as they build the focal unit of analysis of this research. IMNs are multidimensional. They contain structural and infrastructural elements with high dynamic and detail complexity (Ferdows, 2018). Moreover, IMNs hold multiple and often conflicting contingencies, such as size or strategic direction (Colotla et al., 2003). The contingency theory contradicts the "one-best-way" paradigm (Donaldson, 2001) and assumes a great variety and multiple perspectives (Doz & Prahalad, 1991). This is in line with IMN scholars' suggestion that contingency factors influence the design of manufacturing networks (Olhager et al., 2015) and that "there is no one best way to organize the international manufacturing network" (Blomqvist & Turkulainen, 2019, p. 142)[9]. In their literature review about IMNs, Cheng, Farooq, and Johansen (2015, p. 410) explicitly call for future IMN research incorporating contingency theory.

Second, the theory should be applicable to study plant roles, as they build the focal phenomenon of this research. Contingency theory does not suggest a closed framework but can be adapted to different research environments (Donaldson, 2001). Moreover, the theory allows for differentiated strategies that are central to the concept of plant roles (Doz & Prahalad, 1991). More specifically, Vereecke et al. (2006, p. 1746) encourage a contingency perspective on plant roles in IMNs.

Based on the arguments presented above, contingency theory can be considered appropriate to view IMNs and the research phenomenon of plant role models because it reasonably reflects their key characteristics. Although contingency theory constitutes the dominant theory to view organizations and the phenomenon of company-specific plant role models, other theories' relevance is recognized. In particular, power and relationship theories that acknowledge the role of individuals in an organization's "network of relationships" (Doz & Prahalad, 1991, p. 152). An example of critical individuals in the context of this thesis are plant leaders who largely influence a "plant's network conduct" (Wiech & Friedli, 2021, p. 1171) and hence the operation of the entire manufacturing network.

1.2.4 Research Framework

At the beginning of a research project, a research framework helps to provide an overview of constructs and categories and the existing relations between them (Voss et al., 2002, p. 199)[10]. The proposed framework of this thesis is grounded in the contingency theory described in the previous chapter. It is depicted in Figure 4.

Company-specific plant role models (i.e., the research phenomenon) build the core of the research framework. Derived from the main research question – *How to design and deploy company-specific plant role models in IMNs* – the two main constituents of company-specific plant role models (i.e., design and deployment) are reflected in the research framework.

The dependence on the *organizational context* shown in Figure 4 describes the core assumption of this thesis – that companies develop their own version of plant role models (i.e., company-contingent). Contingency factors in the context of IMNs are rarely discussed. Olhager et al. (2015) mention firm size, industry, core competencies, corporate strategy, product type, product architecture, process type, and decoupling point. Several articles study the relationship between specific plant roles and the organizational context, such as management practices (Demeter et al., 2017), decision autonomy (Olhager & Feldmann, 2022), or supply chain integration (Cheng, Farooq, & Jajja, 2021). However, these articles focus on single plant roles rather than holistic plant role models.

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9 Blomqvist and Turkulainen (2019) refer to Hayes et al. (2005).

10 Voss et al. (2002) refer to Miles and Huberman (1994).

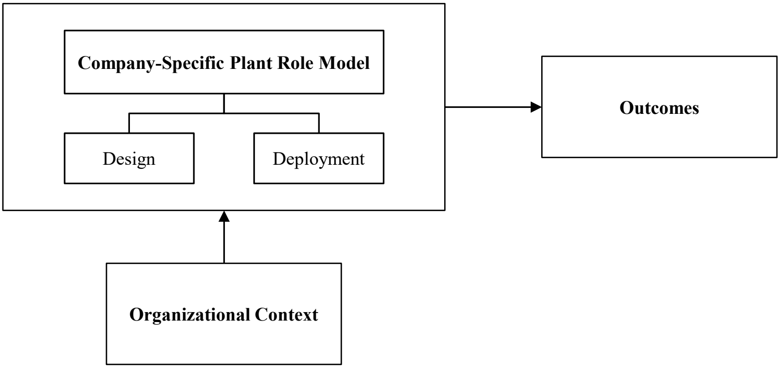


Figure 4: Contingency research framework of company-specific plant role models

Lastly, this thesis assumes that introducing plant roles in an industrial context leads to specific outcomes in organizations (cf. Figure 4). Research on these effects is scarce in IMN literature. Lohmer et al. (2021) are one of the few studies examining plant roles' effects. The authors found that assigning plant roles helps achieve specific network capabilities. This research focuses on designing and deploying company-specific plant role models (cf. MRQ). Nevertheless, the empirical studies in this thesis implicitly address the link to the organizational context and the outcomes.

1.3 Thesis Structure

After introducing the background, relevance, and research design in the current chapter, *chapter 2* forms the theoretical background of this thesis. It first provides an overview of international manufacturing networks (chapter 2.1) before introducing plant roles (chapter 2.1). Chapter 2 closes with a summary and related research gaps in chapter 2.3.

Chapter 3 contains an overview of the empirical studies conducted for this thesis. It elaborates on the research design of the three studies and how each addresses the research gaps outlined in the previous chapter. Moreover, a brief abstract of each study and a summary of the results are provided.

C*hapters 4, 5, and 6* each contain one complete empirical study. Every study has a similar structure. They start with a methodology section before outlining and discussing the empirical results. The conclusion contains the contribution to literature, managerial implications, limitations, and further research.

The thesis closes with a general discussion and outlook section in *chapter 7*. Chapter 7.1 synthesizes the empirical studies' results as a step-by-step guide to designing and deploying plant role models. Finally, chapter 7.2 outlines future research on a more general level than the respective sections in the empirical studies do.

2 Theoretical Background

A comprehensive understanding of basic literature and literature close to the research topic sets the foundation to identify robust research gaps (Webster & Watson, 2002). Chapter 2.1 introduces the concept of IMNs, whereas chapter 2.2 delineates the knowledge base in the literature about plant roles in IMNs. Lastly, chapter 2.3 outlines the research gaps that build the foundation for this research.

2.1 International Manufacturing Networks

2.1.1 Definition

Research on manufacturing networks has its roots in the operations management of single factories (Rudberg & Olhager, 2003). With the internationalization of the manufacturing base, scholars recognized the need to manage *multi-plant organizations* instead of single factories (Rudberg & Olhager, 2003). Since the late 1980s, research on IMNs has gained considerable attention. It became an established literature stream in (global) operations management (Cheng, Farooq, & Johansen, 2015; Ferdows, 2018).

Nowadays, most large firms manufacture in so-called *value networks* (Rudberg & Olhager, 2003). To categorize the literature about such networks, Rudberg and Olhager (2003) propose four different types depending on the number of organizations in the network and the number of sites per organization (cf. Figure 5).

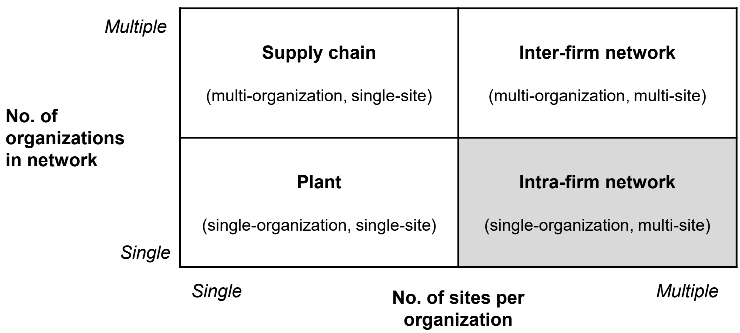


Figure 5: Types of value networks (adapted from Rudberg and Olhager (2003, p. 35))

Supply chain research looks at value networks with multiple organizations, i.e., *external networks*. It stems from logistics research and focuses on the links in the value network, i.e., physical distribution and materials management (Rudberg & Olhager, 2003). In contrast, IMN research focuses on the nodes (i.e., factories) in the value network (Rudberg &

Olhager, 2003), acknowledging that each node affects the other ones and can hence not be managed in isolation (Rudberg & Olhager, 2003; Shi & Gregory, 1998).

IMN research usually applies the *intra-firm network* perspective on value networks. Accordingly, an IMN "is generally defined as a coordinated aggregation (network) of intra-firm plants/factories located in different places" (Cheng, Farooq, & Johansen, 2015, p. 393)[11]. Scholars typically study IMNs as wholly owned networks in which the plants are under the complete financial control of the firm (Cheng, Farooq, & Johansen, 2015). This research takes the intra-firm perspective to define the focal unit of analysis (as highlighted in Figure 5).

Following Porter's (1986) categorization of networks, IMN research can generally be grouped into two dominating areas – *configuration* and *coordination*. Several scholars have used Porter's (1986) model as a basis for more detailed conceptual models (e.g., Friedli et al., 2014; Meijboom & Vos, 1997; Miltenburg, 2005, 2009; Rudberg & Olhager, 2003; Shi & Gregory, 1998). The management model proposed by Friedli et al. (2014) adds a strategic layer to highlight a manufacturing network's dependence on the overarching manufacturing and network strategy. The following two chapters focus on these three layers.

2.1.2 Manufacturing and Network Strategy

Manufacturing strategy has its roots in the early works of Skinner (1965, 1969, 1974). He identified it as the "missing link" (Skinner, 1969, p. 136) between corporate strategy and production. A manufacturing strategy aims to achieve a competitive advantage by aligning a firm's resources and capabilities with the market's requirements (Slack & Lewis, 2002). Since the 1960s, many scholars have investigated the content and process of manufacturing strategies, which underlines its importance in academia (e.g., Hayes & Wheelwright, 1984; Hill, 1993; Voss, 1995).

From a manufacturing network perspective, the manufacturing strategy builds the link between the network's targets and its external environment (Thomas et al., 2015, p. 1712). Although authors stress that the manufacturing network should be included in the manufacturing strategy (Macchion et al., 2015; Miltenburg, 2009), only a few articles about it can be found in the literature. Two important concepts to define a manufacturing network's strategy are proposed in Friedli et al.'s (2014) management framework.

The concept of *competitive priorities*[12] describes key success factors firms use to compete in the market (Voss, 1995). Commonly used competitive priorities comprise price, quality, delivery, flexibility, innovation, and service (Friedli et al., 2014; Hayes & Wheelwright, 1984; Miltenburg, 2009). Each factor's importance can be assessed using Hill's (1993) approach. The author differentiates between *qualifiers* and *order winners*. Whereas

[11] Cheng, Farooq, and Johansen (2015) refer to Ferdows (1989); Shi and Gregory (1998); Rudberg and Olhager (2003).

[12] Friedli et al. (2014) use the term "manufacturing priorities" instead of competitive priorities in Voss (1995).

qualifiers are essential to enter the market, order winners can be used to gain additional orders from competitors (Hill, 1993, 2000).

The concept of *network capabilities,* first introduced by Shi and Gregory (1998), describes the capabilities resulting from the network's global configuration and coordination. The concept acknowledges the interplay between plants and the network (Colotla et al., 2003). It conceptualizes that the overall manufacturing strategy is more than the sum of the individual plant-specific manufacturing strategies. The network capabilities can be broken down into the categories of *strategic targets accessibility* (e.g., strategic markets, production factors), *thriftiness ability* (e.g., economies of scale and scope), *manufacturing mobility* (e.g., product mobility, managerial skill mobility), and *learning ability* (e.g., national capability integration) (Shi & Gregory, 1998).

By defining the desired state of network capabilities, manufacturing firms set strategic targets for their IMNs. These targets are linked to the capabilities and characteristics of the network's individual plants (Thomas et al., 2015).

2.1.3 Network Configuration and Coordination

To support the manufacturing and network strategy, manufacturing firms can use the configuration and coordination of their IMNs (Friedli et al., 2014). The configuration refers to the *structure* of networks, whereas the coordination is concerned with the *infrastructural* processes to link activities between plants (Colotla et al., 2003; Hayes & Wheelwright, 1984).

Much more attention has been devoted to configurational issues in IMNs (Cheng, Farooq, & Johansen, 2015; Pontrandolfo, 1999; Toni & Parussini, 2010). Decisions associated with the configuration of IMNs include the *geographical dispersion of plants*, the *allocation of resources* (Meijboom & Vos, 1997), the *specialization and strategic role of plants* (Scherrer & Deflorin, 2017), as well as the design of the *internal supply chain* between the plants (Friedli et al., 2014). Several typologies that explain the overall structure of IMN configurations can be found in the literature (e.g., Bartlett & Ghoshal, 1989; Hayes et al., 2005; Meyer & Jacob, 2008; Miltenburg, 2009; Schmenner, 1979; 1982). One of the first is the one from Schmenner (1979, 1982). Analyzing plant characteristics of the Fortune 500 companies, he identified four *multi-plant strategies*: the *product plant strategy* (i.e., every plant focuses on a designated set of products), the *market area plant strategy* (i.e., every plant focuses on a particular market), the *process plant strategy* (i.e., segments of the production process are assigned to a separate plant), and the *general purpose plant strategy* (i.e., plants are assigned to any of the responsibilities above).

Compared to the configuration, research on IMN coordination is scarce (Cheng et al., 2016; Szwejczewski et al., 2016). Decision categories related to IMN coordination can be linked to one of the four categories: *centralization and autonomy*, *formalization and standardization*, *incentives and rewards*, and *means of knowledge transfer* (Wiech & Friedli, 2021). Although this research's topic of plant roles is considered part of the network configuration (Olhager & Feldmann, 2022), most of the aforementioned categories are closely linked to the topic of plant roles. For example, plants with different roles are likely to have different degrees of autonomy (Cheng & Farooq, 2018; Olhager & Feldmann, 2022). Additionally, different plant roles should have different management practices in place (Cheng & Farooq, 2018; Maritan et al., 2004), which affect the incentives and rewards given to the individual plants.

In conclusion, network configuration and coordination are the keys to achieving the aforementioned network targets (Friedli et al., 2014). Although formally positioned in the area of network configuration (Olhager & Feldmann, 2022), the topic of plant roles is related to a wide variety of constructs in IMN literature, such as the network capabilities (Shi & Gregory, 1998), the multi-plant strategy (Schmenner, 1979; 1982), the specialization of plants (Scherrer & Deflorin, 2017), and the centralization and autonomy. The concept of plant roles will be presented in detail in the following chapter.

2.2 Plant Roles in International Manufacturing Networks

This thesis is concerned with company-specific plant role models. The current chapter hence first summarizes the origins of the idea of plant roles. It then outlines Ferdows's (1989, 1997b) plant role model as the most recognized one in IMN literature. The chapter ends by discussing plant role types and dimensions of studies related to Ferdows's model.

2.2.1 Origins of Plant Roles

In IMN literature, the term *plant role* is commonly used to distinguish plants in a manufacturing network. Plants may be differentiated through a multitude of dimensions, such as the *reason for establishment* (Ferdows 1989, 1997b), the *decision-making authority* (D'Cruz, 1986; Taggart, 1997a), or their *capabilities* (Bartlett & Ghoshal, 1986; Benito et al., 2003). Typically, scholars use only a few dimensions without defining their general understanding of plant role models.

The *focused factory concept* introduced by Skinner (1974) can be regarded as the first contribution to the concept of plant roles (A. Feldmann & Olhager, 2013). From the observation that common factories attempt to fulfill too many conflicting tasks, Skinner proposes that the focused factory should be focused on a particular manufacturing task demanded by the firm's overall strategy (Skinner, 1974). In the literature about international operations strategies, Hayes and Schmenner (1978) introduced the concept of the product- and process-oriented organization, which can be translated into product- and process-focused plant roles. In his study of the Fortune 500 companies, Schmenner (1979, 1982) identified two further plant types: the *market area plant* and the *general purpose plant* (cf. chapter 2.1.3). Hayes and Wheelwright (1984) adopted Schmenner's (1979, 1982) typology and added the dimensions of *plant size*, *location*, and *specialization* as strategic choices that have to be made for each plant.

In the literature about MNCs, subsidiaries' strategic roles have been discussed since the

1980s. Multiple typologies have been developed since then[13] (e.g., Bartlett & Ghoshal, 1986; 1989; Birkinshaw & Morrison, 1995; D'Cruz, 1986; Gupta & Govindarajan, 1991; Jarillo & Martíanez, 1990; Poynter & White, 1984; Taggart, 1997b; 1998a). The typologies of Poynter and White (1984) and Bartlett and Ghoshal (1986, 1989) can be exemplarily named as they are one of the first and most influential ones in MNC literature (Daniel, 2010). Poynter and White (1984) suggest the dimensions of *market scope*, *product scope*, and *value-added scope* resulting in five different roles (i.e., miniature replica, marketing satellite, rationalized manufacturer, product specialist, and strategic independent). Based on questionnaire data from 618 subsidiaries, Bartlett and Ghoshal (1986, 1989) propose a two-by-two matrix along the axes of *strategic importance of local environment* and *level of local resources and capabilities.* The matrix classifies subsidiaries into the roles of strategic leader, black whole, implementer, and contributor.

Although the idea of strategic roles had already been around for some time, Ferdows (1989, 1997b) was the first scholar to translate the classification of subsidiaries into a classification of manufacturing plants (Cheng & Farooq, 2018). Recognized to be the most influential plant role model in IMN literature, it will be described in detail in the following section.

2.2.2 Ferdows's Plant Role Model

As depicted in Figure 6, Ferdows's (1989, 1997b) plant role model consists of six different plant roles based on the two dimensions of *site competence* and *strategic site reason*. Ferdows (1989, 1997b) proposes two different plant roles depending on their respective competencies for each strategic site reason.

Site reasons (see x-axis in Figure 6) are described as the *strategic reason* to establish or "exploit" the plant (Vereecke & van Dierdonck, 2002, p. 495). The model contains of three main site reasons (1) *access to low-cost*, (2) *access to skills and knowledge*, and (3) *proximity to market* (Ferdows, 1997b). In his earlier publication, Ferdows (1989) mentions two more reasons: (4) *control and amortization of technological assets* and (5) *pre-emption of competition*. However, he reports that the latter two are less prevalent (Ferdows, 1989); hence, he does not include them in his model. As the first scholars to empirically test Ferdows's model, Vereecke and van Dierdonck (2002) suggest a more detailed list of site reasons, including *socio-political climate*, *proximity to competition*, and *access to low energy costs*. Although there may be various reasons for establishing and exploiting plants, there seems to be an agreement between IMN scholars that the three proposed by Ferdows (1989, 1997b) are the most important ones (A. Feldmann & Olhager, 2013; Olhager & Feldmann, 2022).

[13] For a comprehensive overview of subsidiary roles see e.g., Vokurka and Davis (2004), Enright and Subramanian (2007), Daniel (2010).

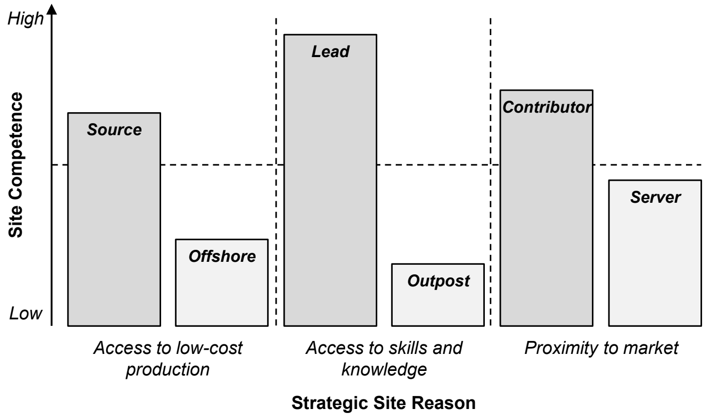


Figure 6: Ferdows's plant role model (Ferdows, 1997b, p. 77)

Initially coined as the *extent of technical activities* (Ferdows, 1989), Ferdows defines *site competencies* (see y-axis in Figure 6) in his later article as the extent to which the following activities are present at the plant: *production*, *process technical maintenance*, *procurement*, *local logistics*, *production planning*, *production and process development and improvement*, *development of suppliers*, *supply of global markets*, and *global hub role for product and process knowledge* (Ferdows, 1997b). The model assumes that the activities mentioned above are built successively, i.e., from the bottom to the top of the y-axis shown in Figure 6. The hierarchical character of Ferdows's operationalization of the y-axis has been subject to criticism. For example, Vereecke and van Dierdonck (2002) point out that, in reality, a plant might be given the responsibility for product development while it might not be given the responsibility for its own supplier development. Thus, the authors developed a direct measure for a plant's competency using a 9-point Likert scale that was also used in later studies (Ferdows et al., 2016). A. Feldmann and Olhager (2013) identified that the site competencies proposed by Ferdows could be grouped into three logical bundles of competencies: related to *production*, the *supply chain*, and *development*. The first group of plants only contains production related, the second one both production and supply chain, and the third all three bundles. Based on a sample of 606 plant data, Cheng and Farooq (2018) confirmed the three plant types proposed by A. Feldmann and Olhager (2013).

Ferdows (1989, 1997b) and scholars of related articles stress that plant roles are not static and can be adapted dynamically (Cheng et al., 2011; A. Feldmann et al., 2013). Ferdows (1989) observed that new plants usually start with low strategic roles, i.e., either as servers or offshores. To increase their chance of survival, plants then naturally move toward higher strategic roles (Ferdows, 1989), e.g., through competence development or knowledge sharing (Demeter et al., 2017). Although firms might choose to keep these plants in their initial roles (e.g., to keep development near domestic operations), this might result in a decline in the overall network's performance. A potential reason is that such factories might be endangered to stagnate and fall behind in technological progress (Ferdows, 1989).

2.2.3 Plant Role Types and Dimensions

As Ferdows's (1989, 1997b) article gained recognition in IMN literature, it has become the "springboard" (Cheng & Farooq, 2018, p. 17) for many articles both confirming and exploring his model.

One strand of articles used Ferdows's model to *describe and categorize* existing plant configurations mainly using case research (e.g., Blomqvist & Turkulainen, 2019; Cheng et al., 2011; Fusco & Spring, 2003; Kim et al., 2011; Mediavilla et al., 2015; Meijboom & Voordijk, 2003; Miltenburg, 2015a; 2015b; Scherrer & Deflorin, 2017). Fusco and Spring (2003) and Meijboom and Voordijk (2003) apply the model in their multiple-case studies to illustrate the current and potential future roles of the respective plants. Similarly, Miltenburg (2015a, 2015b) uses the model to analyze the North America Heinz manufacturing network in a single-case study. In Meijboom and Vos (2004) and Cheng et al. (2011; 2015), the dynamics in the roles of plants are examined from a network perspective: the first two articles investigate the evolution and interaction of plants, whereas the latter one focuses on the interplay between production and Research & Development (R&D) in their globalization process. Criticizing the applicability of Ferdows's model, Mediavilla et al. (2015) are one of the first authors focusing on the plant role model implementation process. The authors propose a four-stage process for plant role assessment and future roadmap creation for each plant. Although the aforementioned articles show the general applicability of Ferdows's plant role model, it is not investigated how plant roles are related to company-specific factors such as the manufacturing or network strategy (A. Feldmann & Olhager, 2013; Maritan et al., 2004). Moreover, literature on the deployment of the model remains scarce (Mediavilla et al., 2015).

A second strand of articles focused on *testing and further understanding* Ferdows's model. Most of these articles are empirically based on large survey samples (e.g., Demeter et al., 2017; A. Feldmann & Olhager, 2013; Maritan et al., 2004; Olhager & Feldmann, 2022; Vereecke & van Dierdonck, 2002). Vereecke and van Dierdonck (2002) used questionnaires from 59 plants to test Ferdows's model. Although the authors found some support for the model, they reported that the perception of the central network management and the plant management concerning the roles might differ. Drawing on a sample of 196 plants from 47 firms, Maritan et al. (2004) examined the relationship of Ferdows's six plant roles with different degrees of autonomy concerning planning, production, and control decisions. Only planning-related autonomy was found to be significantly different between the two plant role pairs, source-offshore, and lead-outpost. Feldmann and his colleagues (A. Feldmann & Olhager, 2013) operationalized the two plant role dimensions proposed by Ferdows and found no statistical dependence between the site competence and strategic site reason. However, they found that plants can be grouped into three competence bundles, i.e., production-related, supply chain-related, and development-related (cf. chapter 2.2.2). In a later study, the authors investigated the relationship between the aforementioned competence level and decision autonomy (Olhager & Feldmann, 2022). They found that plants with high production levels, supply chain, and development competencies usually have higher decision-making autonomy. In contrast, the plants with low decision-making autonomy entail only a specific set of production-related competencies (Olhager & Feldmann, 2022). Articles in this stream add a significant understanding of how the initial plant roles proposed by Ferdows are related to plants' characteristics, such as decision-making autonomy. However, one may criticize that they mostly draw on plant data, neglecting the network perspective toward plant roles. Articles that take the network as the unit of analysis are scarce (Cheng, Farooq, & Johansen, 2015; Olhager & Feldmann, 2018).

A third strand of articles aimed to *complement and extend* Ferdows's model, resulting in new plant role models. The characteristics of the most important models are shown in Table 3. Rooted in the knowledge flow subsidiary role model introduced by Gupta and Govindarajan (1991), Vereecke et al. (2006) identified four plant role types based on their *degree of communication* with other plants in the network. *Isolated plants* (1) have almost no communication, whereas *receiver plants* (2) receive knowledge but contribute little to the rest of the network. Both *hosting* (3) and *network players* (4) actively engage in network communication. In a later article, Szász et al. (2019) adapted Vereecke et al.'s (2006) communication dimensions to further explore knowledge-sending and receiving plants and their related capabilities in an IMN context. Norouzilame and Wiktorsson (2018) classified plants into (1) *leading*, (2) *supporting*, and (3) *following* based on their autonomy in coordination activities. The authors linked the identified plant role types back to Ferdows's model. *Leading plants* (1) manage coordination activities with high autonomy and provide access to knowledge. *Supporting plants* (2) support leading plants with limited autonomy and can take any of Ferdows's three strategic site reasons. Lastly, *following plants* (3) have the lowest autonomy and usually provide access to low-cost or markets. Based on case studies of product subnetworks, A. Feldmann and Olhager (2019) categorized three types of plants along with their position in the material flow: (1) *component plant*, (2) *assembly plant*, and (3) *integrated plants* (i.e., both component and assembly). Moreover, the authors propose two additional plant roles, i.e., (4) *full lead plants* and (5) *strategic feeder plants*. Full lead plants (4) have the full responsibility for R&D and product/process development for both component manufacturing and the assembly of finished goods. The strategic feeder plants (5), in contrast, hold the responsibility for strategically important components which they "feed" into assembly plants.

Table 3: Characteristics of selected plant role models

Article	Dimensions	Plant role types	Empirical data
Vokurka & Davis, 2004	(1) Product volume (2) Product variety (3) Process flexibility (4) Process complexity (5) Material availability (6) Material variety (7) Customer variety (8) Scheduling flexibility (9) Labor complexity (10) Plant size	(1) Standardizer plant (2) Customer plant (3) Automator plant	Questionnaire with 305 plants
Vereecke et al., 2006	(1) Communication centrality (2) Innovation indegree (3) Innovation outdegree (4) People indegree (5) People outdegree	(1) Isolated plant (2) Receiver plant (3) Hosting network player (4) Active network player	Case studies of 8 firms with 4-10 plants (59 plants in total)
Norouzilame & Wiktorsson, 2018	(1) Production know-how coordination (2) Production system coordination	(1) Leading plant (class A) (2) Supporting plant (class B) (3) Following plant (class C)	Case studies of 3 firms with 11, 15, and 17 plants
Cheng & Farooq, 2018	(1) Site competence (2) Location advantage	(1) Star plant (2) Old school plant (3) Expert plant (4) Replaceable plant	Questionnaires with 606 plants
A. Feldmann & Olhager, 2019	(1) Material flow (2) Site competence	(1) Component plant (2) Assembly plant (3) Integrated plant (4) Strategic feeder (5) Full lead	Case studies of 20 product subnetworks of 5 firms (49 plants in total)
Szász et al., 2019	(1) Information sending (2) Information receiving (3) Innovation sending (4) Innovation receiving (5) Offering training (6) Receiving training	(1) Net receiver plant (2) Active receiver plant (3) Balanced actor plant (4) Net sender plant	Case studies with 13 plants in 4 countries
Blomqvist & Turkulainen, 2019	(1) Site competence (2) Dependence of plants in network (3) Scope of activities and responsibilities	(1) Lead plant (global, regional, product) (2) Dependent plant (server, offshore, satellite) (3) Generalist plant (source, contributor) (4) Special task plant (production process, product specialist, sourcing outpost)	Case studies of 5 firms with 2-8 plants

Based on large-scale surveys, Vokurka and Davis (2004) and Cheng and Farooq (2018) identified different plant role types. Vokurka and Davis (2004) deployed a factor analysis on 305 plant data to determine the major dimensions that differentiate plants and then grouped them into (1) *standardizers*, (2) *customizers*, and (3) *automators*. Standardizers (1) are typically large plants with high volumes and low product, material, and customer variety. As the name suggests, customizers (2) customize their products leading to a wide variety of products, materials, and customers with lower volumes. (3) Automators are relatively small plants with large volumes and high product variety.

Drawing on a sample of 606 plant data, Cheng and Farooq (2018) used Ferdows's original dimensions of site competence and location advantage to verify their model empirically. The authors derive a plant role taxonomy containing four new plant roles, i.e., (1) *star plant*, (2) *old school plant*, (3) *expert plant*, and (4) *replaceable plant*. The four plants differ not only regarding their strategic site reasons but also concerning the applied management practices (e.g., decision autonomy, supplier integration). In Cheng, Farooq, and Jajja (2021), the four plant roles were linked to manufacturing network integration, supply chain integration, and operational performance. Using data from five case studies of plant networks, Blomqvist and Turkulainen (2019) propose an enhanced plant role model compared to Ferdows's. It consists of 11 plant roles grouped into four main role types along with the dimensions of *activities and skills* as well as the *dependence of the plant* with other ones in the network (e.g., intensity of information/knowledge exchange flows). *Lead plants* (1) have the highest scope of activities and competence. They can be global, regional, or product lead plants. *Special task plants* (2) have a high competence level but a focused scope of activities. The authors distinguish between production process specialists (e.g., process improvement), product specialists (e.g., new product introduction), and sourcing outposts with a global sourcing mandate. Moreover, the authors name *dependent plants* (3), i.e., server, offshore, and satellite plants whose task is to fulfill a special focus efficiently with little management and development activities on site. Lastly, *generalist plants* (4) contain source and contributor plants from Ferdows's model, i.e., these are plants with fewer activities than the lead plants but are more independent than special task plants.

Overall, most of the literature outlined assumes that plant role models can be universally applied to each company. It does not consider that companies develop their own versions of plant role models. Hence, questions such as how many plant roles a firm should have or how to balance a portfolio of different plant roles remain unanswered.

2.3 Summary and Research Gaps

Drawing on the previous section, five research gaps in the literature can be identified. Table 4 depicts different authors' statements and how they relate to the research gaps identified. These research gaps only describe the broader themes from the literature review without any claims for completeness. Moreover, they are not mutually exclusive and may depend on each other.

Table 4: Summary of research gaps

Author	Statement	RG1: Network perspective on plant roles	RG2: Oversimplification of plant role models	RG3: Contingency on company-specific factors	RG4: Deployment of plant roles	RG5: Case studies on plant roles
Blomqvist & Turkulainen, 2019, p. 133	*There are only a few studies that combine the interplay between individual roles and the impact on the network level.*	X				
Cheng et al., 2011, pp. 1314–1315	*“Much attention was paid to single plants, but the manufacturing network context was largely neglected (Shi and Gregory, 1998).”*	X				
Mediavilla et al., 2015, p. 800 refer to Cheng et al., 2011	*“most of the debate around plant roles has been focused on the advantages of location and competencies of individual plants without understanding its influence on the entire [IMN]”*	X				
Cheng, Farooq, & Johansen, 2015, p. 412	*“the existing literature still lacks overall evidence on the interactions between the individual plants and the manufacturing network as a whole (Cheng et al., 2011).”*	X				
Cheng & Farooq, 2018, p. 27	*“future research is needed to take a network perspective in better understanding the roles of individual plants.”*	X				
A. Feldmann & Olhager, 2013, p. 740	*“research is needed to investigate how the concept of plant roles ... is related to the configuration and coordination aspects of networks (Porter, 1980; Shi and Gregory, 1998).”*	X		X		
Mediavilla et al., 2015, p. 803	*The question of how to balance strategic roles, competencies, and responsibilities of IMNs remains unanswered.*	X		X		
Cheng & Farooq, 2018, p. 17	*“[Ferdows’s plant role model] 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.”*		X			
Granlund et al., 2019, pp. 97–98 refer to Enright & Subramanian, 2007; Thomas et al., 2015	*There is a need that research on plant roles considers more dimensions than just the two identified by Ferdows as more factors impact the network structure.*		X			
Mediavilla et al., 2015, p. 819	*There is a lack of knowledge about making Ferdows’s model operational and practical for IMNs.*		X		X	
Thomas et al., 2015, p. 1714	*“We propose that a comprehensive classification of sites should be multi-dimensional, involving a set of dimensions”*		X			
Blomqvist & Turkulainen, 2019, p. 144	*“Research focusing on the factors affecting plant roles could also give important insights into the potential future roles that plants ... are likely to play”*			X		
A. Feldmann et al., 2013, p. 5708	*The network strategy is potentially an important influencing factor besides site reason and level of technical activities.*			X		
Maritan et al., 2004, p. 500	*“[Ferdows’s framework lacks a discussion of how] networks of plants might fit with particular firm organizations or business unit strategies.”*			X	X	
Thomas et al., 2015, p. 1728 refer to Luo, 2005	*Aspired-to changes of sites’ positions to performance measurement and incentive systems should be addressed by future research.*			X	X	
Olhager & Feldmann, 2022, p. 252	*Detailed case studies from a network perspective can add insights into the distribution of plant roles.*	X				X

The first research gap (RG) refers to the missing *network perspective on plant roles (RG1)*. Most of the literature focuses on the single plant level, e.g., analyzing extensive plant-level survey data. Taking a network perspective on plant roles means expanding the previous discussion about single plants to the question of the right balance of plant roles and how they are interconnected. The second research gap deals with the *oversimplification of plant role models (RG2)*. Most of the models available in theory only incorporate two or three dimensions. They hence do not reflect the real-world complexity of classifying plants. Research gap three, *contingency on company-specific factors (RG3)*, deals with the assumption in the literature that plant role models are of generic nature, i.e., they can be applied independently of the company-specific context (e.g., manufacturing or network strategy).

Research gap four, the *deployment of plant roles (RG4)*, underlines that there is a scarcity of articles that explicitly deal with the process of deploying plant roles rather than how to describe them. For example, how management systems such as performance management or incentive systems are intertwined with the deployment of plant roles has not yet been addressed by literature. Lastly, the research gap *case studies on plant roles (RG5)* stresses the need for more case study-based research in this field. This aligns with Ferdows's (2018) call for more case-study research in IMN research.

This research aims to fill the identified research gaps. It hence looks at plant roles from a network perspective (RG1). It grounds its empirical part on company-specific versions of plant role models instead of those available in research (RG2, RG3). Particular care is taken to investigate how companies design their plant role models (RG2, RG3) and how they can be deployed in their IMNs (RG4). The author relies on case research (RG5) to address the research gaps outlined.

3 Overview of the Empirical Studies

This chapter provides a compact overview and summary of the three empirical studies designed to answer the sub-research questions of this thesis.

Table 5 presents an overview of the three empirical studies' research design. The first study investigates the content of 29 plant role model documentations. It is hence focused on the design of plant role models. In contrast, study 2 sheds light on both the design and deployment of plant role models. The collection of the study's four retrospective cases allowed for data gathering of "historical events" (Voss et al., 2002, p. 203). Last, study 3 used a longitudinal single case (Voss et al., 2002) focusing on deployment principles.

Table 5: Overview of the three empirical studies' research design

	Empirical study 1	**Empirical study 2**	**Empirical study 3**
Constituent of MRQ			
Design	X	X	(X)
Deployment		X	X
Sub-research questions (SRQs)	SRQ1 What is the content of company-specific plant role models?	SRQ2/SRQ3 How are company-specific plant role models created and deployed? What is the effect on network capabilities?	SRQ4 How can network management introduce company-specific plant role models?
Addressed research gap			
RG1: Network perspective	X	X	
RG2: Oversimplification	X		
RG3: Company-specific	X	X	X
RG4: Deployment		X	X
RG5: Case studies	(X)	X	X
Methodological purpose*			
Exploratory	(X)	X	X
Descriptive	X		
Explanatory		(X)	
Case study mode**	Theory elaboration	Theory generation	Theory generation
Methodological reference***	"Eisenhardt method"	"Eisenhardt method"	"Gioia method"
Case study type*	Embedded multiple-case study	Holistic multiple-case study	Embedded single-case study
Underlying data			
Unit of analysis	Plant role model	Multi-plant network	Multi-plant network
Embedded unit of analysis	Plant role	-	Plant
Number of cases (embedded unit of analysis)	29 (92)	4	1 (9)
Primary source of evidence	Documentation	Interviews (Documentation)	Interviews (Survey, Documentation)
Sampling period	09/2022 – 11/2022	01/2023 – 02/2023	01/2021 – 05/2023
Level of analysis	Network	Network	Network, Plant

Note: (X) denotes secondary addressed research gaps and/or methodological purposes; * according to Yin (2018); ** according to Ketokivi and Choi (2014); *** according to Langley and Abdallah (2011, pp. 205–206)

Each of the research gaps outlined in the previous section is at least addressed by one empirical study. While the first two studies take the *network perspective* (i.e., RG1) exclusively, study 3 integrates the plant level – in the form of the plant leaders' perspective.

By analyzing the content of 29 industrial plant role models, study 1 particularly takes on the observed *oversimplification* (i.e., RG2) of the often two-dimensional classification of plants in IMN literature (Thomas et al., 2015). While all three studies take the *company-specific* (i.e., RG3) perspective on plant roles, only the latter two investigate related dynamics (i.e., deployment in RG4). Last, all studies use a case study design (Yin, 2018). Study 1 relies on a comparative design without a detailed case description, so brackets () are depicted for RG5 in Table 5.

This research is mainly exploratory, which is appropriate for studying new phenomena such as company-specific plant role models. While studies 2 and 3 use a *theory generation* approach (Ketokivi & Choi, 2014), study 1 uses descriptive analysis to *elaborate* on the content of theory-based plant role models. In the first two studies, the "Eisenhardt method" is applied to analyze distinct cases and develop "testable propositions" (Langley & Abdallah, 2011, p. 205). In contrast, study 3 uses the "Gioia method" as a more interpretive approach in search of plant leaders' understanding of plant role models. Last, Table 5 summarizes the underlying data for each empirical study.

3.1 Empirical Study 1

The first study investigates the content of company-specific plant role models. A multiple-case study design is deployed based on the documentations of 29 industrial plant role models from MNCs mainly headquartered in German-speaking countries. A theory-based reference framework is developed to allow the comparison of differences and similarities across the plant role models' content. As a result, a conceptual framework for practitioners aiming to build their own company-specific plant role models is suggested. Using documentations rather than interviews allows for a comparably high number of cases, thus, increasing the generalizability of the results.

3.2 Empirical Study 2

The second study explores the dynamics of company-specific plant role models. Four cases of multi-plant networks are selected based on (1) diversity and (2) a high degree of plant role model implementation. The cases are analyzed for differences and similarities regarding the plant role model creation and deployment process as well as its impact on network capabilities. Overall, the results indicate the high relevance of plant roles in improving plant-network interaction. In addition, specific implications for creation and deployment principles for managers are drawn. The originality of this study stems from its unique access to fully deployed plant role models from a retrospective perspective.

3.3 Empirical Study 3

The purpose of study 3 is to outline the plant role introduction process at an internationally operating medical technology company in great depth. The single case is chosen based on its revelatory nature and the author's excellent access to stakeholders from network and plant levels. The plant level is integrated systematically by using data from a series of nine plant leader interviews. Grounded in these data, a model of plant role introduction, including perceived conditions, management strategies/tactics, and potential outcomes, is derived. Its underlying themes provide managers aiming to introduce plant roles in their organizations with a guiding framework. This study is one of the few in IMN literature that unfolds the "black box" (Cheng et al., 2011, p. 1315) of plants by including the perceptions of key individuals in manufacturing networks – the plant leader.

3.4 Overview of Study Results

Table 6 summarizes the contribution to the literature, the managerial implications, and the limitations of each empirical study. It can be used by practitioners and scholars as an executive summary, not aiming to read each study thoroughly.

Table 6: Overview of the three empirical studies' results

	Empirical study 1	**Empirical study 2**	**Empirical study 3**
Contribution to literature	• Increase *understanding* of plant roles from a network perspective • Novel *data collection methods* by using documentations • Derivation of five *propositions* regarding the content of company-specific plant role models	• Increase *understanding of dynamics* of plant roles • Complement previous studies on the *network effects* of plant roles • Derivation of four *propositions* regarding the creation and deployment of plant role models	• *In-depth exploration* of plant role introduction in an industrial context • Inclusion of *individual level* in IMN research (i.e., plant leader) • Integrating *plant* and *network* levels in IMNs
Managerial implications	• *Complementarity dimensions* and *plant role names* can be used as a checklist • Plant role models suffer from insufficient usage of *KPIs* • Plant role models *overemphasize configurational* aspects	• Managers should use plant roles to increase *plant-network interaction* • Plant role models should not be used in a one-size-fits-all principle • Managers should integrate plant leaders and adjacent functions • Plant roles should be derived from specific network capabilities • *Central* standards and *decentral* autonomy should be balanced	• Managers should integrate *prior plant-role-related activities* and give a *voice* to individuals • Plant roles should be integrated into an *overarching model,* including *roadmap building*, *product & technology allocation*, and *role-specific* performance management • Managers should continuously *communicate the sense* of all plant roles and monitor outcomes of plant role introduction
Limitations	• Usage of documentations as the primary source of evidence • Inability to capture *dynamic aspects* • Case companies exclusively headquartered in *high-cost countries*	• *Limited generalizability* of performance link • *Number of cases* • Case companies exclusively headquartered in *Germany*	• *Limited generalizability* due to single case operating in the medical technology industry and headquartered in the US • Not capturing the whole introduction process limits the *validity* of potential outcomes

4 Empirical Study 1[14]

After introducing the theoretical background and deriving the respective research gaps, this chapter's purpose is to answer the first sub-research question, namely:

What is the content of company-specific plant role models?

Chapter 4.1 serves to introduce the methodology. In chapter 4.2, a theory-based reference framework will be introduced to enable the comparison across the company-specific plant role models' content. Chapter 4.3 presents the results of the data analysis and discusses them compared to existing literature. Finally, the study concludes with contributions to literature, managerial implications, limitations, and future research opportunities in chapter 4.4.

4.1 Methodology

The theory of plant roles is well-established in the literature. Scholars have suggested different contents of plant role models, e.g., using dimensions such as plant competence and location advantage (Ferdows, 1997b) to differentiate plant roles (cf. chapter 2.2). However, knowledge about plant role models' content from the company-contingent perspective is scarce. Hence, this study's purpose can best be described as an *elaboration of theory* (Bluhm et al., 2011; Lee et al., 1999). As argued in chapter 2.3, most of the models, such as the one by Ferdows (1997b) or Vereecke et al. (2006), are oversimplified and therefore limited in their applicability. We[15] aim to elaborate on those models by introducing a more detailed understanding of plant role models' content, which can be applied in real-world settings. *Descriptive case study research* is considered appropriate as we aim to describe the phenomenon of plant role models in its "real-world context" (Yin, 2018, pp. 286–287), i.e., company-specific plant role models. Moreover, we chose a multiple-case design to enable the comparison between cases and therefore increase the generalizability (Voss et al., 2002; Yin, 2018) of our theory elaboration.

4.1.1 Case Selection

In this study, cases are plant role models with their respective plant roles as the embedded unit of analysis (Yin, 2018). To select the cases, we applied *purposive sampling* based on several criteria (Bryman, 2015). Potential case companies must operate in the manufacturing sector and operate a manufacturing network of at least five globally dispersed plants. Moreover, the potential case company must have a plant role model, which we can analyze. Practical factors such as the willingness to share the plant role model documentation and the existence of prior research activities and contact with our institute applied to facilitate the data collection. To enable a meaningful comparison (Yin, 2018), we controlled

[14] Parts of this chapter, which are not further demarcated in the text, were initially submitted for publication in Kaiser and Friedli (2023a).

[15] "We" is used in empirical study 1 to acknowledge the help of the coauthor of the submitted article.

(Voss et al., 2002) the companies' plant role models (i.e., the cases) using the following criteria (i.e., boundaries of the cases, Yin (2018)):

(1) the plant role models must contain distinct roles, and
(2) the roles must be abstracted (i.e., not a distinct role for each plant), and
(3) the roles must be described, and
(4) the roles must be formalized before the inquiry (i.e., no subsequent descriptions of the plant roles by the contacted persons)

Based on the described control criteria, we had to exclude seven cases mostly because of vague descriptions (criterion 3) or missing formalization before the inquiry (criterion 4).

4.1.2 Data Collection

Our first SRQ investigates plant role models' content without considering dynamic aspects such as the creation process. We, therefore, decided to use documentations such as slides or text files as our *source of evidence* (Yin, 2018). Compared to more common data sources such as interviews[16], this allows us to gather a relatively large number of cases with limited effort. Moreover, documentations are *specific* (Yin, 2018); e.g., they contain exact plant role names (as compared to interviews). Finally, documentations are *stable* (Yin, 2018), which allows us to review them often and across multiple researchers.

To ensure a sufficient *quality of our data*, we checked them against Scott's (1990)[17] four criteria to assess the quality of documents in qualitative research (i.e., *authenticity*, *credibility*, *representativeness*, and *meaning)*. First, we could trace back the identity of the producers of the documentations to address *authenticity*. Second, we explicitly targeted informants from the network level with positions such as VP Manufacturing or Head of Global Operations who are likely to have sufficient knowledge about their manufacturing network and hence provide accurate and *credible* information. Moreover, our institute had prior engagements with most informants. Third, to address *representativeness*, we explicitly ask the informants for textual descriptions, diagrams, or frameworks in the form of a few pages of slides or text files. One may criticize that these highly condensed documents miss important details of the companies' plant role models' content. However, analogously to Netland's (2013) argumentation in the context of company-specific production systems, we think this strategy yields the most important and prioritized aspects of the plant role models' content. This is because the case companies can be expected to summarize the content in the form of an overarching "overview document". An important limitation of the representativeness may be that we were unable to capture changes in the documents over time. Dynamic aspects such as creating or changing the models' content are part of the subsequent empirical studies of this thesis. Scott's (1990) last criterion,

[16] Most case study based articles in IMN literature use interviews as primary source of evidence, see e.g., Cheng et al. (2011), Blomqvist and Turkulainen (2019), Lohmer et al. (2021).

[17] Scott 's (1990) criteria for the assessment of the quality of documents are commonly used in social research and recommended in textbooks such as Bryman (2015).

meaning, was met by all documents. We did not encounter any difficulties regarding the clarity and comprehensiveness of the documents.

Regarding the *collection of data*, we followed two main strategies. First, we searched our institute's database for former research collaborations in which either a plant role model was created (labeled "direct" in Table 7), or we were given access to the company's model (labeled "external" in Table 7). With this first strategy, we gathered 17 cases (11 direct, six external).

To increase our database and hence the external validity of this study, we started an additional inquiry (September to November 2022) in a second step. We mainly contacted firms that our institute had prior contact with. As a benefit of sending us their documentation, the firms were granted access to the results in the form of a report. Contacting 65 firms yielded 18 plant role model documentations (i.e., response rate 28%), out of which we excluded six (cf. chapter 4.1.1). Twenty-two firms declined, most because they did not have a plant role model or could not provide them due to data protection. The rest remained silent.

To increase the reliability of our cases, we established a research database that was continuously updated throughout the two data collection steps. The final sample of 29 plant role models and their characteristics are presented in Table 7. All plant role models belong to MNCs headquartered in a high-cost manufacturing country (Ketokivi et al., 2017). Except for three models (two in the US, one in Japan), all headquarters are in German-speaking countries. All major industries are represented in the sample. While most of the models cover all plants of the case companies, eight only apply to one business unit.

Table 7: Database of 29 company-specific plant role models

#	Plant role model name	Plant role unit	# Plant roles	Cover-age	# Plants	HQ	Main industry	Source/Year
1	Individual production center	Production unit	4	BU	5	GER	Optoelectronics	External 2020
2	Plant profiles and modular operating units	Production unit	4	Company	16	GER	Automation	External 2022
3	Plant types	Production site	3	Company	40	CH	Plastics	Direct 2012
4	Pharma network site roles	Production site	3	BU	18	GER	Pharma	Direct 2021
5	Site role framework	Production site	3	Company	12	US	Medical devices	External 2022
6	Network site roles	Production site	3	Company	18	CH	Medical devices	Direct 2022
7	Plant types	Production site	3	Company	>100	GER	Automotive	External 2022
8	Strategic site roles	Production site	4	Company	18	CH	Military	Direct 2022
9	Manufacturing level model structures freedom and duties of plants	Production site	4	Company	23	GER	Automotive	Direct 2017
10	Site roles	Production site	3	Company	9	AUT	Aerospace	Direct 2021
11	Supply chain site categories	Production site	2	Company	48	GER	Security	Direct 2018
12	Site role responsibilities and autonomy	Production unit	3	BU	12	GER	Chemicals	Direct 2018
13	Site roles	Production site	4	Company	8	GER	Semiconductor	External 2022
14	Definition organizational roles	Production site	3	Company	6	CH	Drive technology	External 2022
15	Roles of production plants	Production site	6	Company	50	GER	Automotive	External 2022
16	Factory roles	Production site	3	Company	22	GER	White goods	Direct 2014
17	Plant role concept	Production site	3	Company	32	US	Automotive	External 2022
18	Concept for the definition of site roles	Production site	6	Company	32	CH	Machinery	Direct 2015
19	Specialization – site	Production site	4	Company	18	GER	Sealing components	Direct 2010
20	Unknown	Production site	2	Company	8	CH	Electrical	Direct 2012
21	Responsibilities and tasks of a center of competence	Production site	4	Company	8	CH	Food	Direct 2012
22	Lead factory concept	Production unit	2	BU	5	GER	Traffic technology	External 2014
23	Design principles to arbitrate between locations' production purpose	Production site	3	BU	18	GER	Electrical	External 2020
24	Site role in the production network	Production site	5	BU	5	GER	Electrical	External 2018
25	Roles, tasks, and responsibilities of master and secondary plants	Production site	2	Company	22	GER	Machinery	External 2016
26	Lead factory concept	Production site	3	Company	38	GER	Automotive	External 2022
27	Manufacturing set up	Production site	4	BU	7	GER	Optoelectronics	External 2022
28	Plant roles	Production site	3	BU	53	GER	Automotive	External 2022
29	Technology site roles	Production site	4	Company	29	JP	Pharma	External 2022

4.1.3 Data Analysis

Our research question guided our data analysis strategy. We assigned descriptive codes (Saldaña, 2013) such as "role names" or "plant mission statement" to identify the structural elements of the plant role models' content. To describe how plant role models integrate complementarity across plant roles, we treated the theoretically derived plant role dimensions from our reference framework (e.g., “location advantage” or “plant size”, see chapter 4.2) as a pre-defined list of codes. We then deductively (Miles et al., 2014) assigned the plant role models’ content to these codes. This strategy helps generalize plant role dimensions' relevance across the cases (Eisenhardt, 1989b). Dimensions that were not covered by the initial reference framework were added. The coding was performed and checked several times to increase the reliability of this subjective process.

Besides the subsequent analysis of commonalities and differences across the plant role models’ content, we compared them with existing literature as recommended by Eisenhardt (1989b). The comparison with conflicting and similar literature increases the internal and external validity (Eisenhardt, 1989b) and is critical to addressing the purpose of this study – the elaboration of the theory of plant role models’ content.

Finally, we controlled the results for the *type of industry*, whether the model is *external or internal*, the *number of covered plants*, and whether the model covers only a *BU*. Only minor changes from this analysis arose; they are presented in this study's results and discussion section.

4.1.4 Validity and Reliability

As with any case study research, ours is also subject to methodological limitations. To assess the quality of qualitative research, four tests have been well-established in social sciences – construct validity, internal validity, external validity, and reliability (Yin, 2018). The four tests and the main measures we have taken in this study are presented in Table 8.

Table 8: Measures of addressing validity and reliability criteria

Tests according to Yin (2018)	**Main measures taken in this study**
Construct validity	• Review of constructs and (intermediate) results by multiple peer researchers. • Complementarity dimensions as primary constructs are drawn from a systematic literature review (cf. chapter 4.2). • Review of a draft report of results by key informants.
Internal validity	• Not of importance in this study since no causal relationships have been established (cf. Yin, 2018).
External validity	• Usage of purposive rather than statistical sampling (cf. Bryman, 2015). • Comparably high number of cases from various contexts (i.e., industry, size) with only minor changes when controlling for them. • Enfolding of literature for the interpretation of results (cf. Eisenhardt, 1989b).
Reliability	• Usage of a continuously updated case study database to ensure transparency about data collection and analysis.

4.2 Reference Framework

An external reference is needed to enable the comparison across the plant role models’ heterogeneous content. For this purpose, we develop a theory-based reference framework in this chapter, as Miles and Huberman (1994) and Yin (2003) recommended. To develop our reference framework, we chose to conduct a systematic literature review to gather all important plant role dimensions from the literature while making the process replicable. The following chapter describes the literature review process. Chapter 4.2.2 introduces the reference framework with all relevant complementarity dimensions.

4.2.1 Literature Review Process

The reference frameworks only intend is to enable the external comparison of the plant role model's content (cf. chapter 4.1.3). Hence, the main purpose of the literature review process is to gather relevant articles from the IMN literature that contain dimensions of plant role models. As our latter aim is to assign the plant role complementarity dimensions from practice to the dimensions from theory, we included more rather than fewer articles in case of doubt. Another common purpose of our literature review process is to increase the transparency about selecting and excluding sources (vom Brocke et al., 2009).

From the vast number of articles that recommend how to conduct a literature review (e.g., Baker, 2000; H. M. Cooper, 1988; Levy & Ellis, 2006; Okoli, 2015; Rowley & Slack, 2004; Thomé et al., 2016; vom Brocke et al., 2009; Webster & Watson, 2002), we chose a five-step approach adapted from Thomé et al. (2016) and vom Brocke et al. (2009). As any literature review process, ours is also subjective to a certain degree (Okoli, 2015). This primarily stems from the individual assessment of the author in steps 3 and 4.

In the first step, we selected the databases. We chose the four major databases *Web of Science*, *EBSCOhost*, *Science Direct,* and *ProQuest (ABI/INFORM)* for a keyword search. To ensure a reasonable quality, we only included *peer-reviewed articles*. We did not select any specific set of journals to ensure that no relevant article was excluded. *English* was chosen as the language; the period of time was *all articles until the present*. It was searched in the *abstract, title,* and *key/subject terms*. The detailed search settings for each database can be found in the appendix.

In the second step, we performed a keyword search. The keywords and their respective sources are presented in Table 9. The search was conducted in October 2022. In total, we included 11 different keywords in two categories (cf. Table 9). Keywords related to manufacturing networks have been included to ensure that the articles connect to the overarching topic of IMNs. Keywords related to plant roles are, in turn, likely to contain complementarity dimensions that we can use as an external reference to compare the plant role models from the industry. We decided to include the keyword "subsidiary role*" (cf. Table 9) from the MNC literature stream since they can be regarded to be the predecessor of plant roles (cf. chapter 2.2.1). Moreover, the MNC literature contains a rich number of articles about subsidiary roles that might contain complementarity dimensions, which are also useful for plant roles. We combined each of the manufacturing-related with the plant role-related keywords with an *AND-Operator* resulting in 30 search strings.

Table 9: Keywords for literature search

Category	#	Keywords	Sources
Manufacturing network related	1.1	Manufacturing network*	Cheng & Farooq, 2018; Cheng, Farooq, & Johansen, 2015; Friedli et al., 2014; Miltenburg, 2009; Shi et al., 1997; Vereecke et al., 2006
	1.2	Production network*	Abele et al., 2008; Ferdows, 2018
	1.3	Plant network*	Vereecke & van Dierdonck, 2002
	1.4	Factory network*	De Meyer, A. and Vereecke, A., 2009; Ferdows, 1989
	1.5	Multi-plant*	Chew et al., 1990; Netland & Aspelund, 2014; Schmenner, 1982
	1.6	Multiplant*	
Plant role related	2.1	Site role*	Thomas et al., 2015
	2.2	Plant role*	Blomqvist & Turkulainen, 2019; A. Feldmann & Olhager, 2013; A. Feldmann et al., 2013; Lohmer et al., 2021; Olhager & Feldmann, 2022; Scherrer & Deflorin, 2017; Szász et al., 2019
	2.3	Strategic role*	Ferdows, 1997b; Vereecke & van Dierdonck, 2002; Vereecke et al., 2006
	2.4	Factory role*	Blomqvist et al., 2014; Meijboom & Vos, 2004
	2.5	Subsidiary role*	Baskici, 2019; Hogenbirk & van Kranenburg, 2006; Jarillo & Martíanez, 1990

Note: * allows the databases to include the plural form of each keyword

We reviewed the titles and abstracts in the third step to reduce the high number of hits. Articles from the IMN literature stream were only left in the sample if they were concerned with plant roles. Articles from the MNC literature stream were only included if they had a clear link to manufacturing networks. For example, if the dimensions they used also applied to production units.

The fourth step served to refine the selected articles from the previous step. To do so, *abstracts and full texts* were screened. Besides revisiting if the article had a direct relationship to our research topic of plant roles, articles that do not contain complementarity dimensions were taken out of the literature sample.

In the last step, *alternative searches* were performed. First, a backward search by reviewing the articles' references was performed. Second, a forward search by adding additional sources that cited the remaining articles after step 4. Last, articles were added based on discussions with peer researchers. The same inclusion criteria as in steps 3 and 4 were applied for the alternative searches.

The characteristics of the final selection of 45 articles are presented in Table 10. While most articles deal with plants in IMNs, 15 articles from the MNC literature have been found to have a direct link to manufacturing networks. The dominating methodology among the articles are quantitative surveys, often based on large empirical studies. All 25 direct hits from the keyword search are academic journals or conference papers, i.e., peer-reviewed. Six out of the 20 articles that were derived from the alternative search are magazines (Bartlett & Ghoshal, 1986; Ferdows, 1997b; Nassimbeni et al., 2018), book chapters (Ferdows, 1989; Randøy & Li, 1998) or a working paper (Khurana & Talbot, 1999). Although not peer-reviewed, these articles were included in the literature sample because they were regarded to be highly important for our research topic.

Table 10: Characteristics of the literature sample (45 articles)

Characteristic	**#/% of articles per specification**					
Role type	Plant (IMN) 30 (67%)			Subsidiary (MNC) 15 (33%)		
Research methodology	Single-case 3 (7%)	Multiple-case 14 (31%)	Mixed methods 1 (2%)	Quantitative survey 21 (47%)	Conceptual 5 (11%)	Simulation (2%)
Publication type	Academic journal 37 (82%)	Conference paper 2 (4%)	Magazine 3 (7%)	Book chapter 2 (4%)	Working paper 1 (2%)	
Publication year	1980-1989 3 (7%)	1990-1999 14 (31%)	2000-2009 6 (13%)	2010-2019 19 (42%)	2020-2022 3 (7%)	

A complete list of all included articles and their related search strings can be found in the appendix of this thesis.

4.2.2 Development of the Reference Framework

To derive the relevant complementarity dimensions for our reference framework, we analyzed the literature sample of 45 articles using the qualitative analysis software Atlas.ti. First, we assigned *in vivo* or *descriptive codes* (Saldaña, 2013) to generate a long list of all potential plant role complementarity dimensions. In the second step, the long list of complementarity dimensions was consolidated. This was done by clustering similar dimensions and removing redundancies between dimensions. Moreover, we used subcodes to capture the specifications for the different dimensions (e.g., the *number of SKUs* as a specification of the dimension *product variety*).

To increase the face validity of the reference framework, the results were shown to and discussed with peer researchers several times. Based on the feedback, the consolidation step was repeated until no suggestions for improvement were made anymore. Although the described strategy led to a more objective structure of the reference framework, one may still criticize that some dimensions are missing, overlapping, or inaccurately clustered. However, the reference framework's only purpose is to enable the comparison of the gathered plant role models. Hence, we think the framework's degree of subjectivity is acceptable.

Table 11 shows the final reference framework we use. It contains 28 complementarity dimensions clustered in four categories.

Table 11: Reference framework for plant role complementarity dimensions

Category	#	Complementarity Dimension & Main Source	Exemplary Operationalization
External	1.1	Location advantage (Ferdows, 1997b)	Proximity to market, Access to low-cost factors, Access to skills and knowledge, etc.
	1.2	Geographic location (Demeter & Szász, 2016)	Europe, Americas, Asia-Pacific
Plant mandates from HQ	2.1	Plant focus/specialization (Khurana & Talbot, 1999)	Product plant, Market area plant, Process plant, etc.
	2.2	Plant competence bandwidth (Ferdows, 1997b)	Production, Technical maintenance, Process improvement, etc.
	2.3	Network competence reach (Ferdows, 1997b)	Activity performed for plant alone, Selected plants, Network
	2.4	Plant competitive priorities/performance (A. Feldmann & Olhager, 2013)	Cost efficiency, Quality, On-time delivery, Delivery speed, etc.
	2.5	Market scope (Poynter & White, 1984)	Domestic, International, Global markets
	2.6	Plant decision autonomy (Maritan et al., 2004)	Planning decisions, Production decisions, Control decisions
	2.7	Incentivization basis of plant (Gupta & Govindarajan, 1991)	Individual for each plant, for a group, identical for all plants
	2.8	Products produced by plant (Vokurka & Davis, 2004)	Product A, Product B, etc.
	2.9	Processes/technologies held by plant (Cheng & Farooq, 2018)	Process/technology A, Process/technology B, etc.
Level of plant embeddedness	3.1	Inter-plant people flow (Vereecke et al., 2006)	Intensity of people in- / outflow (e.g., travels of managers)
	3.2	Inter-plant knowledge/information flow (Vereecke et al., 2006)	Frequency of communication (e.g., best-practice sharing)
	3.3	Inter-plant flow of physical goods (A. Feldmann & Olhager, 2019)	Intensity of goods in- / outflow (e.g., components)
	3.4	Internal integration with R&D department (Cheng & Farooq, 2018)	Organizational integration, Communication technologies, etc.
	3.5	Internal integration with purchasing & sales departments (Cheng & Farooq, 2018)	Information sharing, Joint decision-making, etc.
	3.6	Supplier integration (Cheng & Farooq, 2018)	Information sharing, Joint decision-making, etc.
	3.7	Customer integration (Cheng & Farooq, 2018)	Information sharing, Joint decision-making, etc.
	3.8	University & research integration (Corti et al., 2014)	Collaboration with universities, Research centers, etc.
Plant characteristics	4.1	Plant size (Taggart, 1997b)	Sales volume, Number of employees
	4.2	Plant age (Taggart, 1997b)	Young plant, Mature plant
	4.3	Product supply chain position (A. Feldmann & Olhager, 2013)	Component manufacturing, Assembly, etc.
	4.4	Product uniqueness in network (Cheng & Farooq, 2018)	Products produced by one multiple plant(s)
	4.5	Product volume (Khurana & Talbot, 1999)	One-of-a-kind, Low volume, Higher volume, etc.
	4.6	Product variety (Taggart, 1998a)	Number of SKUs, Number of setups required
	4.7	End-product maturity (Arndt et al., 2019)	Organizational experience with the product in years
	4.8	Product customization (Jarillo & Martíanez, 1990)	Engineer-to-order, Make-to-order, Assemble-to-order, etc.
	4.9	Automation level (A. Feldmann & Olhager, 2019)	Manual with low automation, Machine assistance, etc.

Although some of the complementarity dimensions have been mentioned by multiple authors (e.g., location advantage), we only included the main source in Table 11 for better visibility. To give the reader a better understanding of each complementarity dimension, we included an exemplary operationalization in the last column of Table 11. A more detailed list of operationalizations, including the respective source, can be found in the appendix of this work.

We now discuss the complementarity dimensions following the suggested classification into *external factors*, *plant mandates from HQ*, *level of plant embeddedness,* and *plant characteristics*.

4.2.2.1 External Factors

First introduced by Ferdows (1989), the concept of *location advantage (1.1)* has become a common concept across the analyzed literature. While Ferdows (1989) initially suggests three main advantages (cf. chapter 2.2.2), Vereecke and van Dierdonck (2002) propose the most comprehensive list of location factors in IMN literature, adding factors such as proximity to suppliers, social-political factors, etc. As a supplementary dimension, we added *geographic location (1.2)* to the reference framework (cf. Table 11). As stated by Cheng, Fredriksson, and Fleury (2021, p. 1118), MNCs can be expected to “cultivate” their production in three independent regions, i.e., Northern America, European Union, and Asia-Pacific.

4.2.2.2 Plant Mandates from HQ

A critical decision area in the strategic planning of MNCs is which mandates or tasks are given to the plants (Vokurka & Davis, 2004). An important complementarity dimension is the *plant focus/specialization (2.1)*, which goes back to Schmenner's (1982) concept of multi-plant strategies (cf. chapter 2.1.3). Complementarity can be achieved by giving one plant the mandate for a particular product while another one the mandate for a market area, etc. The competence level of plants plays an important role across the literature sample. We use Scherrer-Rathje et al.'s (2014) distinction into *plant competence bandwidth (2.2)* and *network competence reach (2.3)* to enable a more detailed analysis. Whereas the former describes the competencies at plants, the latter describes if the plant performs the competencies for other plants in the network (Scherrer-Rathje et al., 2014). MNCs can use the complementarity dimension of *plant competitive priorities/performance (2.3)* to focus their plants on specific priorities or KPIs (cf. focused factory concept in chapter 2.2.1) so that the plants collectively add to the MNC’s competitive priorities.

Further possible plant mandates found in the literature sample include *market scope (2.5)*, *plant decision autonomy (2.6),* and the *incentivization basis of the plant (2.7)*. Moreover, we decided to add the two dimensions of *products produced by plant (2.8)* and *processes/technologies held by plant (2.9)*. These dimensions can be seen as an additional level of detail of *the plant focus/specialization (2.1)*. They answer the question if MNCs assign specific products, processes, or technologies to their plant roles.

4.2.2.3 Level of Plant Embeddedness

Based on their specific role, MNCs can further be expected to embed their plants differently within the company (i.e., internally) and with their environment (i.e., externally).

We included three complementarity dimensions of the internal inter-plant flows: *people flow (3.1)*, *knowledge/information flow (3.2)*, and the *flow of physical goods (3.3)*. In all these dimensions, complementarity can be achieved by altering the degree of inflow, outflow, or frequency, as Vereecke et al. (2006) suggested. A further part of internal embeddedness is the plant roles' integration with other functional departments: we included the two dimensions of *internal integration with R&D department (3.4)* and *internal integration with purchasing & sales departments (3.5)* as proposed by Cheng and Farooq (2018).

To cover the complementarity across plant roles' external embeddedness, we included the dimensions of *supplier integration (3.6)*, *customer integration (3.7)* as well as the *university & research integration (3.8)*.

4.2.2.4 Plant Characteristics

Besides the described plant mandates, MNCs might differentiate their plant roles on an even more detailed level, i.e., by defining specific characteristics of the plant roles. Although assigned to this category, it must be mentioned that most of the nine complementarity dimensions in this category may also be a plant mandate, e.g., depending on the degree of centralization and autonomy in the MNC's IMN. Two general plant characteristics are related to a *plant's size (4.1)* and *age (4.2),* as mentioned in Taggart (1997b).

Further plant characteristics in the literature sample relate to plant roles' products. Besides the *product volume (4.5)*, *variety (4.6)*, *maturity (4.7)*, and *degree of customization (4.8)*, a plant may be characterized by the *supply chain position of its products (4.3)*. That is, if the plants produce components, perform assembly, or both (A. Feldmann & Olhager, 2013). The *product uniqueness (4.4)* considered by Cheng and Farooq (2018) describes if a plant's products can be found anywhere in the IMN. Lastly, a plant can be characterized by its equipment and machines. A common theme across the articles of our literature sample was the *automation level (4.9)*. MNCs can be expected to alter the degree of automation to countermeasure the increasing wage level (Friedli et al., 2014).

4.3 Results and Discussion

After introducing this study's methodology and deriving a theory-based reference framework, this chapter presents the analysis results of our sample of 29 plant role models. Chapter 4.3.1 investigates the structure of plant role models. Next, chapter 4.3.2 analyzes the complementarity dimensions across the models using the reference framework from the previous section. Finally, chapter 4.3.3 summarizes the results in a conceptual framework that managers can use to develop a plant role model.

4.3.1 Structure of Plant Role Models

From the analysis of the 29 plant role models' content, we identified eight relevant structural elements in decreasing order of their occurrence listed in Table 12.

Table 12: Structural elements covered by 29 plant role models

Rank	Structural Element	#	%
1	Role names	27	93%
2	Textual descriptions	17	59%
3	Frameworks/diagrams	13	45%
3	Allocation of plants	13	45%
5	Plant mission statement	7	24%
6	KPIs	6	21%
7	Evolution path of plant (roles)	5	17%
8	Link to manufacturing strategy	3	10%

4.3.1.1 Role Names

The plant role names seem to be the most essential element of the plant role models as they appear in almost all analyzed models (93%). One of the remaining models uses manufacturing regions (East Europe, West Europe, Asia-Pacific), and the other uses actual plant names in a matrix instead of abstracted role names.

Like most plant role models in the literature (cf. chapter 2.2.3), most models incorporate three or four plant roles (22, 76%). While four models use only two roles, three use even more (five or six). Out of four models with only two roles, three can be labeled as the so-called "lead-factory concept" (cf. Deflorin et al. (2012), Granlund et al. (2019)) in which the lead plants hold the responsibility for innovation incl. prototyping, new process introduction, etc. The scope of these models is restricted to specific technologies or products and hence does not apply to all plants of the cases' IMNs. For those models, one lead plant and a recipient plant are formalized, as Deflorin et al. (2012) described.

The analyzed models tend to include a mixture of roles that cover the three main strategic site reasons suggested by Ferdows (1989, 1997b). Out of the 92 plant roles found in the 29 models, we were able to assign 78 to either of Ferdows's three site reasons access to low-cost production, access to skills and knowledge, and proximity to market. As shown in Table 13, plant roles in the cluster access to skills and knowledge dominate the sample (36%) while the other site reasons (i.e., proximity to market and access to low-cost production) are almost equally present. The extraction of keywords from the role names shows that the case companies make partial use of labels that are also discussed in the literature. For example, *Lead*, *Contributor*, Server Plant in Ferdows (1989, 1997b)) or "Assembly" in A. Feldmann and Olhager (2019). However, the dominating part of the names does not originate from literature (e.g., *Market*, *Mass*). This supports the contingency perspective in company-specific, i.e., that companies develop their own company-specific versions of plant roles. As opposed to certain hardly applicable role labels in literature (e.g., "replaceable plant" in Cheng and Farooq (2018) or "isolated plant" in Vereecke et al. (2006)), Table 13 provides practitioners with real-world examples which may be easier to use in practical implementation.

Table 13: Distribution of role names assigned to Ferdows's (1989, 1997b) site reasons

Access to low-cost production	#	%	Access to skills and knowledge	#	%	Proximity to market	#	%
Cost	**5**	**5%**	***Lead***	**11**	**12%**	***Region***	**6**	**7%**
Advanced Cost Plant	1	1%	Lead Plant	9	10%	Regional Competence Plant	1	1%
Cost-Focused Plant	1	1%	Leading Plant	1	1%	Regional Center of Competence	1	1%
Cost Focus Plant	1	1%	Global Technology Lead Plant	1	1%	Regional Hub (New Subsidiary)	1	1%
Basic Cost Plant	2	2%	***Competence***	**8**	**9%**	Regional Hub (Established Subsidiary)	1	1%
Center	**2**	**2%**	Competence Plant	3	3%	Regional Plant	1	1%
Production Center	2	2%	Global Competence Center	1	1%	Regional Engineer	1	1%
Mass	**2**	**2%**	Competence Plant Innovative Products	1	1%	***Market***	**4**	**4%**
Mass Lead	1	1%	Center of Competence Production	1	1%	Marketeer	2	2%
Mass Sister	1	1%	Center of Competence (Whole Product Group)	1	1%	Basic Market Plant	1	1%
Further	**12**	**13%**	Center of Competence (Part of Product Group)	1	1%	Advanced Market Plant	1	1%
Scale OU***	1	1%	***Engineering"**	**3**	**3%**	***Local***	**2**	**2%**
XL Plant	2	2%	Advanced Production Engineering Center	1	1%	Local Assembly Centers	1	1%
Large Plant	1	1%	Producing Engineer	1	1%	Local for Local Production Plant**	1	1%
Operational Excellence Plant	1	1%	Production Engineering Center	1	1%	***Contributor***	**3**	**3%**
Long-Term Supply Plant	1	1%	**Further**	**11**	**12%**	Contributor Plant	2	2%
Comp. Plant Mature Products	1	1%	Pilot OU***	1	1%	Contributor	1	1%
Extended Workbench**	1	1%	Mother Plant	1	1%	***Assembly***	**2**	**2%**
Application Plant	1	1%	Headquarter	1	1%	Assembly Company	1	1%
Variety Assembly OU	1	1%	The Principal	1	1%	Assembly Plant	1	1%
Specialized Production Plant	1	1%	Production Campus (Americas/EMEA/APAC)	1	1%	**Further**	**7**	**8%**
Producer	1	1%	Master Plant	1	1%	Server Plant	1	1%
			Product Owner	1	1%	Cluster Plant	1	1%
			Innovation and Industrialization Plant	1	1%	Scout Plant	1	1%
			Strategic Plant	1	1%	Customer Specific Plant	1	1%
			Man. Tech. Center	1	1%	Variety Production OU	1	1%
			Specialist Plant (Serial Production)	1	1%	System Assembly	1	1%
						Project Execution	1	1%
Sum:	**21**	**23%**	**Sum:**	**33**	**36%**	**Sum:**	**24**	**26%**

Note: Further plant role names that could not be assigned to one strategic site reason include "Standard Plant (2)", "Emerging Plant (2)", "Start-Up Plant (1), etc. Moreover, terms such as "factory", "site" etc. have been renamed to "plant" for better readability; **Translated from German; ***OU = Operating Unit; differences in your column totals can be explained by rounding errors

4.3.1.2 Textual Descriptions

Seventeen models (59%) use textual descriptions, primarily in the form of (half-) sentences. Out of the 12 remaining models, nine contain frameworks/diagrams. Hence, the case companies seem to decide either way when developing their models. Most textual descriptions are visualized in tables (10 out of 17) as bullet points, whereas four models use text only with full sentences. The high usage of textual descriptions enables the companies to fit the plant roles to their company-specific context and describe each role in depth. A description and visualization based on two dimensions, as usual in most conceptual articles (e.g., Bartlett and Ghoshal (1986), Ferdows (1989, 1997b), Jarillo and Martíanez (1990)) seem hence not adequate to make them usable in real-world applications.

4.3.1.3 Frameworks/Diagrams

Out of the 13 models that use frameworks/diagrams for better visualization, four use matrices along several axes, three radar charts (with differentiating dimensions at the edges), two relationship diagrams, and two process diagrams[18]. Four models use the plant role portfolio proposed by Friedli et al. (2014). However, three of those models are direct. Hence the case companies had a prior engagement with our institute. One model even developed an adapted version of Ferdows's (1989, 1997b) original model with only three roles (case 22).

Compared to the primarily two-dimensional matrices from the literature, the analyzed company-specific ones tend to incorporate more dimensions. Besides Friedli et al.'s (2014) plant role portfolio, such a matrix can be found in Thomas et al. (2015). It allows to map an IMN's plants along multiple dimensions and comparing them with their aspired target levels. Own versions of such a visualization were also found in our sample.

4.3.1.4 Allocation of Plants

Thirteen plant role models assign the as-is position of their multiple plants, including names to the different plant roles. Ten cases out of this sub-sample have multi-plant networks of less than 30 plants. Two of the remaining models only list exemplary plants in each role. One model uses a table to present the number of plants in each defined role (case 28). Seven models use visual elements to present some characteristics of the plants, e.g., the production volume, the product portfolio, or functions present at the plant[19]. Similar visual elements of plants can be found in case studies presented by Friedli et al. (2014, pp. 197–251) or in the most recent version of the textbook (Friedli et al., 2021).

The allocation of plants to the company-specific defined roles allows practitioners for strategic considerations in managing their IMNs. Like Ferdows et al.'s (2016) framework for gauging plant subnetworks, such consideration may include spotting anomalies in allocating products or competencies to plants, the fit of current and future missions, etc. The allocation of actual plants to the defined roles helps hence bringing the manufacturing and network strategy to the plant level.

4.3.1.5 Plant Mission Statement

The notion of plant missions has been discussed in literature from different angles. Schmenner (1982) mainly stresses structural elements (e.g., assignment of products, processes, etc.) in his description of plant "charters", while Khurana and Talbot (1999) define the mission in terms of the competitive priorities (cf. chapter 2.1.2) assigned by senior management. The plant missions in the seven plant role models include various of the

[18] The models incorporate a different number of frameworks/diagrams, some even combined with textual descriptions.

[19] Six out of these models are, however, direct and had hence prior engagement with our institute to get to know the visual elements in Friedli et al. 's (2014) textbook.

above-mentioned elements. They are mostly formalized in a one-liner. The following examples show two typical plant missions:

- "Fulfill orders for products for a defined market without engineering" (case 1)
- "Focus on high volume, low complexity at the lowest possible cost." (case 28)

4.3.1.6 KPIs

As noted by Cheng and Farooq (2018), companies should not only understand the role of each plant but also differentiate their management practices individually to ensure that the plants can achieve their desired role. Plant-role-specific KPIs may be such a management practice. Interestingly, only six models in our sample (21%) use KPIs. The number of KPIs per model ranges between one and five. They mainly measure structural elements of the plant role, such as the hourly labor rate or the capacity utilization, while "softer" KPIs, e.g., to measure the knowledge exchange of plants, are missing.[20]

4.3.1.7 Evolution Path of Plant

Analogously to the allocation of plants (cf. chapter 4.3.1.4), mapping the evolution path in the plant role model helps to address the "interaction" between network and plant levels, which is a major component of a successful IMN (Colotla et al., 2003; Olhager & Feldmann, 2022). Only five models (17%) include evolution paths in their models. These models use two different units to describe the evolution.

Three models use the plant role itself. They contain an explicit hierarchy of roles. For example, case 3 prescribes the development of any start-up plant into a standard within a period of three to five years. The idea of hierarchies between plant roles has already been observed by Ferdows (1989), who found that plants would gradually move toward the lead plant.

The remaining two models use the actual plants of their multi-plant networks as the unit of analysis. Similar to the visualizations in Cheng et al. (2011) and Thomas et al. (2015), they use arrows to indicate the (potential) future position of each plant in several years.

4.3.1.8 Link to Manufacturing Strategy

The link to manufacturing strategy is the least often covered structural element found in the sample of 29 plant role models. In our sample, only three models contain an explicit link to the manufacturing strategy. Concepts such as the network capabilities or competitive priorities (cf. chapter 2.1.2) are used to formalize the manufacturing strategy. The plant roles are linked with their contribution to elements of either the network capabilities (e.g., thriftiness ability, manufacturing mobility) or the competitive priorities (e.g., price, quality, delivery). All three models are direct (cf. chapter 4.3.1.3); hence, an affinity to

[20] A list of all KPIs assigned to the reference framework's categories can be found in the appendix.

concepts may mainly stem from prior engagement with our institute.

4.3.2 Complementarity Dimensions in Plant Role Models

As a central argument of our research, we assume that MNCs use plant roles to implement differentiated structures across their IMNs to respond to various external pressures. Table 14 presents the occurrence of dimensions to differentiate plant roles (i.e., complementarity dimensions) from the reference framework we established in chapter 4.2.2.

Table 14: Complementarity dimensions covered by company-specific plant role models

Rank	Complementarity Dimension	Category	#	%	Rank	Complementarity Dimension	Category	#	%
1	Plant competence bandwidth	HQ	23	79%	21	Inter-plant people flow	EMBEDD	3	10%
2	Inter-plant knowledge/inform. flow	EMBEDD	17	59%		Inter-plant flow of physical goods	EMBEDD	3	10%
3	Location advantage	EXTERN	16	55%		Internal integration with purchasing and sales departments	EMBEDD	3	10%
4	Network competence reach	HQ	13	45%		Degree of HQ-investment*	HQ*	3	10%
5	Market scope	HQ	12	41%		Equipment flexibility*	PLANT	3	10%
6	Plant comp. priorities & performance	HQ	11	38%		Processes/technologies held by plant	HQ	3	10%
7	Product variety	PLANT	10	34%	27	Incentivization of plant	HQ	2	7%
8	Plant focus/specialization	HQ	9	31%		Supplier integration	EMBEDD	2	7%
	Plant decision autonomy	HQ	9	31%		University & research integration	EMBEDD	2	7%
	Product volume	PLANT	9	31%		Digitalization/industry 4.0 level*	HQ*	2	7%
11	End-product maturity	PLANT	8	28%	31	Customer integration	EMBEDD	1	3%
	Product supply chain position	PLANT	8	28%		Plant age	PLANT	1	3%
13	Plant size	PLANT	7	24%		Plant organizational structure*	HQ*	1	3%
14	Product customization	PLANT	6	21%		Strategic plant importance*	HQ*	1	3%
	Automation level	PLANT	6	21%		Number of divisions/BU's supported*	HQ*	1	3%
16	Products produced by plant	HQ	5	17%		Integration with logistics*	EMBEDD*	1	3%
	Internal integration with R&D depart.	EMBEDD	5	17%		Shift system*	PLANT*	1	3%
18	End-product complexity*	PLANT*	4	14%		Production experience*	PLANT*	1	3%
	Value-added scope*	PLANT*	4	14%		Process/technology complexity*	PLANT*	1	3%
	Geographic location	EXTERN	4	14%	40	Product uniqueness in the network	PLANT	0	0%

Note: * Complementarity dimension not listed in reference framework in Table 11. The categories are in accordance with the one introduced in chapter 4.2.2

4.3.2.1 Overall Integration and Dominating Dimensions

Most of the 202 dimensions found across the 29 analyzed plant role models fit into the reference framework. Two dimensions are covered one time (i.e., *customer integration*, *plant age*), and *product uniqueness in the network* was not part of any model at all. Twelve dimensions emerged additionally from the analysis that could not be assigned to the original dimensions of the reference framework. They were hence newly added to Table 14 (indicated by asterisks (*)).

The dimensions of *plant competence bandwidth*, *inter-plant knowledge/information flow,* and *location advantage* seem to be the most relevant, as they are covered in more than half of the analyzed models. Overall, this empirical finding supports the proposed dimensions in two of the literature's most influential plant role models. On the one hand, differentiating plant roles based on external factors and competence in Ferdows (1989, 1997b). On the other hand, to differentiate them based on knowledge/information flows as proposed by Vereecke et al. (2006). The high importance of differentiated levels of competence throughout the IMN can also be observed in literature as not only Ferdows (1989, 1997b) uses this dimension (see, e.g., Khurana and Talbot (1999), Cheng and Farooq (2018), A. Feldmann and Olhager (2019), Blomqvist and Turkulainen (2019)).

The analysis of the dominating dimension of each model[21] results in a diverse picture. While *plant competence bandwidth* and *plant focus/specialization* account for around half of the dominating dimensions (both 45%), there is a wide variety of dominating dimensions across the remaining models. For example, one model defines its three roles along the *plant locations* West Europe, East Europe, and Asia (case 23). In contrast, model 5 defines its criteria along the *plant sizes* in the three roles “standard site”, “large site”, and “XL site”. The diversity in the dominating plant role dimensions fits the contingency aspect in the “company-specific” of plant role models again.

The analysis of the *number of complementarity dimensions* per model results in a similar variance. While on average, 7.6 dimensions are integrated into the models; four models only integrate four dimensions or less (see appendix). Eight models integrate ten dimensions or more. The multi-dimensionality in our empirical sample is in contrast with the often (over-)simplified models in the literature using two dimensions only (e.g., Bartlett and Ghoshal (1986), Ferdows (1989, 1997b), Jarillo and Martíanez (1990)). None of our analyzed models only incorporates two dimensions. The high average of dimensions is hence in line with the call to incorporate multiple dimensions by IMN scholars (e.g., Thomas et al. (2015), Enright and Subramanian (2007), Granlund et al. (2019), Cheng and Farooq (2018)). At the same time, it gives important evidence on how to make the theoretical models from literature operational, as demanded by Mediavilla et al. (2015).

4.3.2.2 External Factors

Out of the category of external factors, *location advantage* ranks number three across the analyzed models. The *geographic location*, in contrast, is only incorporated by four models. Most of the analyzed models' operationalization of *location advantage* fits into one of Ferdows's (1989, 1997b) or Vereecke and van Dierdonck's (2002, pp. 513–514) list of location advantages. Compared to the other location advantages, access to low-cost production is disproportionately named in the models. Besides its importance, this may be because it is easier to operationalize (e.g., through the hourly rates, cf. chapter 4.3.1.6) than most other location advantages. It hence seems that plant roles with access to low-cost production as *location advantage* are more explicitly defined than others as they are

[21] The most relevant or dominating dimension of each plant role model could mostly be detected by analyzing the models’ role names, frameworks/diagrams, plant mission statements, etc.

easier to measure.

4.3.2.3 Plant Mandates from HQ

Six out of the top 10 dimensions belong to the category plant mandates from HQ (cf. Table 14). Hence it seems that the analyzed MNCs use their plant role models primarily to assign and/or communicate different mandates or tasks to its plants through the plant roles.

As already discussed in the previous sections, the most often occurring dimension (79%) is the *plant competence bandwidth*. The definition of the *network competence reach* (45%) seems to go hand in hand with the former. Only one model only integrates the latter one (case 18). Two additional competence types emerge when comparing the models' operationalization of both kinds of competencies with the vertical axis in Ferdows's (1989, 1997b) model. First, the *ramp-up* or *launch competence for new products*. They are particularly prevalent in models that are based on the lead-factory concept, as introduced in chapter 4.3.1.1. Second, the *operational excellence* and/or *continuous improvement competence*[22] from the lean perspective. It seems that some of the analyzed MNCs do not expect all their plants to achieve a standard level of lean maturity. Instead, these MNCs expect their plants to implement a different maturity level based on their role. This finding from the HQ's perspective points in a similar direction as Demeter et al.'s (2017) survey results: the authors find that only certain plant roles (i.e., lead and source plants in Ferdows's (1989, 1997b) model) use lean management with a positive impact on certain performance dimensions.

Market scope as a plant mandate can be found in 12 models (i.e., 41%). The models' operationalization mainly fits the one proposed in the literature (e.g., in Poynter and White (1984), Cheng and Farooq (2018)). A common differentiation across the models is the "local-for-local" or "for the market plant" versus the "global market plant", similarly already described in Poynter and White's (1984) early article about foreign subsidiaries.

Both the dimensions of *plant competitive priorities & performance* (38%) and *plant focus/specialization* (31%) are mainly operationalized as proposed in the literature (i.e., quality, cost, etc. for the former and market area, technology, etc. for the latter). Out of the nine models (31%) that incorporate *plant decision autonomy*, case 24 stands out: it uses a matrix along 27 decision categories (e.g., location strategy, organization development, etc.) and the degree of autonomy (i.e., none, supportive & reactive, prescriptive & proactive, and responsible) to categorize its five plant roles. A similar matrix along "manufacturing decision-making categories" and degree of centralization from a plant's perspective can be found in a study by Olhager and Feldmann (2018).

4.3.2.4 Level of Plant Embeddedness

Plant role models influence both decision layers of IMNs, i.e., configuration and

[22] The notions of operational excellence and continuous improvement stem from the lean literature, some of the most influential publications include Ohno (1988), Rand et al. (1997), Shah and Ward (2003), Liker (2004).

coordination (A. Feldmann & Olhager, 2013). However, the configurational dimensions dominate across our analyzed sample. The low integration of dimensions in the category of plant embeddedness reflects this. Only the dimension of *inter-plant knowledge/information flow* appears under the top 10 dimensions (cf. Table 14). Most of the models either formalize the sharing of best practices[23] or define lead-recipient plant relationships for products and/or technologies (cf. lead-plant concept in chapter 4.3.1.1). The overrepresentation of configurational aspects across our plant role models' content is also mirrored in IMN literature. Scholars highlight that research on IMN coordination is scarce compared to IMN configuration (cf. chapter 2.1.3). However, this essentially seems to be the same in our case companies' considerations when establishing their plant role models.

4.3.2.5 Plant Characteristics

The two most important complementarity dimensions in the plant characteristics category are *product variety* (34%) and *product volume* (31%). As one would expect, the models stress the opposing direction of the two dimensions. That is, plant roles with high volumes tend to have a limited product range and vice versa.

Although used by less than 30% overall, the dimension of *end-product maturity* and *plant size* are the dominating dimensions (cf. chapter 4.3.2.1) for one model each. The former is used by case 7, which differentiates plant roles for innovative, mature, and cost-focused products – the latter by case 5, with a distinction into standard, large, and XL sites. Although categorized as plant characteristics in our reference model, these case companies seem to use the aforementioned dimensions as plant mandates explicitly given by HQ. As described in chapter 4.2.2.4, this may be due to a company-specific high degree of centralization or autonomy.

4.3.2.6 Occurrence of Additional Complementarity Dimensions

Twelve complementarity dimensions emerged from the analysis, which could not be assigned to the dimensions of the reference framework. Only five of these principles occurred more than once (cf. Table 14).

An interesting dimension is the *value-added scope* contained in four models. Some of these models put the product value creation in proportion to their material cost. This proportion can be used to indicate the right choice of a location's average hourly rates (cf. chapter 4.3.2.2). Another interesting dimension is the *digitalization/industry 4.0 level* contained in two models. Like the observation about the lean maturity in chapter 4.3.2.3, we can conclude that a few case companies intentionally differentiate the expected digitalization/industry 4.0 level based on their plants' roles.

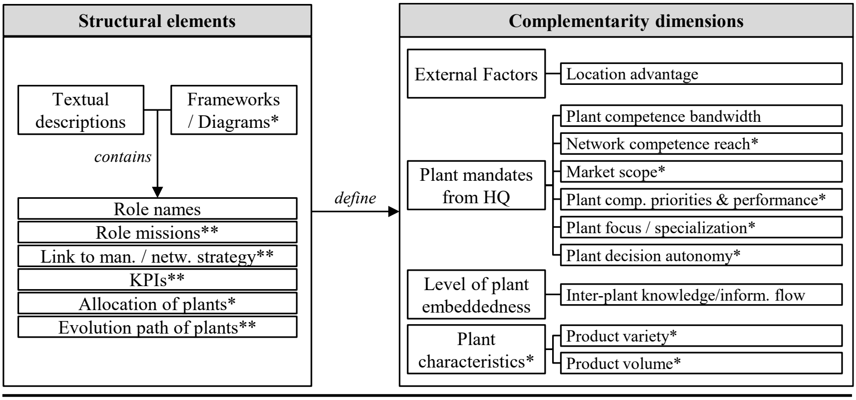
We controlled the sample for differences in the additional complementarity dimensions across the case companies' main industries. However, we did not detect any major

[23] The interested reader is referred to Demeter et al. (2017, pp. 1776–1778) for a more detailed discussion of best practices in operations management.

variances.

4.3.3 Conceptual Framework of Plant Role Model Content

The conceptual framework presented in Figure 7 summarizes the analysis results of our 29 company-specific plant role models' content. It does so by showing the eight structural elements prevalent in the models' content which define through which dimensions companies primarily achieve complementarity across their plant roles and hence in their multi-plant network.



Note: * in 30 to 50% of plant role models covered; ** in less than 30% of plant role models covered

Figure 7: Conceptual framework of plant role model content

Structural elements and complementarity dimensions that are only used by less than 50% of the case companies are marked with one asterisk (*). The ones used by only less than 30% by two asterisks (**). The conceptual framework primarily serves to answer our research question. Additionally, practitioners can use it as a guiding framework, e.g., like a checklist, when defining the company-specific content of a new plant role model.

4.4 Conclusions

The purpose of this chapter's study was to answer the first sub-research question:

What is the content of company-specific plant role models?

We chose a multiple-case design to answer the research question and analyzed the 29 company-specific plant role models for similarities and differences. To increase the generalizability and internal validity, we compared our results to similar and conflicting literature, as suggested by Eisenhardt (1989b). To enable the comparison of the plant models' complementarity, we established a reference framework (Miles & Huberman, 1994) containing 28 complementarity dimensions in four categories.

4.4.1 Contribution to Literature

This study contributes to the literature by elaborating on the theory of plant roles (Ferdows, 1997b). To our knowledge, this is the first study that systematically analyzes the "company-specific" aspect of plant role models from a contingency perspective. With that, we enable the analysis of plant role models and how they are practically used in a “real-world context” (Yin, 2018, pp. 286–287). In addition, we contribute to the understanding of plant roles from a network perspective, as demanded by various IMN researchers (Blomqvist & Turkulainen, 2019; Cheng & Farooq, 2018; A. Feldmann & Olhager, 2013). Last, we deviate from common data collection methods in IMN research, such as interviews, by using documentations as the primary source of evidence. This allows us to analyze a relatively high number of models with manageable effort.

From the data analysis of this study, we derive the following propositions about the phenomenon of company-specific plant role models:

(1) They typically consist of three or four plant roles formalized by the aid of *textual descriptions*, *frameworks,* and/or *diagrams*.
(2) Further important structural elements of the models include *role missions*, the *link to the overarching manufacturing/network strategy*, *KPIs*, the *allocation of plants*, and the *evolution path* of the plants.
(3) The models serve to differentiate the MNCs’ plants into four categories *external factors*, *plant mandates from HQ*, *level of plant embeddedness*, and *plant characteristics*, with plant mandates as the most prevalent one.
(4) *Plant competence bandwidth* is the most important dimension to differentiate plants, followed by *inter-plant knowledge/information flow* and the *plants' location advantage*.
(5) MNCs typically use *multiple dimensions* (seven to eight) to operationalize complementarity across their company-specific plant roles. However, the dimensions prioritized are highly different, which hints at the unique context in which the analyzed MNCs operate.

4.4.2 Managerial Implications

Our study’s implications for managers can be summarized in the following points:

(1) The list of sorted complementarity dimensions (Table 14) and used plant role names (Table 13) can be used as a *benchmark,* and *the conceptual model (*Figure 7) as a checklist when creating a company-specific plant role model.
(2) MNCs' contemporary plant role models suffer from an insufficient usage of plant-role-specific KPIs, which limits their potential to improve HQ-plant and inter-plant deployment.
(3) MNCs' contemporary plant role models overemphasize configurational aspects, preventing them from fully leveraging the coordination aspects of their IMNs.

4.4.3 Limitations and Future Research

As with any case-based study, ours also comes with several limitations (Yin, 2018). While we took care in meeting established best practices of qualitative research such as *accuracy checks*, a *strong theoretical foundation,* and *transparent methods analysis* (Bluhm et al., 2011), the primary usage of documentations poses a major limitation to this study, especially to the construct validity. However, as argued in the data collection section, we think this procedure's advantages outweigh its disadvantages. A second limitation of the used data source comes with the inability to capture *dynamic aspects* such as the creation or change process of the plant role models' content. For example, we could not address the deployment of plant roles and the organizations' respective "cultural readiness" to do so. This limitation will be addressed in this thesis' subsequent studies 2 and 3. Lastly, as for most case study-based research designs, a limitation comes with the *number of cases* and the underlying *selection procedure*. Our sample consists of 29 plant role models based on a purposive rather than statistical sampling logic with case companies exclusively headquartered in high-cost countries. Future research using sampling logic (i.e., large-scale surveys) might incorporate models from low-cost countries and more industries to test our findings. This would enable comparing cultures, industries, company sizes, and further factors. Such a quantitative approach could be used to test the above-stated propositions statistically.

5 Empirical Study 2[24]

The previous empirical study (cf. chapter 4) analyzes the content of company-specific plant role models. In contrast, this chapter's case research aims to explore dynamic aspects (Yin, 2018) associated with plant role models. The research questions (i.e., SRQ2, SRQ3) guiding this chapter are:

How are company-specific plant role models created and deployed? What is the effect on network capabilities?

Chapter 5.1 introduces the methodology used in this study. Chapter 5.2 outlines the within-case patterns of each case, while chapter 5.3 seeks generalization from the cross-case analysis, including the comparison to existing literature. Finally, this study closes, analogously to the previous one, with contributions to literature, managerial implications, limitations, and future research opportunities in chapter 5.4.

5.1 Methodology

Although research on plant roles is rich, there is almost no knowledge about the process of creating and deploying them (cf. chapter 2.3). Hence, we[25] pursue an *exploratory theory-building approach* in this study (Eisenhardt, 1989b; Ketokivi et al., 2017; Yin, 2018). We chose a *holistic multiple-case design* (Yin, 2018) to capture the phenomenon of creating and deploying plant role models under various contextual conditions. Compared to single case studies, studying multiple cases allows for increased generalizability of this study's findings (Voss et al., 2002; Yin, 2018).

5.1.1 Case Selection

In this study, a (sub-) network (Ferdows et al., 2016) of manufacturing plants (i.e., IMN) is a case to which the case company applies a plant role model. *Retrospective cases* (Voss et al., 2002) were chosen as they allow us to oversee the focal phenomenon of this study, i.e., the creation and deployment process of company-specific plant role models. Moreover, this allowed us to capture the effect of the plant role model rollout on the case companies' IMNs after several years.

A vital question in multiple case study research is how to select the cases (Voss et al., 2002). We did so by applying *purposive sampling* (Bryman, 2015) based on two overarching criteria:

(1) *Diversity of cases.* The central argument of this work is that companies create and deploy company-specific versions of plant role models dependent on their contextual conditions. Hence, we aimed for various contextual conditions to enable a meaningful generalization across the cases. We used common characteristics such as industry,

[24] This chapter is based on the following manuscript in preparation: Kaiser and Friedli (2023b).

[25] Analogous to study 2, "we" is used to acknowledge the help of the coauthor of the manuscript.

company size (i.e., revenue), and IMN size (i.e., number of plants) to achieve diversity between the cases.

(2) High degree of implementation. We aim to use this study's cases to draw managerial implications about the beneficial creation and deployment of plant role models. Consequently, we sought to identify cases in which we found a high degree of implementation of the plant role model. This seemed to us an inevitable precondition to observing positive network effects, which enables drawing managerial implications.

To enable a selection that meets the above-described criteria, we used the database of 29 plant role model documentations from empirical study 1 (cf. Table 7 in chapter 4.1.2). While we had all the relevant information to ensure the diversity across the cases (criterion 1), it was particularly challenging to assess the degree of implementation of the plant role models (criterion 2) without interviewing all 29 cases in a time-consuming "trial-and-error" approach. Therefore, we pursued the following strategy: First, we excluded 16 of the 29 cases for which we assumed the plant role models were conceptual only. Considerations that led us to this exclusion included that these models did not include specific KPIs, deployment processes, etc., in the documentation. We contacted the informants (e-mail, telephone) for the remaining plant role models to verify our assumed high degree of implementation. The first criterion and the willingness to participate (four out of five contacted) in our study determined the final case selection.

5.1.2 Data Collection

Compared to study 1 (cf. chapter 4), this study aims to broadly explore the process of creating and deploying plant role models. We consider interviews a highly suitable *source of evidence* for this aim. This stems from the fact that interviews can precisely target our phenomenon and provide rich explanations simultaneously.

Table 15 provides an overview of the cases. As shown in the bottom half, we conducted one main interview with either one (case A, B, D) or two (case C) informants from the network level. The interviews were conducted remotely in January 2023. All interviews were recorded and transcribed in German.

A *semi-structured interview guide* was used to steer the interviews. The structure of the interview guide (i.e., creation process, deployment process, and implementation & network effects) was derived from the research questions. We partially used concepts from the *multi-plant improvement* literature (e.g., Netland and Aspelund (2014), Netland (2012), Netland (2014), Hekneby et al. (2022)) as well as the *IMN literature* (e.g., Lohmer et al. (2021)). Of particular interest to this study is the effect of plant role models on the *network capabilities*. Since its first introduction by Shi and Gregory (1998), the construct of network capabilities has widely been accepted in IMN literature and used in various articles (Flaeschner et al., 2021; Lohmer et al., 2021; Thomas et al., 2015). We used Lohmer et al.'s (2021) breakdown of network capabilities into four categories: *learning ability*, ma*nufacturing mobility/flexibility*, *efficiency ability*, and *strategic targets accessibility*. While all questions about the creation and deployment process were open-ended, we used some closed-ended questions on 5-point scales to capture the effect on network capabilities. A draft interview guide was discussed with peer researchers and subsequently adapted to improve *construct validity* (Yin, 2018). It is attached to the appendix of this work.

To *triangulate* the data from the main interviews (Eisenhardt, 1989b; Yin, 2018), we also used the plant role model documentation from empirical study 1 (cf. chapter 4), *archival records* from a plant leader survey (case A), and a manufacturing strategy document (case C). Moreover, we used data from previous interviews (cases B, D).[26]

As shown in Table 15, our four cases meet the criterion of diversity (cf. case selection) as they represent various industries, company sizes, and IMN sizes.

Table 15: Overview of case characteristics

Case Company*	A	B	C	D
Main Industry	Chemicals	Optoelectronics	Automotive	Automotive
Main Products	Specialty Chemicals	Lasers, Metrology Systems, Optics	Vehicle Parts, Electric Components	Automotive Parts, Other
HQ Location	GER	GER	GER	GER
# Employees	>4,500	>3,500	>30,000	>100,000
2021 Revenue (B€)	>1	>0.65	>6	>20
Case Coverage	BU	BU	Company	Company
# Plants Covered in Case	12	5	50	>100
Plant Roles	Lead Plant Competence Plant Emerging Plant	Leading Plant Comp. Assembly C.** System Assembly C. Project Execution C.	Lead Plant Strategic Plant Operational Exc. P.** Regional Plant Cluster Plant Customer Specific P.	Comp. Plant Innovative Products Comp. Plant Mature Products Cost-Focused Plant
Model Usage Period	2018 - Present	2018 - Present	2014 – Present	Conception Phase
Informants (#)	Director of Supply Chain Management (1)	VP Global Operations and Supply Chain (1)	Director Factory Planning (1), Factory Planner (2)	VP Manufacturing Coordination (1)
Duration of Main Interview (mins)	64	72	75	68

Note: * The case companies in this study correspond to the one from study 1 as follows: A=12, B=1, C=15, D=7; ** C.=Center, P.=Plant

5.1.3 Data Analysis

We analyzed the transcripts from the main interviews using the qualitative analysis software Atlas.ti and performed coding in several steps. First, we *deductively* assigned interview quotes to a pre-defined list of *descriptive codes* (Saldaña, 2013), which was derived from the structure of the interview guide. This procedure allowed us to stay close to the informants' words while ensuring sufficient comparability between the cases for the

[26] In May 2021, interviews with the case companies B (53 mins, same informant as in Table 15) and D (80 mins, same position as informant in Table 15) were already conducted in the area of plant roles. Although, these interviews were not coded, it was listened repeatedly to the recordings from these interviews to fill in missing information from the main interviews (see table 15) conduced in 2023. The 2021 interviews served as a data source of a German practitioner contribution on plant role specific performance targets in IMNs, see Verhaelen et al. (2022).

subsequent cross-case analysis. In the next step, we merged, aggregated, and excluded codes iteratively to reduce the initial list of codes into a manageable number. The results of this coding procedure were complemented by the additional data sources (i.e., survey, archival records, further interviews) and then used for the within-case analysis of this work. To enable the cross-case analysis of similarities and differences (Eisenhardt, 1989b), we subsequently developed *pattern codes* (Saldaña, 2013) based on the informants' quotes from the first coding step. The iteratively adapted coding frame can be found in the appendix of this work.

To increase the quality and validity of our *emerging theory* (Voss et al., 2002), we thoroughly enfolded our findings in the literature (Eisenhardt, 1989b). This was done by comparing our cross-case findings against the literature to identify similarities and conflicts. The result of this analysis is reported in the *cross-case analysis* of this study.

5.1.4 Validity and Reliability

To ensure a high quality of our case research, we paid particular attention to Yin's (2018) four tests of qualitative research. The respective measures taken in this study are summarized in Table 16.

Table 16: Measures of addressing validity and reliability criteria

Tests according to Yin (2018)	Main measures taken in this study
Construct validity	• Usage of multiple sources of evidence (i.e., triangulation), besides main interview data, also documentation, archival records, and additional interviews. • Review and validation of the within- and cross-case analyses by each case company's informant.
Internal validity	• Less of importance to our study as we only partly try to establish causal relationships (i.e., for the effect of plant role model introduction). • Causal relationship between plant roles and network capabilities grounded in prior research (i.e., Lohmer et al., 2021). • Information about causal relationships provided by highly senior managers (i.e., VP or SVP level) overviewing the whole IMN (i.e., network level) rather than single plants.
External validity	• Use of multiple case studies with independent case companies with a high diversity of contextual conditions (i.e., industry, company size, IMN size). • Description of the context (Yin, 2018) and background of the cases' plant role models.
Reliability	• Usage of a case study protocol and a case study database (Yin, 2018) to ensure transparency about data collection and analysis. • Usage of an interview guide (see appendix B) in all main interviews; moreover, recording, transcription, and coding of all main interviews.

5.2 Within-Case Analysis

Before generalizing from cross-case analysis, it is essential to analyze each case as a "stand-alone entity" (Eisenhardt, 1989b, p. 540). This is needed to acquire an in-depth understanding of the unique patterns of every case as a prerequisite for the cross-case analysis (Voss et al., 2002) in chapter 5.3. Each of our four cases (cf. Table 15) is analyzed using the following chapter structure: case introduction, creation process, deployment process, and effects on network capabilities.

5.2.1 Case A

5.2.1.1 Case Introduction

Case company A develops and produces materials and products in the specialty chemicals industry, e.g., from carbon. With about 4,500 employees worldwide, it generates a revenue of approximately €1 billion in 2021. Most of its about 30 manufacturing plants are in Europe, followed by North America and Asia. The plant role model is implemented at one of the case companies' four BUs. This is because, at the time of the introduction of plant roles (i.e., 2018), only one BU had initiated an IMN optimization project. Today, a technological linkage between plants and a different level of capabilities across plants to enable a proper inter-plant exchange is still a basic requirement for plant roles. The BU analyzed is in a strong growth phase and will become a supplier to the fast-growing semiconductor industry. The BU operates an IMN of 12 plants divided into two subnetworks (Ferdows et al., 2016). The first produces materials supplied to the second one, the machining subnetwork.

The main characteristics of case A's plant role model are depicted in Table 17.

Table 17: Main characteristics of plant role model of case A

Complementarity Dimension (Category)	Emerging Plant	Competence Plant	Lead Plant
Location advantage (EXTERN)	Proximity to market or access to low-cost	Proximity to market or access to low-cost	Access to skills & know-how
Plant competence band-width (HQ), End-product maturity (PLANT)	Lowest competence & band-width/number of processes	High competence & limited band-width/number of processes	Highest competence & band-width/number of processes
	-	-	New product/process introduction
Network competence reach, Plant decision au-tonomy (HQ)	Own process engineering, formal review with lead/competence plant for process change implementation	Own process engineering, information of lead plant for process change implementation	Dedicated process engineering resources to support emerging sites (min. 2 FTE)
Plant competitive priorities & performance, Incentivization of plant (HQ)	-	-	Lowest cost of poor quality
	Own cost, quality, delivery objectives	Own cost, quality, delivery objectives	Shared cost, quality, delivery objectives
Inter-plant knowledge /inform. people flow (EMBEDD)	Participation in operations competence teams		
	Own process engineering	Own process engineering	Dedicated process engineering resources to support emerging sites
	-	-	Organizes regular exchange between all sites

The model consists of three plant roles which are applied to product segments within larger manufacturing plants[27]. The *emerging plant* is typically located in a low-cost country or near a market with restricted know-how to protect IP. In contrast, the *lead plant* usually has a high cost exposure, the highest capabilities, and production experience in the network. Lead plants are responsible for supporting other plants. They have dedicated resources to do so. Moreover, in comparison to the other roles, plant leaders of lead plants are incentivized not only based on their own plant's performance but also on the plants they support. The *competence plant* is capability-wise between the other roles and does not usually need support from the lead plant.

5.2.1.2 Creation Process

The creation of the plant role model was triggered by the head of operations (i.e., top-down) of the analyzed BU in 2018. At that time, the BU undertook an IMN optimization project with the help of external consultants. The plant role model was mainly initiated as part of this project because the BU needed a formal mechanism to support "weak" plants in the network. At that time, a Chinese plant had performance deviations, and how to better manage the local processes was unclear. The main question was how to get competent people close to the HQ to take ownership of the Chinese site. Therefore, the plant role model helped to convey the need for a formal support mechanism in the organization. The creation process of the plant role model's content lasted around three months (i.e., steps 1 to 3) and included the following distinct phases:

(1) definition of requirements (i.e., current pain points, the purpose of the model),
(2) comparison of the plants' capabilities in the subnetwork (i.e., who can take the lead plant role),
(3) pilot implementation in the subnetwork with the highest need,
(4) implementation in further subnetworks after around two years[28].

The central operations department has mainly created the plant role model in cooperation with external consultants. Plant leaders of critical plants (i.e., designated to become lead plants) have been involved in workshops and additional interviews. All plant leaders took part in a survey. The survey was used to ask for the plant leaders' opinions about their contribution to the network. The survey topics included the plant's future role, potential improvement opportunities, etc. Free spaces were included to give the plant leaders room for additional thoughts. After several feedback loops, also with central sales, the plant role model was approved by the management team (incl. head of operations) of the examined BU.

[27] One production plant or one production location can have multiple plant roles since the roles are applied to product segments only.

[28] The implementation of the plant role model of another subnetwork of a BU not in the scope of this work has been halted as the affected plants did not have a sufficient variety of capabilities and the model hence did not create enough benefits anymore.

5.2.1.3 Deployment Process

Today, the plant role model is known at all levels of the organization (i.e., top management, network level, plant leader, and white-collar workers in the plants). It can hence be said that the roles are lived daily. Due to various reorganizations, the plant role model is still mainly applied in one BU. However, this BU is responsible for about 40% of the sales of the entire case company. Formally, the head of operations of the BU is the owner of the model. Plant leaders and process engineers at lead plants carry "lead" in their title to formalize the ownership of specific products and/or processes across the network. In the annual plant strategy meetings and the plant strategies, the plant leaders refer to their intended role (i.e., the vision of the plant). In addition, lead plants are responsible for conducting monthly network calls. The agenda of these calls include (1) informing about the current network performance, (2) current network issues, (3) needed support from lead plants, etc. The overarching architecture of the plant role model is only reviewed every three to five years in the operations strategy review meeting.

Quantitative scoring of the plants based on their roles is only intended in preparation for the operations strategy review meeting. The score is based on a competence classification, the number of complex processes at the plant, and further factors. As the scoring is mainly based on a self-assessment of the plants, it gets cross-checked and approved by the operations management board of case company A.

Overall, the implementation degree of the model in the examined BU has been assessed to be high.[29] However, it is not very high because the informant still sees a need to live the roles even more, especially by the lead plants.

5.2.1.4 Effects on Network Capabilities

Considering what has changed since the model's introduction in the examined BU, the informant sees a significant effect on network capabilities, even in quantitative figures. Table 18 shows the effects since the introduction in 2018.

The model has greatly affected learning ability and manufacturing mobility/flexibility. In the context of *learning ability*, the informant believes that, without the model, it would not have been possible to obtain support for the emerging plants. Other learnings effects of the model are (1) improved cooperation in the network, (2) increased understanding of the plant leaders about their role in the network, and (3) improved deployment of investment projects in the network.

According to the informant, the increased *manufacturing mobility/flexibility* directly results from increased learning ability. That is, the lead plants share their product knowledge with the emerging plants, increasing the product mobility between these plants. The direct partnership of lead and emerging plants for specific products can even be observed in the

[29] Based on informant rating on a 5-point-scale: 1 = "very low", 2 = "low", 3 = "medium", 4 = "high", 5 = "very high". The assessment refers only to the BU described. In the other BUs of case company A, the model was either withdrawn or not implemented at all.

scrap cost figures: “We are definitely seeing measurable success in our scrap costs. So, our scrap costs have actually gone down since we have this model.”

Table 18: Effects of plant role model introduction on network capabilities in case A

Characteristics	Improve-ment*	Initial and today’s level*	Informant statement**
Network capabilities			
Learning ability	++	1 → 3	It is a motivating factor that the lead plant, which before always felt deprived and had some inhibition to give their knowledge. Now it has clearly adopted this into its DNA.
Manufacturing mobility/flexibility	++	2 → 4	Flexibility used to be decided top-down and implemented grudgingly. And now, it is no longer implemented grudgingly but rather with a certain pride.
Efficiency ability	o	3 → 3	We have built up a certain overhead in some places. On the other hand, we have, of course, been able to do it without, for example, additional process engineer positions in other plants.
Strategic targets accessibility	+	3 → 4	We had the strategic target of generating market access, and we supported and achieved that with the model. We are now more capable of serving local for local.

Note: * Based on informant rating on a 5-point-scale: 1 = “very low”, 2 = “low”, 3 = “medium”, 4 = “high”, 5 = “very high”; the number of “+” indicates the number of improvement steps on the 5-point-scale; ** Translated from German

Regarding the *efficiency ability*, the informant cannot state whether the positive or negative effects predominate. Hence, the neutral rating (cf. Table 18). On the one hand, the informant observes an improvement in the cost position for the non-lead plants. So, for all plants that benefit from the expertise of the lead plant. On the other hand, the need for designated resource capacity building at the lead plants has been named as a cost driver.

Last, concerning the *strategic targets accessibility*, the informant also sees an effect. This especially holds for establishing new plants in a low-cost environment, as exemplified in the example of China in section 5.2.1.2.

5.2.2 Case B

5.2.2.1 Case Introduction

Case company B employs around 3,500 people worldwide and generated a revenue of approximately €650 million in 2021. As a provider of optical components, company B delivers to the semiconductor, electronics, and medical equipment industries. The plant role model examined covers one BU within the company. The BU focuses on industrial metrology solutions. Its manufacturing network comprises five production locations[30] (i.e., the case) in Europe (Germany, France), the US, China, and India. The BU is organized in a matrix organization: local production directors report to the general manager of the production location (i.e., vertical line) as well as to the VP Global Operations and Supply Chain (i.e., horizontal line) – the informant of this case.

The main characteristics of the plant role model are shown in Table 19. It consists of three main roles along the value chain: component assembly center, system assembly center, and project execution center. These roles apply to production units, i.e., one production

[30] This case uses the term manufacturing “location” to refer to the whole geographical site which can contain multiple production units.

location can have multiple roles. However, the role of the *leading plant* applies to a production location as a whole. Leading plants are co-located with component assembly centers to ensure the proximity of R&D to the component development.

Table 19: Main characteristics of plant role model of case B

Complementarity Dimension (Category)	**Leading Plant**	**Component Assembly Center**	**System Assembly Center**	**Project Execution Center**
Product supply chain position, product customization (PLANT)	-	Make-to-stock of standardized components	Assemble-to-order	Engineer-to-order
Products produced by plant (HQ)	Three leading plants for products A, B, C	Standard components	Individually configured devices	Individually configured engineering systems
Plant competitive priorities & performance (HQ)	-	Delivery ability to system assembly centers, economies of scale, modularity, continuous improvement	Build in time, cost, quality	Build in time, cost, quality
Plant competence bandwidth, plant decision autonomy (HQ)	Product management, R&D, sales, operations, procurement, ownership of product line over the lifecycle	Operations, supply chain management, procurement, responsibility for demand planning	Operations, supply chain management, procurement, manufacturing engineering	Sales, design engineering, product management, project operations
Market scope (HQ)	Unrestricted	Unrestricted	Defined market	Defined market
Inter-plant knowledge /inform. physical goods flow (EMBEDD)	Training, certification, technology roadmap building	Supply system assembly center with components	-	Best practice sharing

There are three *component assembly centers* for three distinct technologies in the network. This plant role is responsible for supplying the system assembly centers with standardized and modular components with high economies of scale. *System assembly centers* are only located close to reasonably large markets (measured by local sales volume) and always have an integrated sales department. Lastly, the *project execution center* fulfills customer-specific orders and has, therefore, its own design and engineering department. Compared to the component assembly center, the latter two plant roles have the same set of KPIs (especially cost, quality, and time), however, with different target values.

5.2.2.2 Creation Process

The creation of the plant role model was triggered by the informant (i.e., top-down) in 2018. Due to a highly unstructured historical growth of the BU's manufacturing network from 2008 to 2014, there was a need for a network-wide optimization of product and responsibility allocation that would enable further network expansion.

As a first step in establishing the plant role model, the literature was searched, and the *hub-and-spoke* network structure (Abele et al., 2008, p. 164) was found to be the most suitable for the BU's manufacturing network. In this structure, the component assembly center is responsible for realizing high *economies of scale*, while the other roles achieve a high *local adaption* through market proximity (Abele et al., 2008). The definition of the criteria for each plant role was mainly performed in a workshop week. Besides global operations and supply chain, R&D, and purchasing but not the local general managers took part in this workshop. Academic thesis workers were assigned to elaborate the model based on the workshop's results. After finalizing the model, one plant role was first implemented at the German plant close to the HQ (i.e., the pilot plant). In a second step, a network-wide consolidation of the product allocations was carried out, which in some cases led to reallocations to fit the new roles of the model. For example, the criterion of *local sales share* is applied to determine whether a production unit can become a system assembly center. To become one of the three plant roles, every production unit has to undergo a five-step *stage-gate process* which includes checklists and specific quantitative measures (e.g., process maturity).

The introduction of the plant role model coincided with the introduction of the before-described matrix organization, which first introduced a *global incentive* share. Having full control over their production locations before introducing the matrix organization and the plant roles, the general managers viewed the change critically in the beginning. However, they started to acknowledge the benefits of the roles with clear incentives after implementation.

5.2.2.3 Deployment Process

Today, the model is known at all management levels of the BU (i.e., top management, network level, general managers, and operations directors), and each production unit is assigned to one plant role. The informant is the formal owner of the model. Under his supervision, four global operations meetings with the local operations directors are held annually. Product and role (re-) allocations are discussed and agreed on in these meetings. Significant changes, such as assigning new plant roles, typically happen in a dialogue between the informant and the local general managers.

There are two main drivers for the plant role assignment. The first is a potential *introduction of new technologies*. In such a case, the fit to one of the three component assembly centers (i.e., "make") is compared to the "buy"-option. Since the component assembly centers hold unique R&D capabilities and product knowledge, a reassignment of this role seldom happens. The second driver is the *market development*. For example, if a specific threshold of the market size[31] (i.e., local sales volume) is hit, establishing a system assembly or project execution center is assessed. The same holds for de-investments in case a lower threshold of local sales volume is fallen below. A requirement to become a project execution center is sufficient prior experience as a system assembly center. As introduced above, all new roles are only released once the audited stage-gate process has been completed.

Overall, the informant rates the implementation degree as high (i.e., a four out of five points). As improvement potential, he names an assessment of the model that goes beyond the current drivers of *market development* and *new technology introduction*.

[31] To assess the profitability of such a new location, the case company relies on a mathematical optimization tool.

5.2.2.4 Effects on Network Capabilities

Table 20 shows the effect of the plant role model on case B's network capabilities since its introduction in 2018.

Table 20: Effects of plant role model introduction on network capabilities in case B

Characteristics	Improvement*	Initial and today's level*	Informant statement**
Network capabilities			
Learning ability	+	2 → 3	Our locations tend to operate independently, and only the German location is responsible for network-wide learning.
Manufacturing mobility/flexibility	+++	1 → 4	We have become much better at that. Compared to before the introduction, wherever we have a system assembly center, we can exchange and support each other because of capacities, missing parts, etc., and so we have very high breathing.
Efficiency ability	+	2 → 3	On the component side, we pursue economies of scale, and on the system assembly side, we pursue customer proximity. In other words, we combine two sometimes contradictory requirements.
Strategic targets accessibility	++	2 → 4	The model is very strong on the customer side. E.g., in rapidly developing markets, we can build a project execution center in half a year due to high standardization.

Note: * Based on informant rating on a 5-point-scale: 1 = "very low", 2 = "low", 3 = "medium", 4 = "high", 5 = "very high"; the number of "+" indicates the number of improvement steps on the 5-point-scale; ** Translated from German

The informant sees positive effects on all four network capabilities. Regarding the *learning ability*, a clear leading plant for each of the three product families has been defined through the plant role model (cf. Table 19). This facilitates the exchange of the former relatively independent operating plants.

The greatest effect has been observed for *manufacturing mobility/flexibility*. The introduction of standards increased the ability to exchange orders. This directly affected the delivery figures at the case company B: "We have the shortest possible lead time for customer-specific solutions. Before we introduced the plant role model, it was that a Chinese person had to travel to Germany to make a mold."

With the introduction of the hub-and-spoke network structure through the help of the model, case B is able to provide improved economies of scale (i.e., *efficiency ability*) and better proximity to customers (i.e., *strategic targets accessibility*) at the same time. Regarding the *efficiency ability*, the informant states that before the introduction of plant roles in 2018, the general managers focused on their local market only. This was not cost-effective from a network perspective because each location had high overheads, even for small production volumes. Based on the figures, the informant describes a positive effect of the plant roles on the contribution margin. Regarding *strategic targets accessibility*, the stage-gate process as a standard procedure facilitates opening new plants and access to strategic markets.

5.2.3 Case C

5.2.3.1 Case Introduction

Case company C is a family-owned automotive supplier with door systems, electronic components, and seats as some examples of its broad product portfolio. With more than

30,000 employees, the company generates a revenue of about €6 billion. The manufacturing network comprises around 50 fully owned plants (i.e., the case) distributed in five regions: North America, South America, Europe, South Africa, and Asia. The two informants of this case work in the IMN department, which has four dedicated employees and some additional project managers in the regions that irregularly take over special projects. The department is responsible for the global production strategy and *global factory planning*, e.g., factory expansion, closures, and relocations. The department has defined a standardized *manufacturing footprint planning process* to deploy the production strategy and implement changes on the factory footprint level.

Case C's plant role model is depicted in Table 21. It combines a technology and a delivery perspective.

Table 21: Main characteristics of plant role model of case C

Complementarity Dimension (Category) – Technology Perspective	**Operational Excellence Plant**	**Strategic Plant**	**Lead Plant**
Plant competence bandwidth (HQ)	Temporary involvement in new topics, improvement on lean projects	Regular development and improvements of processes, products, technologies depending on ramp-up load	Permanent development and improvements of products, technologies, processes, and technical functions
Plant comp. priorities & performance (HQ)	Average operational performance		
Processes/technologies held by plant (HQ)	Sum of different areas of technology in addition to a conventional final assembly		
Product variety (Plant)	Sum of different product groups		
Value-added scope (Plant)	Operational performance - direct material costs		
Complementarity Dimension (Category) – Delivery Perspective	**Customer-Specific Plant**	**Cluster Plant**	**Regional Plant**
Product customization (Plant)	One customer	Limited number of customers	Broad range of customers
Market scope (HQ)	<30km geographical range with high logistics costs compared to production costs	100-500km geographical range with medium logistics costs compared to production costs	>500km geographical range with low logistics costs compared to production costs
Automation level (Plant)	-	-	Low salary or high automation
Plant size (Plant)	Average number of employees		

From the *technology perspective*, operational excellence plants have the lowest capability level, whereas lead plants have the highest. The latter ones are globally responsible for certain products/processes, including dedicated resources for worldwide support. Along the *delivery perspective*, the roles are distinguished according to the number of customers. Customer-specific plants have only one customer and are always located in rented production halls. In contrast, case company C usually owns cluster and regional plants. Although the plant roles along the two perspectives can be combined theoretically, the lead plants are typically regional plants, the strategic plants are either regional or cluster plants, etc. (i.e., downward compatibility).

5.2.3.2 Creation Process

At case company C, the activities around plant roles already started in 2014 with the definition of a *lead plant concept* (cf. Deflorin et al., 2012). At that time, the formalization of lead plants followed the demands of certain plant leaders (i.e., bottom-up), who criticized the considerable support efforts, e.g., for plants that had difficulties launching new products[32]. However, invoicing such support services (e.g., maintenance services) was at the expense of the supporting plants without compensation. Thus, directly negatively affecting the plants' P&L. While the lead plant concept mainly increased the inter-plant exchange of technological know-how, the IMN department recognized that this concept alone was not useful in optimizing product allocations across the whole manufacturing network. Hence, the IMN department defined further roles for the remaining plants that were not appointed lead plants. To do so, the production directors of case company C's divisions (i.e., SVP and VP level), the regions' COOs, and the plant leaders of strategically important plants were consulted to support the definition of additional roles. The approval for the roll-out was finally given by the executive management circle and was communicated to the plant leaders at a global plant leader meeting.

5.2.3.3 Deployment Process

Today, case C's plant roles are primarily deployed in the IMN department's *manufacturing footprint planning process*. This process is triggered by new requirements from the overarching corporate strategy or by other events, such as a large customer request. The process first defines an ideal footprint state utilizing a mathematical model to find an optimal location for a new or existing product. After defining a temporal plant role based on the result of the mathematical model, the release of a structural investment to realize the role follows. This includes the definition of required floor space, available buffers, etc. Finally, the manufacturing footprint planning process is concluded with the opening of a new plant and the structural extension or closure of an existing plant.

In addition to the afore-described event-triggered planning process, the IMN department performs an annual *plant clustering* based on the criteria listed in Table 21. All plants are ranked based on their final aggregated score, compared to their role. Operational excellence plants should, e.g., have low overhead and high capacity utilization. In contrast, lead plants should have many different product groups. Although roughly estimated, fixed plant-role-specific targets do not exist. According to the informants, this has the advantage of more flexibility in the model, especially when considering product allocations. The plant leaders are incentivized in their variable salary component on the scoring of their plant and have a high interest in a good scoring performance.

The architecture of the plant role model has not fundamentally changed since its introduction. Soon, however, the model should be expanded from a pure consideration of production areas to include test, trial, and administrative areas, which will require the definition of new roles.

Overall, the informants consider today's implementation level of the plant roles to be very

[32] At the time between 2000 and 2010, the case company's manufacturing network expanded by a double digit number of new plants partly leading to product launch difficulties and an increased need for support from more "experienced" plants.

high as “the role of the plant is the plant strategy”.

5.2.3.4 Effects on Network Capabilities

Table 22 lists the effects of the plant role model introduction on case C’s network capabilities.

Table 22: Effects of plant role model introduction on network capabilities in case C

Characteristics	Improvement*	Initial and today’s level*	Informant statement**
Network capabilities			
Learning ability	++	2 → 4	Through the model, we have established lead plants in each region. And I do believe that a Chinese plant can teach a Chinese plant things differently than if the German always does it.
Manufacturing mobility/flexibility	o	3 → 3	Half of our products fall out because you can't relocate them anyway. They were just as difficult to relocate or replace before the introduction of the plant roles as they were afterward.
Efficiency ability	++	2 → 4	I think we have become much more efficient now about our roles and understanding of roles because we are looking very closely at product allocations, for example.
Strategic targets accessibility	+	3 → 4	We now have lead plants in every region, which used to be exclusively in high-cost countries but are now also in best-cost countries, where we now also have much more production space.

Note: * Based on informant rating on a 5-point-scale: 1 = “very low”, 2 = “low”, 3 = “medium”, 4 = “high”, 5 = “very high”; the number of “+” indicates the number of improvement steps on the 5-point-scale; ** Translated from German

For the majority of the improvements (especially for the learning and efficiency ability), the informants acknowledge a causal relationship to the plant roles. However, since the model introduction was already in 2014, the effect on the capabilities may partly be explained by the significant growth of case company C’s manufacturing network. Regarding the *learning ability*, case company C established lead plants outside their home region (i.e., close to their HQ). This led to a better regional exchange with fewer cultural barriers (cf. statement in Table 22). While increased network thinking is considered a primary advantage, there is also a drawback: the structure is centrally imposed and prone to overlook local conditions and changes.

While *manufacturing mobility/flexibility* plays a minor role in case C, the effect on the *efficiency ability* has been rated high. In the opinion of the informants, without the plant role model, case C’s plant leaders would naturally strive for greater complexity to make their plants more important in the network. The informants used an example several years before the model's introduction: in that example, new customer orders were quoted between plants, and the lower cost plant received the order. Since the model's introduction, such competition has decreased significantly[33], and product allocation is performed more efficiently than before.

Last, a minor effect on the *strategic targets accessibility* has been named. By introducing the plant role model, network management has more strategically dispersed its managerial skills in the manufacturing network (i.e., by lead plants in each region).

[33] In the contract competitions, some plants calculated with the most inexpensive hourly wage instead of the average one. The project costs subsequently incurred often far exceeded the calculated costs.

5.2.4 Case D

5.2.4.1 Case Introduction

Case company D is a large engineering and technology conglomerate with more than 100,000 employees and a revenue of more than €20 billion. The company is organized into several industry sectors, including one for automotive. Each of case company D's divisions operates at least one manufacturing subnetwork (Ferdows et al., 2016) with a typical size of three to 15 own plants. Around 80% of the more than 100 worldwide plants serve one division only, while the remaining ones serve multiple divisions (i.e., "zebra plants"). The informant works in the central IMN department, which is responsible for all the case's subnetworks. Exemplary tasks of this department include plant location selections, investment decisions, and crisis management (e.g., management of the corona crisis). Besides this IMN department, there are separate IMN departments in every division in charge of more tactical decisions (i.e., divisional IMN departments).

The company-wide plant role model of case company D is depicted in Table 23.

Table 23: Main characteristics of plant role model of case D

Complementarity Dimension (Category)	Competence Plant Innovative Products	Competence Plant Mature Products	Cost-Focused Plant
Location advantage (EXTERN)	High proximity to suppliers, image to external customers, access to talents & employees with university degree	Sufficient proximity to suppliers, access to talents & employees with university degree	Best cost access
Plant competitive priorities & performance (HQ)	Medium – High	High	High
	Delivery, quality, cost performance		
	High	Medium	Low
	Innovation, digitalization performance		
Inter-plant knowledge/information flow (EMBEDD)	High	Low to Medium	Low
	Extent of activities in the manufacturing network		
University & research integration (EMBEDD)	Medium – High	Medium	Low
	Cooperation with universities and involvement with competence centers		
End-product maturity (PLANT)	Low	Medium	High
	Portfolio age, range		
Product variety (PLANT)	High	Medium	Low
Plant size (PLANT)	All plant roles should range within min/max limits		

The two roles, *competence plant innovative products* and *competence plant mature products*, are historically located in high-cost environments, whereas the *cost-focused plant* provides the company with best cost access.[34]

5.2.4.2 Creation Process

Case company D started by introducing a lead plant concept (cf. Deflorin et al., 2012)

[34] Since the plant role model is still in the development phase, the role names are working titles only and may be changed in the further process.

more than 20 years ago. As a result of its significant growth, there was a need to formalize the responsibilities and competencies across the large manufacturing network. Today, each subnetwork has one lead plant responsible for setting standards, industrializing new products, etc. For specific technologies/processes, *centers of competencies* are defined additionally.

The creation of the new plant role model (cf. Table 23) was initiated by the IMN department in 2020 (i.e., top-down) without any specific project order from top management. Although no single main reason was mentioned for the initiation, there were various considerations: On the one hand, the informant mentioned that about a third of all plants have a center of competence function for a specific product, which is considered to be a misbalance. Moreover, to realize its *decoupling strategy*, the central IMN department wanted to achieve a better regional distribution of its competencies, which needed a reallocation of specific products/processes.

The central IMN department followed no structured process to create the new plant role model. Instead, after drafting the model in workshop sessions, it was shown to multiple stakeholders in the organization, such as the directors of the divisional IMN departments or to plant leaders of the larger plants (i.e., SVP and VP level). As the model is not yet been formally rolled out in the organization, the IMN department is currently initiating a pilot formalization of the model in the biggest sector, namely the automotive sector. The reason for choosing this sector is the greatest need to separate the industrialization competence from the lead plant to implement the decoupling strategy. The final decision on whether to fully deploy the model is to be approved by the case company's executive board.

5.2.4.3 Deployment Process

The new plant role model is known to the divisional IMN department directors and has been shown to the executive board. However, as it has not yet been formally introduced and is unknown to the plant leaders. From the informant's perspective, however, the model is already implicitly anchored in the organization.

In case of a formal introduction of the model, the IMN department would hold the method ownership while assigning plants to roles, and their evaluation would be the responsibility of the divisions. The most prevalent use case would be reassignments of lead plants, new product/project allocation, industrialization competence allocation, etc. It is planned to use it as part of the *annual site planning process* in the divisions. A second use case is making product allocations explainable to union representatives, which is already done in certain meetings.

The informant is critical of a quantitative measurement of plant-role-specific indicators, as he fears that the plants would then primarily focus on achieving the highest score. In his view, initiating a dialog about strategic fields of action is more important. For example, how high the proportion of more competent plant roles (cf. competence plant innovative products and competence plant mature products in Table 23) in China should be in 10 to

15 years from now to serve the Chinese market in a targeted way. The central IMN department is working on a key figure to specify a balanced number of plants in each plant role.

The overall implementation level of the new plant role model is considered to be medium. On the one hand, it is not yet formally introduced in the organization. On the other hand, the informant sees a significant practical implementation. In the event of a favorable decision by the executive board, the informant estimates the time required for a roll-out to be only five to six months since the model is already widely known at the SVP and VP levels.

5.2.4.4 Effects on Network Capabilities

With reference to the early establishment of multiple divisional IMN departments with a high workforce for manufacturing network management, the informant consistently rates the company’s network capabilities as being high.[35] At the same time, he states that if nothing further were done, this high level of manufacturing network maturity would be endangered and eventually decline. This is the essential motivation for introducing the new plant role model.

Asked about the model's main advantage, the informant states, “the advantage is transparency, and the disadvantage is transparency.” On the positive side, in the context of *learning ability*, the team thinking approach and a better understanding of each plant's contribution to the company's success are named. On the negative side, in the event of a transfer of competencies, he states that the plant or the plant leaders affected by a competence reduction would have formalized this immediately. This could make personal exchange about such far-reaching measures more complex, leading to unintended tensions between the plant and network levels.

5.3 Cross-Case Analysis

The analysis of cross-case patterns is vital to enhance the external validity of case research (Voss, 2010). The selection of pairs of cases and its visualization in two-by-two cells helps to identify similarities and differences across cases (Miles & Huberman, 1994; Voss, 2010). Figure 8 depicts our four cases along the two axes degree of implementation and IMN size.

[35] Analogous to the previous cases, the network capabilities were evaluated on a scale from 1 to 5. However, this was only done in the as-is status, as the model had not yet been formally introduced into the organization and therefore did not yet have an impact. The result of the evaluation: Learning ability = 5, Manufacturing mobility/flexibility = 4, Efficiency ability = 4, Strategic targets accessibility = 5.

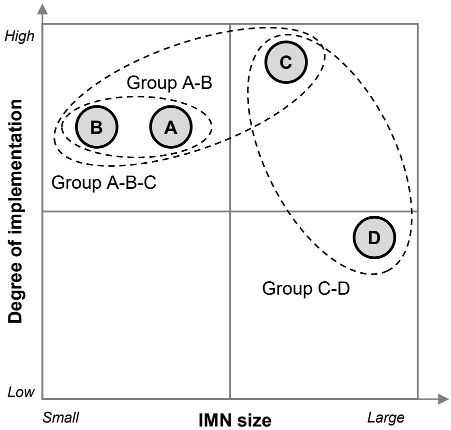


Figure 8: Categorization of the four analyzed cases

The operationalization of the degree of implementation of the cases' plant role model is based on the self-assessment of the informants on a scale from 1 to 5 (cf. chapter 5.2). While the plant role models of cases A, B, and C are implemented and known across all relevant hierarchical levels of the organization, case D's model is still in the conception phase. In contrast to most two-dimensional models from theory, and as suggested by Thomas et al. (2015), all cases' plant role models integrate multiple dimensions. This provides adequate variety to make the models operational and practical for the case companies' IMNs (cf. Cheng & Farooq, 2018; Mediavilla et al., 2015; Vereecke & van Dierdonck, 2002).

As shown in Figure 8, the size of the IMNs to which the models are applied varies significantly across the cases. While cases A and B are smaller networks (i.e., five and 11 plants), case D consists of multiple subnetworks (Ferdows et al., 2016) with more than 100 plants. Case C is with its 50 plants in between the other cases. To facilitate the analysis of within-group similarities and intergroup differences (Eisenhardt, 1989b) in the subsequent sections, three groups of cases with similar characteristics can be distinguished (cf. Figure 8):

(1) *Group A-B.* Although operating in different industries (i.e., chemicals and optoelectronics), the case companies have a comparable size (<5,000 employees and revenue ~€1B). Both case companies do not have a dedicated IMN department. Identically, the case companies' plant role models consist of three main roles, were initiated in 2018, are only rolled out in one BU, and apply for production units rather than a whole production location. Using the network capabilities in 2018 (i.e., before the plant role model introduction) as an indicator, the initial maturity of IMN management can be described as rather low in these cases.

(2) *Group A-B-C.* Cases A, B, and C share a high degree of implementation of the plant role model. The model is formally anchored in the organization and known across all relevant hierarchical levels (i.e., top management, network management, and plant leaders) in all three cases. Moreover, plant role-specific KPIs are used in all three cases.

(3) *Group C-D*. Case companies C and D operate in the automotive industry. Both companies can be distinguished from case companies A and B by their significantly larger size. Especially case company D (>100,000 employees and revenue >€20B). Identically, the plant role models apply to whole production locations and the whole company rather than single BUs. In addition, both companies have multiple years of lead plant legacy (Deflorin et al., 2012) and operate a dedicated IMN department[36]. Combined with the network capabilities assessment, this hints at a very high maturity of the case companies' IMN management.

The following sections describe the cross-case patterns of the cases and groups of cases. The results are discussed in comparison with the literature.

5.3.1 Creation Process

The main characteristics of the creation process across the cases are summarized in Table 24. Differing *motives* to establish a company-specific plant role model can be observed. While case A's motive mainly lies in fostering the coordination across plants, the other three cases primarily target the configuration. For example, through the optimization of product and/or competence allocations. The differing motives to establish plant roles align with Blomqvist and Turkulainen's (2019) argument that the definition of plant roles depends on many different context factors in an IMN (e.g., IMN size, manufacturing strategy). This also supports the central argument of this work that there is no-best-way to create and deploy plant roles.

As shown in Table 24, the plant role models across the cases were established relatively recently (i.e., five to 10 years ago). While plant roles have been discussed in the literature since the late 1980s (Ferdows, 1989a), the phenomenon of company-specific plant role models seems relatively new. As in the automotive cases (i.e., cases C and D), it seems that MNCs have first adopted the concept of lead plants (cf. Deflorin et al., 2012) before considering the introduction of models with multiple plant roles (i.e., holistic plant role models). Lead plant concepts ordinarily only target selected plants in an IMN. The weakness is that most of the IMN's plants are not explicitly assigned to roles. Departing from the lead plant concept, introducing "holistic" plant role models seems to be a logical step.

[36] As described in case D (cf. chapter 5.2.4), the company even operates own IMN departments in each of its divisions.

Table 24: Summary of the creation process across the cases

Characteristics	A	B	C	D
Main initiation motive	Formalize support need for “weak” plants	Realize hub-and-spoke network structure	Optimize product allocation and standardize factory planning	Decouple competencies in region-for-region approach
Main targeted IMN dimension	Coordination	Configuration	Configuration	Configuration
Initiation date	2018	2018	2014	2020
Initiation function	External consultant, Head of BU operations	VP Global Operations and Supply Chain	Plant leaders*, IMN department	IMN department
External support	Yes	Partly	No	No
Mean of creation	Workshops, structured interviews, survey	Workshop week	Conceptual meetings, unstructured interviews	Conceptual meetings, unstructured interviews
Involvement of functions/plants	Operations, sales, plant leaders	Operations, R&D, purchasing	Operations, organizational development, selected plant leaders	Operations, selected plant leaders
Rollout time	<3 months	~2.5 years	<3 months	not yet rolled out

Note: * Only for the lead plant concept prior to the holistic plant role model

Across all cases, there was no explicit mandate or work order from the top management to create a plant role model. The models were initiated on the network level. Case C is an exception: the lead plant concept was actively demanded by those plant leaders (i.e., plant level) who were not financially compensated for the technical support for other plants at that time. However, the holistic plant role model was later initiated by the network level as in the other cases. According to our informants, creating a plant role model is only useful if the affected IMN fulfills certain criteria. The presence of a technological link between the plants is mentioned in cases A and B. Without such a link, the IMN’s plants operate independently (cf. “isolated plants” in Vereecke et al. (2006)), and there is no need to establish interdependent plant roles.

Moreover, case A shows the importance of varying competence levels across the IMN’s plants exemplarily to create a plant role model. The inability to take over responsibilities for other plants (i.e., lead plant) led to the elimination of the whole plant model in one BU of case company A. As an example of a huge organization, case D shows that the acceptance and commitment of union representatives is an essential prerequisite for the plant role model creation.

While the smaller cases (i.e., cases A and B) used external consultants to create (i.e., case A) or challenge (i.e., case B) their plant role model, the other cases used the workforce of their dedicated IMN department. Across all cases, the operations function was in charge of creating the concept of the model, while other functions, such as R&D, purchasing, etc., were explicitly involved in the challenge and approval of the defined concepts. A common pattern across the cases is the strong involvement of plant leaders via interviews, workshops, etc. Predominantly, plant leaders of the larger or more competent plants were involved. An exception is case B: the network level made a conscious decision not to involve the plant leaders (i.e., the general managers of the local legal entities), as they were purely locally incentivized at that time. According to the informant, an early involvement would have endangered the aim to develop a global optimal. However, case B’s informant states that there was a critical phase in the rollout of the plant role model, which involved the plant leaders having to give up some of their autonomy.[37]

As shown in Table 24, the rollout time varies greatly between the cases. In cases A and C, the rollout primarily consisted of communicating the new roles to the plant leaders and the top management's formal release of the roles. In contrast, in case B, the new plant role model initiated a structural reconfiguration of the whole manufacturing network into a hub-and-spoke network structure (Abele et al., 2008). The whole reconfiguration took about 2.5 years (cf. Table 24).

5.3.2 Deployment Process

Table 25 summarizes the deployment process across the examined cases. As already introduced in the previous section, both automotive cases (i.e., cases C and D) had a lead plant concept before the introduction of the current plant role model, while cases A and B started directly with a holistic plant role model, however, relatively late (i.e., 2018). Nevertheless, all rolled-out models (i.e., cases A, B, and C) are widely known in the cases' organizations (i.e., top management, network level, plant leaders). A particularity is case A: the plant role name is carried in the job titles of certain white-collar workers on the plant level (e.g., process engineer). As a result, the plant roles are even known among the plant employees.

In all cases, the *ownership* of the plant role models lies in the operations function at the network level. The automotive cases with their dedicated IMN department (i.e., cases C and D) only have the method ownership. The responsible managers in the direct reporting line of the plant leaders (i.e., production directors of divisions or similar) decide on changes to plant role assignments.[38]

The *use cases* of the plant role models differ across the examined cases since they are primarily derived from the case companies' existing meeting structures. In cases A and B, the model is used as a framework for discussions and final approvals for role assignments during the annual plant leader conferences. Explainable by their significantly larger network size (cf. chapter 5.3), the automotive cases use their models more centrally. That is, the models are used for strategic network planning and the derivation of consequences for future plant development. This is mainly done by the automotive cases' dedicated IMN department, with less involvement of the plant leaders than in cases A and B. Noteworthy is case A: monthly network calls led by the lead plants are conducted to strengthen the collaboration between the plants.

[37] In case B, the introduction of the plant role model coincided with the introduction of a global matrix structure, so that local production directors not only reported to the local general managers but also to the global operations function (i.e., the informant).

[38] Case D's holistic plant role model is still under construction, hence all deployment-related characteristics described here are only planned ones.

Table 25: Summary of the deployment process across the cases

Characteristics	A	B	C	D
Lead plant concept legacy			X	X
Holistic role conception	X	X	X	X
Dedicated roll-out	(X)	X	(X)	
Dedicated deployment	X	X	X	
Awareness	Top management, network level, plant leaders, white-collar workers	Top management, network level, plant leaders	Top management, network level, plant leaders	Network level
Model ownership	Head of BU operations	VP Global Operations and Supply Chain	IMN department	IMN department
Main use cases	Network calls (monthly) Plant strategy meetings (yearly) Operations strategy review (every 3-5 years)	Plant management meeting (monthly) Global operations meeting (quarterly)	Plant clustering process (yearly) Footprint planning process (as required)	Divisional site planning process (yearly)
Role-specific score	X	X	X	
Boundary (target) criteria	X	X	(X)	
Exemplary criteria	# of complex processes Competence score	Yearly sales volume Local market size	Free areas Overhead share Capacity Utilization	Competence share per region Sales share per region
Mean of scoring	Self-assessment	ERP data	ERP data	ERP data
Frequency of assessment	As required (3-5 years)	Yearly	Yearly	Yearly

Note: (X) denotes partly included phases or criteria

According to Lohmer et al. (2021), assigning plant roles to plants can support the deployment of the network strategy over a longer time horizon. In all our rolled-out cases (i.e., cases A, B, and C), the plants (i.e., case C) or the production units (i.e., cases A and B) are indeed assigned to a specific plant role. Prior research implies that MNCs assign multiple roles to plants, e.g., for different products (Blomqvist & Turkulainen, 2019; Ferdows, 1997b; Vereecke & van Dierdonck, 2002). In this regard, our cases show a mixed picture: While case D's still operating lead plant concept indeed defines lead functions for different products at the same plants, case C's holistic plant role model specifies one plant role only for each plant and production location. In the smaller cases (i.e., cases C and D), only one plant role is applied. However, this is done on a production unit level so that one production location can have multiple roles. Hence, creating a plant role model seems to force network management to define and formalize a clear role for each plant. In case there are multiple roles at one location, as assumed by Ferdows (1997b) and Vereecke and van Dierdonck (2002), it seems that the network management resolves this contradiction by dividing the plant into several "plants-within-plants", each with a clear assigned plant role (cf. "focused factory" in Skinner (1974)).

For all rolled-out models, *specific scores* related to the plant role are used for an assessment. In cases B and C, these scores are calculated yearly and based on ERP or CRM data, whereas in case A, the scores are calculated based on a self-assessment of the plant leaders with irregular frequency. In line with prior research that assumes different management systems for different plant roles (Blomqvist & Turkulainen, 2019; Cheng & Farooq, 2018; Maritan et al., 2004), cases A and B even use specific boundary (target) criteria for each plant role. That is, there are specific thresholds of scores that must be fulfilled to be able to adopt a certain role within the plant role model. In case C, there are implicit expectations by the IMN department regarding the scoring; however, these are not formally written down.

In Mediavilla et al. (2015), the Akondia model for assessing plant roles and roadmap creation can be found. The model builds its role assessment primarily on analyzing plants' competencies. While the *competence assessment* also plays an important role across our cases' scores (e.g., cases A and D, as shown in Table 25), the competence assessment alone seems insufficient. Further factors, such as market size (i.e., case B) and overhead structures (i.e., case C), may not be less important. These factors depend highly on the cases' context, which again favors the no one-best-way perspective on plant roles (i.e., contingency perspective) as suggested by Blomqvist and Turkulainen (2019).

In all cases in which the models are rolled out (i.e., cases A, B, and C), no major changes have been made to the overall architecture since the rollout. However, the models are subject to changes in the upcoming years in cases B and C. In case B, the scoring of the plant roles is strongly market-driven. Therefore, an efficiency perspective should be added in the future. In case C, an expansion of the plant roles to include administrative locations is intended.

5.3.3 Effects on Network Capabilities

Table 26 ranks the network capabilities according to the mean of the improvements across our four examined cases. It shows that introducing plant roles can significantly affect network capabilities, even within a few years after the rollout[39]. This outcome supports previous findings on the positive influence of plant roles on network capabilities (Lohmer et al., 2021; Scherrer & Deflorin, 2017; Thomas et al., 2015). It hence also backs Lohmer et al.'s (2021) call to network managers to use plant roles to acquire desired network capabilities.

[39] In the cases A and B, the improvement was measured against the year 2018, in case C against 2014 (i.e., before the introduction of the plant role models).

Table 26: Improvement of network capabilities and indirect effects across the cases

Rank	Network capabilities	Improvement in cases A	B	C	D	Mean	Exemplary positive (+) and negative (-) indirect effects
1	Learning ability	++	+	++	o	1.25	• Overcome local focus of plant leaders (+) • Understanding of the role by plant leaders (+) • Improvement of knowledge transfer (+) • Reduced competition between plants (+) • Generate support for weak plants (+)
1	Manufacturing mobility/flexibility	++	+++	o	o	1.25	• Improvement of quality and delivery levels (+) • Realization of capacity balancing (+) • Overcome decentral solutions (+) • Replace spare parts easier due to higher standardization (+)
3	Strategic targets accessibility	+	++	+	o	1	• Plausible product allocation (+) • Generate additional market access (+) • Decreased time to build new sites/lines (+) • Building balanced capabilities in the network (+)
4	Efficiency ability	o	+	++	o	0.75	• Generate network-wide technology synergies (+) • Reduce local overheads (+) • Additional headcounts for lead plants (-)
	Overall network capabilities (Mean)	1.25	1.75	1.25	0		• Improved network thinking and team approach (+) • Transparency about roles in the network (+) • Risk that plants do not find themselves in their role (-) • Oversimplification of plants into roles (-) • Cementation of status quo of plant assignment (-) • Top-down restriction of individual plant development (-)

The last column of Table 26 lists exemplary indirect effects associated with each network capability that the cases' informants have named. Evidently, the positive effects marked by a (+) dominate over the negative ones marked by a (-).

Learning ability has improved in cases A, B, and C. As shown in the last column of Table 26, plant role models can be used to positively influence the critical interaction between the network and plant level (Olhager & Feldmann, 2022) by better involving plant leaders. They can be used to provide plant leaders with a clear mission so that they understand their contribution to the overarching network strategy, as called for by Wiech and Friedli (2021). The creation of a plant role model forces the network management to define which plant (roles) have an active or "hosting" mission (cf. Vereecke et al. (2006)) in spreading knowledge in the IMN. This fosters *knowledge transfer* in our cases on the positive side. A disadvantage, however, is that dedicated resources in the form of FTEs have to be made available that are responsible for spreading the knowledge. This can negatively affect the efficiency ability (cf. Table 26). As in our case A, the need to invest in resources at the plant level (i.e., primarily the lead plant) is also a theme in Wiech and Friedli (2021). In their article, plant leaders highlight that "strategy slides or nicely labelled plant roles" (Wiech & Friedli, 2021, p. 1180) are insufficient to close capability gaps between plants.

The network capability *manufacturing mobility/flexibility* has improved significantly in the non-automotive cases A and B. In both cases, introducing the plant role model has increased the standardization for similar products/processes between plants, enabling them to allocate products more flexibly in their networks. Case A shows how joint incentivization across plants for similar products/processes can directly impact operational figures such as quality cost.

Similar to manufacturing mobility/flexibility, improving the *strategic targets accessibility* can primarily be traced back to a higher degree of standardization in the network. On the one hand, mapping the current status of the plants within the plant role framework can help network managers identify strategic gaps, e.g., missing access to strategic markets with certain products (see case A). On the other hand, the standardized description of plant roles can enable companies to faster build new plants in new markets with higher demand (see case B).

Indirect effects associated with the *efficiency ability* are, e.g., network synergies and the reduction of local overheads. The network synergies theme aligns with Khurana and Talbot's (1999) idea of reducing redundancies by building complementary skills in IMNs. By doing so, conflicting goals can be addressed simultaneously, as described in Lohmer et al. (2021). For example, in case D, cost-focused plants are intended to target efficiency targets with a low margin for key operating figures. In contrast, the other plant (roles) have more margin to achieve higher innovation levels.

Overall, indirect effects that can affect network capabilities positively are improved *network thinking* and *transparency* (cf. Table 26). These effects may be particularly important for plants rarely involved in interplant knowledge exchange. According to Vereecke et al. (2006), these plants are more likely to adopt a different view about their future role than network management. As described above, creating plant roles forces network management to actively define how plants should engage in interplant knowledge exchange. Negative effects on the overall network capability level include a too centralized approach (i.e., top-down restriction, cementation of status quo, cf. Table 26). This observation aligns with Lohmer et al.'s (2021) argument that network management should achieve a balance of centralized standards and decentralized autonomy. This is crucial to not undermine local plant management and ensure that all plants can sufficiently identify with their role (cf. Table 26).

To conclude, companies with low initial levels of network capabilities can use plant role models as a holistic tool to improve all four network capabilities, even in a short period. Case D implicates that companies that have already achieved a high level of network capabilities can use them to secure their position, as stated by case D's informant.

5.4 Conclusions

The purpose of this study was to answer the second and third sub-research question of this work, namely:

How are company-specific plant role models created and deployed? What is the effect on network capabilities?

To answer the research questions, we explored the plant role creation and deployment process in four IMNs (i.e., multiple-case study). The cases were chosen based on (1) diversity and (2) a high degree of implementation. After analyzing each case as a “standalone entity” (Eisenhardt, 1989b, p. 540) in the within-case analysis (cf. chapter 5.2), we sought to generalize across the cases in chapter 5.3.

5.4.1 Contribution to Literature

This study contributes to the understanding of the practical application of plant role models in a "real-world context" (Yin, 2018, pp. 286–287) from a network perspective, as demanded by various IMN researchers (Cheng & Farooq, 2018; A. Feldmann & Olhager, 2013; Thomas et al., 2015; Vereecke & van Dierdonck, 2002). To our knowledge, this is the first study that systematically analyzes the creation and deployment process of company-specific plant role models. Moreover, it complements previous research (Lohmer et al., 2021) by holistically analyzing the effect of plant role models on network capabilities. Based on the analysis of our four cases, we assume that the following propositions hold true:

(1) Although the majority of MNCs might use implicit roles, it is explicit plant roles that increase the fit in the *plant-network interaction* as they force MNCs to define clear rules that come with the roles (e.g., incentives, additional resources).
(2) Company-specific plant role models are a natural evolution of the widely established *lead plant concept*, as they extend the isolated allocation of responsibilities for single plants to all plants belonging to an IMN.
(3) The introduction of company-specific plant role models can improve all *network capabilities* (i.e., learning ability, manufacturing mobility/flexibility, strategic targets accessibility, and efficiency ability) significantly within a few years after the rollout.
(4) MNCs have varying motives for the introduction of plant role models, which determine its primary use cases (i.e., for configuration or coordination); hence there is *no one-best-way* for the creation and deployment of plant role models.

5.4.2 Managerial Implications

The implications for managers of our study can be summarized in the following key points:

(1) MNCs can use plant role models to achieve a better interaction between the network and plant level; examples of the network effects include better *plant leader involvement*, *network thinking*, and *interplant cooperation*.
(2) MNCs should not apply plant role models following a *one-size-fits-all principle*. Instead, they should be careful in choosing the right (sub-)networks for plant role model application, i.e., appropriate (sub-) networks should contain plants with technological linkages, varying competence levels, etc.
(3) Network management should involve plant leaders and adjacent functions (e.g., R&D) to get buy-in when creating company-specific plant role models.
(4) Network management should create plant roles based on the specific *network capabilities* (e.g., learning ability, manufacturing mobility/flexibility, etc.) they aim to acquire.
(5) When deploying company-specific plant role models, network management should carefully balance *centralized standards* and *decentralized autonomy* in order to both

exploit network synergies and make sure that plants can identify with their roles at the same time.

5.4.3 Limitations and Future Research

As with any case-based research, ours also comes with limitations (Yin, 2018). First, our sample size is limited. Although carefully selecting cases (Yin, 2018) with high contextual diversity, the sample size limits the generalizability of our findings. Future research could use a quantitative research design to validate our findings, especially the propositions drawn in chapter 5.4.1. An interesting approach in such a study would be to investigate the relationship of plant roles to firm performance in a mediation analysis.

Second, our case companies are exclusively headquartered in Germany, i.e., in a high-cost context (Ketokivi et al., 2017). More research is needed to investigate how plant roles are created and deployed in organizations that differ in terms of their culture, cost context, etc.

Lastly, with our research, we aimed to broadly explore the creation and deployment process of company-specific plant role models. This procedure led to an increased understanding of the overall process. On the downside, however, we were able to raise some intriguing questions but could only cover them on the surface. Questions that emerged from our research and need more attention include: What factors lead to successfully introducing plant roles? What factors lead to the dissolution of plant roles in companies or single BUs? What effect do plant roles have on the behavior of plant leaders? To what extent should network management quantitatively measure and monitor plant roles?

Overall, due to the significant effect of plant roles on manufacturing networks observed in this study, we are convinced that this topic should be given more attention in IMN research. As outlined above, many exciting research avenues exist for future plant role research.

6 Empirical Study 3

IMN scholars describe the network and plant level interaction as crucial for successfully managing manufacturing networks (Colotla et al., 2003; Olhager & Feldmann, 2022). In this thesis' first two empirical studies, the network perspective to investigate the phenomenon of company-specific plant role models was taken. First, the content of plant role models was analyzed (cf. chapter 4), then the related creation and deployment process (cf. chapter 5). This study's purpose is to investigate the introduction of plant roles in an industrial context in more depth and answer the following research question:

How can network management introduce company-specific plant role models?

This study chose to systematically include the plant leaders' perspective as a source of evidence for the following reason. Plant leaders hold the responsibility for operating a whole manufacturing plant (Smith et al., 2009; Wiech & Friedli, 2021). They are typically the local point of contact for network managers. For these reasons, plant leaders can be considered mediators between the network and plant level, largely influencing a plant's behavior. Moreover, plant leaders "see themselves as relevant decision-makers who determine the willingness of their plants to engage in intra-network exchange" (Wiech & Friedli, 2021, pp. 1179–1180). In the context of this research, they thus determine a plant's willingness to deploy its appointed plant role. Plant leaders not favoring the concept of plant roles can take a defensive position. For example, as described by Netland and Aspelund (2014), they might "act"; i.e., they only pretend to comply with their intended role while following a different local agenda. As plant behavior influences the deployment of plant role models, network managers must regularly engage with plant leaders.

The following section outlines the methodology of this study (chapter 6.1). Chapter 6.2 introduces the details of the empirical study, while chapter 6.3 contains the results of the plant leader inquiry. This study closes with a discussion and conclusion in chapter 6.4.

6.1 Methodology

Little is known about introducing plant roles in an industrial context; hence, this study follows a *theory generation approach* (Ketokivi et al., 2017; Yin, 2018) based on a single case study (Yin, 2018). Compared to the retrospective cases of study 2, this study's *longitudinal case* enabled the author to investigate "at first hand the sequential relationships of events" (Voss et al., 2002, p. 202). Moreover, compared to multiple case studies, a *single case* allows for greater depth (Voss et al., 2002).

6.1.1 Case Selection

Yin (2018) proposes five rationales for selecting single cases: critical, unusual, common, revelatory, and longitudinal (Yin, 2018, p. 49). This case has primarily been chosen due to its *revelatory* nature and access to *longitudinal* data. The case allowed the author to observe and analyze the phenomenon of plant role introduction in an industrial context.

The extensive collaboration with the case company gave the author an in-depth understanding of plant role introduction. This setting granted access to all relevant stakeholders in the organization, such as the central IMN department, multi-plant managers, and plant leaders.

6.1.2 Data Collection

Real-time data from the case company were collected from January 2021 through May 2023. Additionally, *retrospective data* were gathered to cover preliminary plant role-related activities dating back to the 2000s. This study intensely triangulated the *data collection method* (i.e., interviews, surveys, documentation) and the *data sources* (Denzin, 1978; Patton, 1999).

To systematically include the plant leader perspective, a series of nine plant leader interviews were conducted. Table 27 presents the details of the informants' experience and their plants.

Table 27: Overview of plants and informants' characteristics

#	Plant location	Year of establishment	Plant set-up	# of employees at the plant	Informant's experience as plant leader in years
NA.1	North America	2000s	Acquisition	4,900	10
NA.2	North America	1990s	Acquisition	5,700	5
WEU.1	Western Europe	1990s	Greenfield	4,500	8
WEU.2	Western Europe	2000s	Acquisition	1,200	8
WEU.3	Western Europe	1990s	Greenfield	1,500	8
SCA.1	South and Central America	2000s	Greenfield	1,200	3
SCA.2	South and Central America	2000s	Greenfield	4,500	13
SCA.3	South and Central America	2000s	Acquisition	2,000	2
SEA	Southeast Asia	2010s	Greenfield	900	1

The interviews were conducted online in April 2022 and lasted between 29 and 42 minutes. Each interview started with a brief introduction of the plant leader's background. Afterward, theory of plant roles (i.e., Ferdows's (1989, 1997b) model), a timeline of the intended plant role introduction, and the current status of the plant role model (see case introduction) were presented. The plant leaders were asked to express their general thoughts about plant roles rather than concentrating on details. To avoid emotional reactions, the role names were intentionally left blank and simply named roles A, B, C, and D. *Open-ended questions* such as "What do you expect from the plant role model?" or "What are the benefits and risks from your perspective?" were asked. This strategy had the advantage that the informants could openly formulate their general thoughts about plant roles without getting lost in detail. Complementing this inquiry, each plant leader was provided with a survey containing more detailed questions (e.g., questions about plant role names and specific KPIs). The entire plant role survey is attached to the appendix of this thesis.

Six interviews were conducted before the plant leader interviews with multi-plant managers responsible for managing two to four plants. The aim was to get the buy-in from the superiors for the plant leader interviews. Moreover, the author worked closely with a project team from January 2021 to May 2023. The project team consisted of two senior executives and one project manager (i.e., the primary point of contact) who are part of the case company's IMN department. Together with the project team, the plant role model was iteratively created. The project team took part in most of the plant leader interviews.

6.1.3 Data Analysis

The case introduction section of this study is primarily informed by the collaboration with the IMN department's project team and the multi-plant manager interviews. As these data form the context of our case (Yin, 2018), they were only analyzed unstructured, i.e., primarily using field notes and memos.

The plant leader interviews were analyzed systematically; first, the interview transcripts were read multiple times, notes were taken, and relevant quotes were highlighted. Next, all text sections that were not of interest were excluded. *Open coding* (Glaser & Strauss, 1967) was commenced for each interview separately (i.e., first-order codes). Then, the author analyzed across the interviews and grouped similar codes into *first-order categories* that stay close to the informants' language. In parallel, the first-order codes were assembled into higher *second-order themes* (i.e., researcher-induced theoretical concepts). Finally, the second-order themes were consolidated into three a*ggregate dimensions*. The resulting data structure was reviewed by key informants of the IMN department and subsequently refined. The *data structure* will be presented in the results section of this study.

6.1.4 Validity and Reliability

Analogously to the previous empirical studies, the case research was oriented with Yin's (2018) four tests for qualitative research. Table 28 summarizes the respective measures taken.

Table 28: Measures of addressing validity and reliability criteria

Tests according to Yin (2018)	Main measures taken in this study
Construct validity	• Using multiple sources of evidence and data collection methods (i.e., triangulation) besides interview data, survey data, and documentation of plant characteristics. • Review and validation of a draft report of the study by multiple informants of the case company's IMN department.
Internal validity	• Less of importance to this study as causal relationships are only partly suggested.
External validity	• Detailed description of the case context (Yin, 2018) in chapter 6.2, "Case Introduction". • Usage of multiple embedded units of analysis (i.e., nine plants).
Reliability	• Usage of the same overarching questions for each interview; recording, transcription, and coding of all interviews. • Majority of interviews conducted by the same researcher.

6.2 Case Introduction

Due to confidentiality reasons, the identity of the case company is not revealed. The company is headquartered in the US and operates in the medical technology industry. It operates a manufacturing network of more than 10 plants in all major manufacturing regions. The following sections focus on the context of the plant role model introduction.

6.2.1 Preliminary Activities and Background

To understand the whole "history" of the case company's plant roles, it seems useful to start in the early 2000s when the first balanced scorecard was introduced at the case company. As depicted in Figure 9, several plant role-related activities preceded the emergence of the plant role model at the case company.

The *balanced scorecard* marked the transition from complete plant-level control over KPIs to a network-guided approach. A standard template of KPIs was created in nine dimensions (e.g., safety, quality, service, and cost). For the first time, this template caused the plants to feel that they were part of a larger entity.

After continued network growth through acquisitions, the case company identified the need for a *network optimization* program in 2008. The role of a small dedicated IMN department was formally structured to provide direction for the network. The department's role includes network consolidation and optimization after mergers and acquisitions, as well as network capacity scaling to support growth and increase efficiencies. With the formalization of the IMN department, the case company began to consider its manufacturing plants strategically in relation to the network requirements. The key strengths and competencies of the plants were understood, and two informal plant roles were defined – the component plant and the top assembly plant.

One of the early activities of the IMN department was to refine an Excel-based tool that measured the complexity of the plants – the *complexity/capability model*. The quantitative model included measures such as the number of unique products, the number of employees, development activities, and quality performance. The model increased the understanding at the case company of how each plant contributed differently to the manufacturing network.

With the initial introduction of the balanced scorecard at selected plants, the desire for an aligned set of KPIs across all plants emerged. In the earlier balanced scorecard, the plant leaders still had complete control over their KPIs. With the introduction of the new *global balanced scorecard* in 2008, a governance process for the plant performance review was established, including the target setting for the plants along with inputs from the plants. This allowed the tracking of the network performance and evolution. Today, the global balanced scorecard is still the leading performance management tool for the manufacturing network.

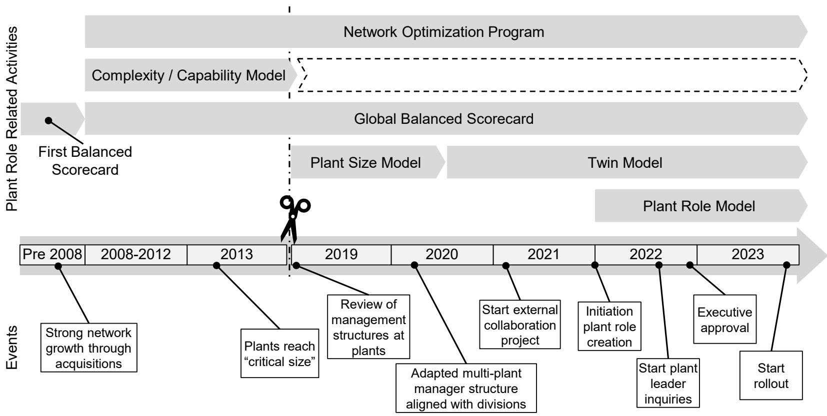


Figure 9: Plant role-related activities and events at the case company

In 2019, a group of plant leaders recognized the need to (re-) define the plant management structures since their plants grew significantly, stretching traditional management structures (i.e., more than 4,000 FTEs). The plant leaders proposed a *plant size model* defining three plant roles: standard, large, and XL. The roles were defined using different quantitative criteria, such as the cost level at the location, number of products, product type, and range of functions. Several plant leaders utilized the model to review the plant management structure. However, it was not systematically rolled out on a network level. The plant size model can be regarded as a predecessor to the current model as the idea of having defined management structures, including maximum plant size, is incorporated in the new model.

In 2020, two plants reached the maximum size defined in the plant size model. Thus, the *twin model* was established. The model defines a modified management structure for manufacturing and support functions (i.e., engineering and quality) at XL plants. The standard management structure includes one director for each plant function reporting to the plant leader. The new model proposed an additional director (i.e., twin) for the production, engineering, and quality functions on a plant level to reduce the management span.

The current plant role model was initiated during the collaboration project at the beginning of 2022. The aim was to further develop manufacturing network planning, optimization, and measurement to support the case company's strong growth. In several workshops between our institute and the IMN department, a first draft was developed and challenged by each of the six multi-plant managers. Based on their feedback, the model was refined before it was shown to the plant leaders.

6.2.2 Details of the Plant Role Model

Figure 10 shows an abstracted version of the case company's plant role model at the time of the plant leader inquiry (i.e., April 2022).

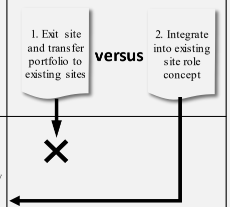
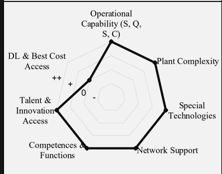
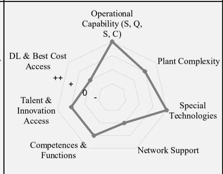
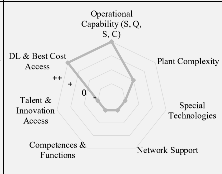
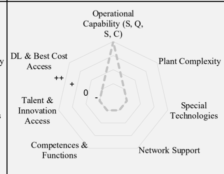
It consists of four main plant roles and an integration site, i.e., a plant that has been acquired and has to be integrated into the case company's existing manufacturing network. The plant role model comprises four primary elements – mission, strategic contribution, competencies, and site ecosystem (cf. Figure 10).

The *mission* is the highest aggregation level of the plant role description. Roles A and B have similar missions. However, while role A is a hub for products and processes for the whole network, role B only focuses on technologies not duplicated in the network. Role C focuses on stable products only, and role D grants access to restricted markets. All roles must comply with safety, quality, service, and cost standards.

The *strategic contribution* details each role's value added to the manufacturing network. As the hub for new products and processes, role A is responsible for ramping up new products and developing new technologies[40]. In contrast, Role B is specialized in fulfilling the customer demand for its unique technologies. Role C provides efficiency, and Role D serves to overcome market restrictions. Last, the integration site takes part in the information and knowledge exchange before a decision has to be taken: either it gets transformed into one of the existing roles or it gets closed with a transfer of the portfolio to existing sites (cf. Figure 10).

The *competencies* section of the case company's plant role model can be compared to the vertical axis in Ferdows's (1989, 1997b) model. All roles have manufacturing, maintenance, quality management, technical support, and capital equipment; however, for different kinds of products. Moreover, different functions are intended for the roles. For example, only roles A and B have a procurement & supply chain function, while an operational excellence function exists at roles A, B, and C.

[40] Some new products or technologies could also be ramped up by role B, in case they are not dispersed in the network.

	Role A	Role B	Role C	Role D	Integration Site
Mission	Service the wider network (hub for product, process) and deliver on S,Q,S,C on complex products	Deliver on S,Q,S,C on complex products and unique technologies	Manufacturing center for high labor content stable products	Local manufacturing to enable / optimize access to restricted markets	
	Safety, Quality, Service and Cost delivery (S,Q,S,C) | All activities to ensure competent and compliant manufacturing activities (maintenance, quality, training etc)				
Strategic Contribution	* Ramp-up new products with high growth potential and complexity * Provide service with quickest response time for direct labor and technology * Develop and expand new technologies and capabilities to enable company	Provision of flexible, quick reaction to customer demand and exploitation of qualified workforce to manufacture complex products	Provision of highest efficiency and quality production for stable products	* Overcoming import licenses of restricted markets * Revenue growth in emerging markets to offset negative economies of scale	* Continue development and service as business development teams get involved * Collaborate and coordinate information and knowledge exchange
Competencies	Manufacturing, Maintenance, Quality Management, Technical Support, Capital Equipment for …				
	…new, transformational products and provide technical support with lead for dispersed technologies	…unique technologies without lead-follower relationship	…stable products with technical support from lead sites throughout product life cycle	…locally demanded products only	
	* Procurement & Supply Chain * New Technology Development * Product Improvement & Development * Coordinate Information & Knowledge Exchange * Experts in Acquisition Integration * Operational Excellence	* Procurement & Supply Chain * New Technology Development * Product Improvement & Development * Acquisition Integration * Operational Excellence	* Industrialization of New Technologies * Acquisition integration * Operational Excellence * Complexity Management: division, technology, volume and mix * Direct ship	* Market requirements knowledge	
Site Ecosystem					

Note: S, Q, S, C stands for safety, quality, service, cost; DL stands for direct labor

Figure 10: Abstracted plant role model of the case company

The *site ecosystem* contains measures and metrics along the seven dimensions of operational capability, plant complexity, special technologies, network support, competencies & functions, talent & innovation access, and direct labor (DL) & best cost access. There are four levels proposed: “emerging”, “competent”, “proficient enabler”, and “network leader”,[41] which are indicated by plus and minus signs in Figure 10. While all roles are designed for the highest operational capability, major differences are intended for the remaining dimensions. For example, role A holds the highest plant complexity, while role C should have the highest direct labor (DL) & best cost access. More detailed measures on each dimension can be found in the appendix of this thesis.

6.2.3 The Role of Plant Leaders

The plant leaders at the case company are senior leaders (i.e., VP level) with typically multiple regional and functional years of experience (cf. Table 27). Each plant leader reports to one multi-plant manager (also VP level) who is responsible for managing three to five plants. The career development for plant leaders is often into a multi-plant manager role.

The primary focus of the plant leaders lies in delivering on the KPIs defined in the global balanced scorecard (i.e., safety, quality, delivery, and costs). Some also have a responsibility to support the manufacturing network. For example, the component plants need to have a support structure with the receiving plants and the divisions they support.[42]

The multi-plant managers manage the plants with a high level of autonomy. While some plant leaders are more focused on their plant’s performance, a desire of many plant leaders to engage more with the network was observed during the plant leader inquiry.[43]

6.3 Results

6.3.1 Overview

The analysis of the plant leader inquiry shows how introducing a company-specific plant role model can change the critical interaction between the plant and network level of manufacturing networks. The emergent model of this change process consists of three overarching dimensions, depicted in Figure 11.

First, the dimension of *perceived conditions* represents plant leaders’ perspectives toward the current manufacturing network management. Second, the *management strategies/tactics* constitute elements network management can use to achieve desired outcomes by introducing the plant role model. Last, the *potential outcomes* represent the effects of the

[41] The characteristics of the scale have been adapted from Miltenburg 's (2009) classification of the level of network manufacturing capability, i.e., “infant”, “average”, “adult”, “world class”.

[42] The divisions are in charge of managing the product portfolio at the case company.

[43] The IMN department estimated the distribution of a plant leader’s day-to-day business time into 80 percent local and 20 percent global.

plant role model introduction. They can be both favorable (e.g., plant contribution awareness) or adverse outcomes (e.g., loss of local responsiveness).

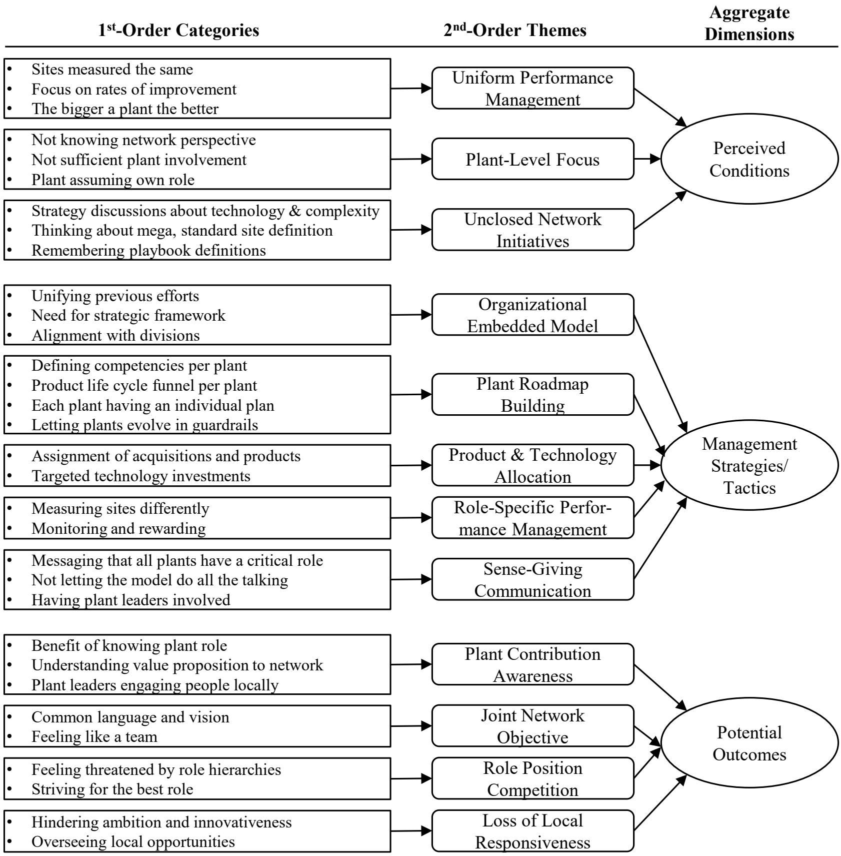


Figure 11: Data structure

The following sections elaborate on the three dimensions constituting the main building blocks of the proposed plant role introduction process outlined in chapter 6.3.5.

6.3.2 Dimension 1: Perceived Conditions

The author identified three main perceived conditions under which the plant leaders operate their manufacturing plants: uniform performance management, plant-level focus, and unclosed network initiatives (see Table 29).

Table 29: Representative quotes underlying perceived conditions (dimension 1)

2nd-order themes	Representative quotes
Uniform Performance Management	"We have to build the confidence to drive year-on-year improvements no matter what, the same as every other site" (SEA) "In the end, you've got your scorecard and your rates of improvement, and that's what the big focus is." (NA.1) "One thing that does call my attention is the delivering on safety, quality, service, costs do not carry out through the four roles. It's our guiding priorities regardless of our role." (SCA.1) "I think that in past years and maybe even today, there can be this belief that, well, a plant leader exists to grow their site. That is success. And I fundamentally don't subscribe to that." (NA.2)
Plant-Level Focus	"Unless you're very connected to another site, you don't have the whole broader [network] perspective to understand" (SCA.1) "I found that there wasn't probably enough conversation, and it wasn't enough to engage me at the network level to drive that" (WEU.2) "I think every site leader is trying to focus on where they can take a site. [With the plant role model] … you can take that to a broader discussion and to a broader set of leaders that are thinking about where the company wants to go" (WEU.2)
Unclosed Network Initiatives	"The work that was done post the [operations] summit in 2019 … how are we going to define a mega site, a standard site, a large site?" (NA.2) "When I think of complexity and technologies, I was trying to intertwine them a little bit [with the plant role model]" (SCA.3) "Core technologies and plant complexity … there's been a lot, probably 80 percent of the whole strategy discussion is focused on those two dimensions." (NA.2)

Uniform performance management (subtheme 1) describes plant leaders' perception that current plant performance is measured equally and with limited KPIs. There was a consensus among the informants that a plant's primary focus lies in driving yearly improvement rates, independent from a plant's role. Multiple plant leaders questioned the usefulness of this "one-fits-all" measurement system, e.g., on the financial KPIs. On the other hand, there seemed to be an agreement that safety, quality, service, and cost-related KPIs form the basis for a plant's competitiveness – for each plant role (see Table 29). Several informants mentioned that plants tended to define success in the form of size. In the past, plant leaders tend to strive for plant growth in a "the bigger, the better" logic.

Various plant leaders explained that their primary focus lay on the *plant level* rather than the network level (subtheme 2). They mentioned that they do not know what happens in the other plants and solely have informal network discussions. Hence, some plant leaders developed their own understanding of their plant's role: "What happened in the past is that the definition, it's coming from the site, and then the site is the one, the only one that believes our role is X, Y, or Z." (SCA.2).

Despite the perceived plant-level focus, the informants mentioned several previous *network-wide initiatives* introduced in chapter 6.2.1 of this study (subtheme 3). There was an agreement that the current manufacturing network is structured along core technologies: "I feel like that basic architecture is what we've done over the years; we don't replicate technologies in many plants if there's one plant that's making the product, we don't have five plants doing it. If one plant is doing drug coating, not five plants do it." (NA.1) Other network initiatives brought up included the plant size and the plant complexity model. The plant leaders questioned how the new plant role model would fit the recent initiatives.

6.3.3 Dimension 2: Management Strategies/Tactics

Management strategies/tactics comprise five subthemes (see Table 30) that express how network management can use the proposed plant role model to manage the manufacturing network.

The first subtheme, the *organizational embedded model*, refers to the need for the proposed plant role model to acknowledge the perceived conditions outlined in the preceding section. On the one hand, to unify previous initiatives in one universal model. On the other hand, to align the model within the organization. Interfaces named by the informants include supplier management, services, and the division which manages the product portfolio.

The second subtheme, *plant roadmap building*, describes creating a plan for how a plant should evolve, including defining its competencies and a product pipeline. A common theme among the plant leaders was the concern that the plant role model could be too prescriptive and reduce a plant's ambition: "every site should also have an appropriate development space, degrees of freedom that they can develop so they don't feel they're boxed in but have development in the context of their role." (WEU.1) The roadmap-building process should hence give a site sufficient space for development while trying to stay in its specific "guardrails" (NA.1).

In contrast to the second subtheme, the *production & technology allocation* theme deals with a structured approach for allocating (new) products and technologies for acquisitions and transfers on a network level. A few plant leaders mentioned that such an approach should be used upfront acquisitions to clarify the strategic role of new plants. Moreover, technology investments could be better targeted to ensure no technology replications occur in the manufacturing network.

Table 30: Representative quotes underlying management strategies/tactics (dimension 2)

2nd-order themes	Representative quotes
Organizational Embedded Model	"I'm just excited that we bring all of these efforts under one umbrella to get a kind of one universal understanding of what our framework [the plant role model] is going to be and that all the important elements are represented within it as we go forward." (NA.2) "I think this [the plant role model] could be used as part of the broader strategy process" (NA.2) "I've been trying to push this idea of a global manufacturing strategy where products and activities have a strategic framework first and then a more tactical decision-making afterward when we're miserable." (WEU.1) "That's also something that if you don't define properly with the divisions, then you have a problem. You can have the perfect model in the manufacturing sites. But if the rest of the organization doesn't commit to that and know what the role is, it can potentially be a big problem and a big disconnect with the organization." (SCA.2)
Plant Roadmap Building	"we have a very clear individual plan by site as to how we fit into [the macro plan] and actually have a synergy across the site network" (SEA) "I think if you [had] a strategic discussion every year … about where the site was going and what the site was doing, and that was facilitated by the network, you felt like it was a really good discussion about your site's future" (WEU.2) "there needs to be an evolution all the time because countries don't stay steady, neither do sites so" (WEU.1) "[Network management] can probably counteract sites having too much ambition, maybe are reaching beyond their skills" (WEU.2)
Product & Technology Allocation	"I think as long as we use that [the plant role model] upfront ... a new product or an integration activity and kind of play with the model ahead of time before making the [decision]. That would also be very helpful." (SCA.1) "the other part will be on investments; I think that when we think about where do we need to invest in the next wave of technologies and so on? You could then target investments the way." (SCA.1)
Role-Specific Performance Management	"Maybe not every site, depending on its strategic role, is going to be measured a certain way or have the same financial targets" (NA.2) "How do I get credit for and measure, monitor and reward the things of new product influence or prototyping or development or acquisition work" (NA.1)
Sense-Giving Communication	"In my mind, we want to send a message that all sites are critical. All sites have a critical role." (NA.2) "One of the watch outs … is we don't want to imply, in my opinion, that any site is superior to another site based on some title or some role in the network." (NA.2) "The risk is if the vision isn't painted clearly and if it isn't communicated well and clearly got understanding and buy-in from the sites, it can become counterproductive." (WEU.1)

The subtheme of role-specific performance management addresses the perceived condition of uniform performance management (cf. chapter 6.3.2). On the one hand, the interviewed plant leaders agreed on the benefits that could come with role-specific performance management. On the other hand, a few plant leaders warned against unintended consequences that could result from such a system. One plant leader reports from a previous job assignment: "But be careful of going up too quickly with the set of metrics that drive unintended consequences. That's a bitter experience in a different life" (WEU.1)

The last subtheme under management strategies/tactics concerns *sense-giving communication* needed to deploy the plant role model. In response to the perceived low involvement of plant leaders (cf. chapter 6.3.2), there was a consensus that the model can foster the plant-network communication. As mentioned by several plant leaders, the communication strategy should also encompass the message that all plants have a critical role in avoiding that sites feel inferior to others.

6.3.4 Dimension 3: Potential Outcomes

The last dimension contains potential outcomes emerging from the introduction of the proposed plant role model. The outcomes expressed by plant leaders can be both favorable ones (i.e., plant contribution awareness and joint network objective) as well as adverse ones (i.e., role position competition and loss of local responsiveness) from a network perspective (cf. Table 31)

The first subtheme under potential outcomes, *plant contribution awareness*, treats plant (leaders') knowledge about the value they deliver for the network in addition to their local business. There was a consensus among the plant leaders that knowing one's role in distinction to the other plants is a major benefit of the plant role model introduction. The plant contribution awareness enables plant leaders to make network-related decisions locally explainable: "It's critical for me as a site leader to be able to explain to folks why we would make some decisions to bring something in or transfer something out of the site." (NA.2)

Table 31: Representative quotes underlying potential outcomes (dimension 3)

2nd-order themes	Representative quotes
Plant Contribution Awareness	"I think the biggest benefit is that the sites will have a clear mission, right?" (SCA.2) "If you're playing soccer, you do need to know whether you're in goal or whether you're center forward." (WEU.1)
Network Thinking	"we all talk the same language, and we understand where we land, it's a great common language and a starting point also to create awareness on those that are not that close by." (SCA.1) "It's a great way to get [everybody] having the same language" (NA.1) "Look at the benefits is getting the network to feel like a supply chain" (WEU.1)
Role Position Competition	"I think where the concern might be is that the attention and the investments and the decision-making always go to role A, versus not prioritizing the needs or B or C or D, right? (SCA.1) "The last thing you want is to inadvertently have sites feel threatened or feel undervalued. That's a feeling that they need to somehow figure out a plan to be something else" (WEU.1) "You always want the No. 10 on your shirt, right?" (SCA.2) "If everybody wants to play center forward on the team, then we gonna lose." (WEU.1)
Loss of Local Responsiveness	"[If] I know that's not your role, your role is A, B, and C, then I might not have seen the opportunity [because] I might not have chased it." (WEU.2) "The risk is you lose innovation. I think if you get too prescriptive and only one site is going to do this. Then, what's pushing me to be innovative and coming up with new things." (NA.1)

Compared to the previous one, the subtheme *joint network objective* stresses understanding the overarching network vision rather than the local contribution. Plant leaders referred to this as "talking the same language" (SCA.1), "feeling like a supply chain" (WEU.1) or feeling like a "team" (SCA.2).

Subtheme 3 is the *role position competition*. The interviewed plant leaders largely agreed that introducing the plant role model can cause plant (leaders) to strive for the "best" role, i.e., the strategically most important one. "But you know everyone's going to want to be lead." (WEU.3) As a main reason, plant leaders name a potential unequal treatment of the plant roles by the network management: "I think where the concern might be is that the attention and the investments and the decision-making always go to role A, versus not prioritizing the needs or B or C or D, right? (SCA.1)

The last potential outcome is the *loss of local responsiveness* caused by a more centralized approach that would come with the plant role model introduction. The interviewed plant leaders largely agreed on the advantages that come with focusing the plants on "a handful of things as opposed to trying to conquer the world all at the same time" (WEU.3). On the contrary, some plant leaders expressed their concern about overseeing local opportunities by trying to comply with central network management's requirements. This could also decrease a plant's ambition and innovativeness: "The risk is you lose innovation. I think if you get too prescriptive and only one site is going to do this. Then, what's pushing me to be innovative and coming up with new things." (NA.1)

6.3.5 Model of Plant Role Introduction

The results of the plant leader inquiry indicate that introducing a plant role model for manufacturing network optimization can significantly change the plant-network interaction – a critical component of a successful IMN (Colotla et al., 2003; Olhager & Feldmann, 2022). Figure 12 places the three aggregate dimensions and 12 second-order themes from the data structure between two points in time – before and after the introduction of the plant role model.

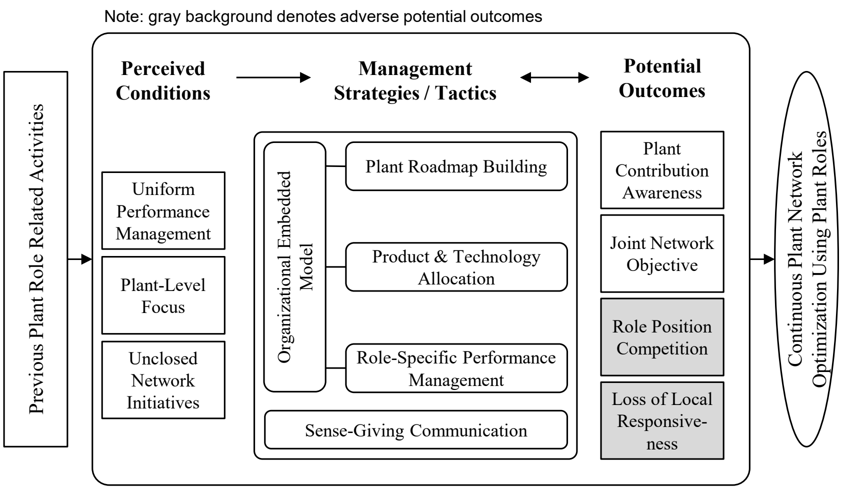


Figure 12: Model of plant role introduction

The model centers around the dimension management strategies/tactics that constitute essential network management deployment mechanisms. The organizational embedded model unifies previous network initiatives in one universal framework; it is the actual plant role model with three main use cases. First, the plant roadmap building is conducted regularly between local plant management and central network management. Second, the product & technology allocation must be performed before acquisitions or transfers of existing products/technologies. Last, the role-specific performance management that measures, monitors, and rewards the plants dependent on its strategic role. The sense-giving communication flanks the afore-described deployment mechanisms. It is essential to get the buy-in for the model from all plants (or rather plant leaders).

The management strategies/tactics interplay with both the perceived conditions and potential outcomes (indicated by the arrays in Figure 12). As an example, the organizational embedded model addresses the perceived conditions of unclosed network initiatives. Likewise, role-specific performance management addresses the current uniform performance management.

The potential outcomes result from network management's strategies/tactics – for example, successful sense-giving communication results in an increased plant contribution awareness. However, on the contrary, management strategies/tactics can also lead to unintended outcomes. For instance, a rushed introduction of role-specific performance management can lead to a role position competition or a reduced ambition of the plants (i.e., loss of local responsiveness).

The proposed model is grounded in plant leaders' perceptions toward the plant role model introduction. Plant leaders are critical decision-makers in manufacturing networks and determine the willingness of plants to engage in network exchange (Wiech & Friedli, 2021). Hence, network managers can use the model to continuously monitor the evolution of conditions and outcomes to adjust the taken management strategies/tactics accordingly.

6.4 Discussion and Conclusions

6.4.1 Discussion

The purpose of this study was to explore the plant role introduction process to guide network managers aiming to introduce plant roles (cf. SRQ4). At the case company, much attention has been devoted to the perception of individuals such as multi-plant managers and plant leaders during the plant role introduction process. The author was hence able to acquire a comprehensive understanding through the lens of critical stakeholders in the manufacturing network (i.e., plant and network level).

6.4.1.1 Dimension 1: Perceived Conditions

The theme of *unclosed network initiatives* showed that plant roles might not be created from scratch but are preceded by closely related activities (e.g., the plant size model, cf. chapter 6.2.1). In addition, the case company made several attempts to measure plants differently (i.e., the complexity/capability model, cf. chapter 6.2.1). Nevertheless, the plant leaders still overwhelmingly perceived performance management as uniform. An explanation may be that none of these role-specific measurement systems were subject to reporting requirements, while the reportable KPIs (i.e., from the global balanced scorecard) were still designed in a “one-fits-all” principle.

Like the *plant-level focus* as a plant leader perceived condition in this study, Wiech and Friedli (2021) observed locally focused plant leaders resulting from false incentives. In the present case, the plant-level focus resulted from a plant-focused performance management system. In line with Wiech and Friedli's (2021) suggestion, the network managers from the IMN department recognized the need to support the intended plant roles with corresponding incentive structures when introducing them.

6.4.1.2 Dimension 2: Management Strategies/Tactics

The central management strategies/tactics concern the need for an *organizational embedded model,* which is also reflected in IMN literature. Previous research shows that plant evolutions (Cheng et al., 2011), as well as network and plant decisions, are strongly interrelated (A. Feldmann et al., 2013). Hence, plants cannot be managed separately but in a “holistic manner” (Blomqvist & Turkulainen, 2019, p. 142; Brush et al., 1999). A few such holistic models can be found in the literature (e.g., Miltenburg (2009), Friedli et al. (2014)). These models have a strong network focus. Instead, this study argues to use plant roles as overarching network management model. Such models can be found in literature, e.g., Thomas et al.'s (2015) plant role portfolio of linking network and plant targets, Scherrer and Deflorin's (2017) QFD[44] to integrate the plant and network perspective or the model of mapping responsibilities of technical activities in A. Feldmann et al. (2013). The benefit of such models is that they combine the individual plant and network levels and thus enable an integrated management of manufacturing networks.

A central part of such a model should be an approach to *product & technology allocation* (cf. Figure 12). Cheng et al. (2011) already showed in their study that product or process[45] transfers and/or relocations at one plant affect the role of other plants. Thus, a network view of allocations is vital for network management to plan plants' evolution and related roles strategically.

Plant roadmap building is a topic that can also be found in Mediavilla et al.'s (2015) Akondia model. The authors suggest a roadmap building with six analysis fields: markets and customers, suppliers, international operations, technology management, HR management, and socio-political and regulatory. The interviews highlight the importance of a defined product portfolio and associated competencies from a plant leader’s perspective. This can be explained by Cheng et al.'s (2011) suggestion that upgrading a plant’s product portfolios and competencies needs a “long response time” (Cheng et al., 2011, p. 1327). Thus, it seems particularly important for plant leaders to know upcoming product

[44] QFD stands for Quality Function Deployment and is a tool developed in Japan used in product development and production to translate customer requirements into technical requirements Chan and Wu (2002).

[45] This study does do not differentiate between technologies and processes.

allocations to prepare for them sufficiently.

The assignment of role-specific performance measures forces network management to commit to the plant roles rather than only having “strategy slides or nicely labelled plant roles” as described by plant leaders in Wiech and Friedli's (2021, p. 1180) article. Although IMN scholars suggest using differentiated management approaches for plant roles (Blomqvist & Turkulainen, 2019; Cheng & Farooq, 2018; Maritan et al., 2004), the question of how to select and deploy plant-role-specific KPIs remains yet unanswered (Cheng, Farooq, & Johansen, 2015; Costa Ferreira Junior & Fleury, 2018; Wiech & Friedli, 2021).

6.4.1.3 Dimension 3: Potential Outcomes

The favorable outcomes of *plant contribution awareness* and *joint network objective* are also reported with slightly different terminology by Wiech and Friedli (2021). The authors suggest that network management should define a network mission to help plant leaders know their network role. Rather adverse potential outcomes based on our plant leader inquiry include *role position competition*. A theme well described in Luo's (2005) article about “coopetition”[46] in multinational corporations. The author suggests cooperation along four dimensions (i.e., technological, operational, organizational, and financial) and competition in three dimensions (i.e., parent resources and support, system position, and market position). Luo's (2005) distinction can be a starting point for network managers seeking to realize specific coopetition structures by introducing plant roles.

6.4.2 Contribution to Literature

To the author’s knowledge, this study is the first one that explores in-depth the introduction of plant roles in an industrial context. It particularly complements prior research (e.g., Mediavilla et al. (2015), Blomqvist and Turkulainen (2019), Lohmer et al. (2021)) on plant role deployment by shedding light on the *individual level* in manufacturing networks – especially the plant leader perspective. IMN researchers tend to treat plants as “black boxes” (Cheng et al., 2011, p. 1315), yet, plant leaders are critical for the conduct of their respective plants (Wiech & Friedli, 2021).

Besides focusing on the individual level, this study combines the two “building blocks” (Cheng, Farooq, & Johansen, 2015, p. 393) of IMNs, i.e., the plant and the network level. The study explored both perspectives during the plant role introduction process: plant leaders served as main informants at the plant level, while multi-plant managers and network managers as informants from the network level. By combining the two levels, this study responds to the call of multiple IMN scholars for integrated analyses (e.g., Cheng et al. (2011), Cheng, Farooq, and Johansen (2015), Mediavilla et al. (2015), Blomqvist and Turkulainen (2019)).

[46] The term coopetition refers to the fact that actors in certain areas can act cooperatively and competitively at the same time (Brandenburger and Nalebuff (1996)).

6.4.3 Managerial Implications

Building on the empirically grounded model introduced in chapter 6.3.5, this study gives rise to several implications for network managers aiming to introduce plant roles in their organization.

(1) Network managers should carefully screen previous plant-role-related activities prior to creating a new model to avoid plant leader confusion about too many conflicting network activities.
(2) Individuals on plant and network levels should firmly be integrated into the creation and introduction process to give them the voice to articulate concerns and get full buy-in.
(3) Plant roles should be integrated into an *overarching model* that does not conflict with other functions/departments and relates to previous plant role-related activities.
(4) Network management should regularly (e.g., yearly) derive *plant roadmaps* in cooperation with the plants to make the model operational and allow them to evolve in their foreseen role.
(5) Network management should establish a network-level *product & technology allocation* map before acquisitions and/or relocations to enable plant leaders to establish the required competencies with an adequate lead time.
(6) *Performance management* should acknowledge the different roles of the plants, i.e., KPIs, rewards, and incentives should support plants' behavior toward fulfilling their roadmap.
(7) Before and after the introduction, network management should continuously communicate the importance of all roles to make sure that all plant leaders are aware of their network contribution.
(8) Potential favorable (e.g., *plant contribution awareness*) and adverse outcomes (e.g., *plant role competition*) should be monitored by network management, and its strategies/tactics adapted accordingly.

6.4.4 Limitations and Future Research

The longitudinal in-depth single-case design allowed the author to gain a comprehensive understanding of the introduction of plant roles in an industrial context. However, a common pitfall associated with single-case study designs – the *external validity* – also forms the major limitation of this study. Although the study included multiple embedded units of analysis (i.e., nine plants), the case is limited to one industry (i.e., medical technology). Moreover, the case is restricted to a specific cultural context, with most informants from the US (i.e., HQ-location of the case company) or English-speaking countries in Western Europe. The author paid particular attention to describing the case's context (i.e., case introduction). Thus, network managers should be able to evaluate for themselves which case findings are also applicable to their own companies.

Another limitation of the study is that it could not capture the process of plant role introduction until full deployment. This particularly limits the validity of the potential outcomes as they are based on previous experiences from the plant leaders. A future study might revisit the case company to investigate the relationship between the proposed management strategies/tactics and potential outcomes.

The study's results give rise to multiple further opportunities for future research: First, the plant leader interviews reveal sense-giving communication to be a significant element of successful network management in the context of plant roles. However, IMN literature addressing this element is underdeveloped. Future explorative studies might identify communication patterns between central network management and plant leaders. These studies could identify which management styles lead to success – under which contextual conditions. Agency theory (Eisenhardt, 1989a) might be an interesting theoretical lens to investigate the communication between plant leaders (i.e., the agent) and the network manager (i.e., the principal).

Secondly, this study encourages scholars to delve into plant roles and their relation to performance management since the question of how to adequately design KPIs for different roles is mainly unexplored in IMN research. However, this research shows that setting the right KPIs, incentives, and rewards is critical to driving a plant's behavior toward its targeted role. Future research could use a Delphi panel (Linstone & Turoff, 2002) to reach an expert-wide consensus for plant-role-specific KPIs. Other research designs, e.g., based on retrospective case data, could investigate the organizational effects of such KPIs on network management.

Lastly, the potential outcomes of this research provide ground for further explorative research. Some questions remain unanswered as the author could not oversee the complete plant role deployment process. For example, how does introducing plant roles affect coopetition structures (Luo, 2005)? Or do plant roles negatively affect local responsiveness, as feared by plant leaders of this study?

To conclude, the author sensed that the topic of plant roles essentially hits all relevant dimensions of IMNs (e.g., configuration, coordination, network level, plant level), making it a vast theme on the one hand. On the other hand, it hence gives rise to multiple research avenues. To pick one pressing topic, the author particularly encourages future research of "soft factors" such as the communication process and individual conduct in IMNs.

7 General Discussion

This thesis started introducing the background and relevance, the research design, and the thesis' structure in chapter 1. Chapter 2 outlined the theoretical background of IMNs and plant roles and described relevant research gaps. Chapter 3 gave a brief overview of the three empirical studies constituting the empirical basis of this thesis. Chapter 4 contained the first empirical study to answer the thesis' first SRQ – *What is the content of company-specific plant role models*? The subsequent two SRQs – *How are company-specific plant role models created and deployed? What is the effect of company-specific plant role models on network capabilities?* – were answered in the second empirical study (i.e., chapter 5). The last SRQ – *How can network management introduce company-specific plant role models?* – was answered in the last empirical study of this thesis (i.e., chapter 6).

This final chapter has two main objectives. First, to synthesize the empirical studies' results to answer the MRQ (chapter 7.1). Second, to outline the thesis' future research opportunities (chapter 7.2).

7.1 Toward Company-Specific Plant Role Models

This chapter aims to systematically answer the thesis' MRQ – *How to design and deploy company-specific plant role models in IMNs?* The empirical studies of this thesis took care of meeting established methodological best practices of qualitative research (cf. Bluhm et al. (2011)). As the last piece of this thesis, this chapter aims at "consulting practice"[47] in H. Ulrich's (1984, p. 193) understanding. Grounded in the three empirical studies' findings, this chapter hence emphasizes the implications for managers.

Although the management of IMNs has been identified as a critical success factor for a firm's competitiveness (Cheng et al., 2011; Hayes et al., 2005; Miltenburg, 2005; Olhager & Feldmann, 2022; Shi & Gregory, 1998), still many of them fail to fully benefit from their manufacturing networks (Abele et al., 2008; Friedli et al., 2014). While global manufacturing strategies are often too abstract and not actionable for local plant management, local plant roadmaps are often too detailed for strategic network management. Managers seem to be collectively overwhelmed by the complexity of managing IMNs. Plant roles are a suitable tool for "delayering" (Ferdows et al., 2016) this complexity to enable managers for an "integrated" management of their manufacturing networks. "Integrated" refers to the two "building blocks" (Cheng, Farooq, & Johansen, 2015, p. 393) of IMNs – the plant and the network level. As a facilitator between these two levels – often characterized by conflicting interests – plant roles are key for an improved plant-network interaction.

This thesis ventured into the largely unexplored subject of company-specific plant role models. It hence increased the understanding of how companies already use their own plant roles to improve the strategic management of their IMNs. The following two sections

[47] Translated from German „Beratung der Praxis“.

discuss the two main constituents of the MRQ – the *design* and *deployment* of plant role models.

7.1.1 Designing Company-Specific Plant Role Models

Embracing plant role legacy

When designing a plant role model, network managers should first identify previous related activities in their organizations. All activities acknowledging that plants are unique and cannot be treated the same from an HQ perspective should be considered. Of course, this phase is highly dependent on a company's context. For example, individual BUs might already have had plant roles that have been discontinued (cf. study 2, case A). There may also already be a plant-specific KPI system, e.g., by assigning different plant performance targets. Network managers must understand the legacy. In addition to the actual activities, they should also know why they failed. Understanding the legacy builds the basis to get buy-in for creating plant roles, especially from local plant leaders.

Getting buy-in for plant role creation

Getting buy-in for plant roles is typically a longstanding process that involves much convincing (cf. study 3). In addition to the commitment of top management, it is particularly important to convince the plant leaders of the benefits as they are the key stakeholders who determine the behavior of plants (cf. study 3). Plant leaders benefit from plant roles because they allow them to position their plants strategically. As plant leaders often spend too much time on local firefighting, it is a chance for them to take part in more strategic discussions on a network level and "lobby" for their plants. To increase the commitment, network managers should make sure that all stakeholders, not only on the plant level, can express their "emotions" (cf. study 2) throughout the plant role creation process. Interviews are a valuable vehicle to do so.

Defining the content of a plant role model

The content of plant role models should first and foremost contain a detailed description of each role. When formulating the roles, network managers need to make sure that the roles are complementary. That means that the roles are differentiated so that they collectively contribute to the overarching strategy (Khurana & Talbot, 1999). Take the example of the automotive company (case D) in study 2: one role is cost-focused while the other is specialized in innovation. In combination, two focused factories (Skinner, 1974) can target both competitive priorities (i.e., cost and innovation) on a network level.

Besides competitive priorities, network managers can use multiple dimensions to differentiate their plants. The most relevant include *plant competence bandwidth*, *inter-plant knowledge/information flow*, and *location advantages* (cf. study 1). A major decision in this phase includes the definition of the system boundary of plant roles. Do they apply to a whole manufacturing location (cf. study 2, cases C and D) or to production units only (cf. study 2, cases A and B)? In the latter case, a location can take on different roles simultaneously, as Ferdows (1997b) and Vereecke and van Dierdonck (2002) suggested.

To make the model operational, network managers must carefully consider which measures to assign to which role. Again, including all relevant stakeholders in the definition process is critical. A hasty definition of plant role-specific KPIs can be counterproductive since it could drive unintended behaviors, e.g., by the plant leaders (cf. study 3). In the context of plant role-specific KPIs, practitioners[48] emphasized "cultural readiness" as a key success factor: such KPIs bring great transparency and make consequences on a plant level very obvious. An organization must be ready for such transparency.

Clarifying the use cases of the model

The scope of a plant role model can be very different. On the one hand, it can contain detailed technical requirements for specific product groups (cf. case 25 in study 1). On the other hand, it can be used for the holistic management of manufacturing networks (cf. study 3). In the latter case, visualizations such as those proposed by A. Feldmann and Olhager (2013), Thomas et al. (2015), or Scherrer and Deflorin (2017) can help determine a good balance of plant roles in the network. Are the plants stable in their assigned role? How do the plants evolve from their current role into other ones? Other use cases for plant roles include global product and technology allocation, the development of plant roadmaps based on their roles, and role-specific performance management (cf. study 3). Network managers should clearly define the use cases and delineate areas not covered, such as whether the model covers supplier management or R&D.

7.1.2 Deploying Company-Specific Plant Role Models

Rolling out of plant roles

The first rollout of the plant roles highly depends on the previously defined content and the company's unique context. A plant role model can be either focused on IMN configuration or coordination. Consider the case of the optoelectronics company (case B) in study 2. The company used the model to realize a *hub-and-spoke* network structure (Abele et al., 2008). The model thus defined the physical requirements (i.e., the layout) of entire production units. The rollout therefore took several years. Take the specialty chemicals manufacturer (case A, study 2) as a contrast: the model essentially defined coordination mechanisms, including dedicated capacities such as process engineers for lead plants. The rollout thus only consisted of communicating the roles in the form of an official release.

[48] Practitioners mentioned cultural readiness in their review of the first study's draft report.

Managing the IMN by means of plant roles

After the initial rollout of the plant roles, network management can use them continuously to optimize their IMN. This applies particularly to the defined use cases from the design phase (cf. chapter 7.1.1). In addition to the discontinuous use of the model for certain decisions, *continuous sense-giving communication* (cf. study 3) on the part of network management plays a central role. This should ensure that all plants can identify with their roles and that all plant leaders are sufficiently involved (cf. study 3). Moreover, a regular review of the as-is roles and the to-be evolution of each plant should be carried out, for example, through a quantitative assessment.

Monitoring the network effects

Introducing plant roles can significantly influence "coopetition" (Luo, 2005) in the network, i.e., whether the plants cooperate or compete for specific resources. The influencing effect is particularly likely if plant role-specific KPIs accompany the plant roles. All network capabilities can be positively changed, as shown in the example of three case companies in study 2. Learning ability and manufacturing mobility/flexibility will likely increase the most (cf. study 2). Additional positive effects include the *plant contribution awareness* or *joint network objective* (cf. study 3).

However, there may also be adverse effects that come with introducing plant roles. For example, an undesired competition between plants to achieve a higher strategic role (cf. study 3). Furthermore, centralization effects can lead to a top-down restriction of individual plant developments (cf. study 2). Moreover, the local responsiveness can be restricted due to the plant roles (cf. study 3).

Adapting the architecture of the model

Strategic plant roles ideally reflect the overarching manufacturing and network strategy. They are, therefore, a "living object" and should be adjusted regularly. Take the example of the specialty chemicals company in study 2 (case A). There the model is reviewed every three to five years as part of the operations strategy review meeting. Exemplary questions that should be answered in this phase: Do the plant roles still reflect the overarching strategy? Do specific plant roles need to be adapted? Do local plant leaders live the roles? If not, why?

Table 32 lists the described phases of plant role model design and deployment and how they are described in the empirical studies of this thesis. Practitioners can use the last column to navigate to relevant figures or tables for each phase.

Table 32: Phases of plant role model design and deployment and reference in this thesis

Phases	Empirical studies 1	2	3	References in this thesis
Designing Company-Specific Plant Role Models				
Embracing plant role legacy		(X)	X	Figure 9
Getting buy-in for plant role creation		(X)	X	Figure 12
Defining the content of a plant role model	X	(X)	(X)	Figure 7, Table 13, Table 14, Table 17, Table 19, Table 21, Table 23, Table 24, Figure 10
Clarifying the use cases of the model		X	X	Table 25, Figure 12
Deploying Company-Specific Plant Role Models				
Rolling out of plant roles		X		Table 25
Managing the IMN by means of plant roles		X	(X)	Table 25, Figure 12
Monitoring the network effects		(X)	X	Figure 12, Table 18, Table 20, Table 22, Table 26
Adapting the architecture of the model		X	(X)	Table 25

Note: (X) denotes indirectly addressed phases in the empirical studies

7.2 Future Research

The current literature on plant roles in IMNs hardly takes the network perspective and tends to oversimplify plant role models. Furthermore, the deployment of plant roles in a company-specific context is underexplored (cf. chapter 2.3). This thesis addressed the aforementioned research gaps and contributed to understanding plant roles for improved IMN management. Although the thesis provides a starting point in understanding the "company-specific" part of plant roles, much more research is needed.

First, this thesis mainly builds on explorative case study research based on purposive sampling (Bryman, 2015). However, as with any case-based research, the generalizability is limited. Thus, quantitative research designs such as surveys are encouraged to validate this thesis' findings deductively, particularly the propositions about plant role models' content (cf. study 1) and its process (cf. study 2).

Second, all companies of the three empirical studies are headquartered in a high-cost context (Ketokivi et al., 2017) with a focus on German-speaking countries (cf. studies 2 and 3) and the US (cf. empirical study 3). Future studies could expand the theory on plant roles from a contingency perspective (Donaldson, 2001) and investigate cultural differences in the design and deployment of plant roles. Further contingency factors, already reported to influence an IMN's design (Olhager et al., 2015, p. 150), include industry, firm size, corporate strategy, and product type.

Third, this thesis integrated the plant leader perspective and thus contributed to overcoming the lack of such individual-level studies in IMN research (Wiech & Friedli, 2021). However, the high relevance of individuals and their communication patterns in the context of plant roles (cf. study 3) give rise to multiple future articles on the individual level.

Future studies should answer questions such as: Which kind of plant leaders fit a specific plant role, such as the lead plant? How do network managers need to adapt their management styles depending on the plant's role? Agency theory (Eisenhardt, 1989a) might be a beneficial theoretical lens to examine the individual ties and communication patterns between plant leaders (i.e., the agent) and network managers (i.e., the principal) (cf. study 3).

Fourth, this thesis mainly relied on informants on a VP and SVP level (both plant and network managers). Future research could shed light on the C-suite perspective on plant roles. For example, what are plant roles (or subsidiary roles) from a CEO's perspective? Would CFOs use different KPIs for different roles?

Fifth, although this thesis explored the creation and deployment process of plant roles (cf. study 2), some intriguing questions about the dynamics of plant roles are still unanswered. For example, what leads to a successful introduction of plant roles, and what factors led to their dissolution in companies or BUs? What is needed from a plant perspective to upgrade one's plant role?

Last, this thesis showed that the topic of plant roles is closely connected to performance management (cf. study 3). However, research on performance management in IMNs is scarce (Costa Ferreira Junior & Fleury, 2018). Therefore, the question of adequately selecting KPIs for different roles is yet to be researched.

To conclude, to the author's knowledge, this is the first thesis systematically exploring the phenomenon of plant roles developed by manufacturing companies. As shown in this research, the design and deployment of plant roles can significantly impact the successful management of IMNs. Hence, the thesis aims to initiate a more extensive discussion among IMN scholars about company-specific plant role models. As outlined above and in the empirical studies of this thesis, there are multiple pathways for relevant future research on this topic.

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APPENDIX

A. Appendix to Empirical Study 1

A.1 Literature Review Process

Table 33: Search settings in four databases

Data-base	*Emerald Insight*	*EBSCOhost (Business Source Complete)*	*Science Direct*	*ProQuest One Business*
Search Fields	▪ *Abstract* ▪ *Title*	▪ *(TI) Title* ▪ *(SU) Subject Terms* ▪ *(AB) Abstract*	▪ *Title, Abstract, or Author-Specific Keywords*	▪ *Document Title - TITLE* ▪ *Abstract - ABSTRACT*
Search Filter	▪ *Journal Articles* ▪ *Abstract* ▪ *Title*	▪ *Peer Reviewed*	▪ *Research Articles*	▪ *Scholarly Journals Conference Papers & Proceedings*

Table 34: 30 search strings for literature review

		Plant role related keywords				
	AND	Site role*	Plant role*	Strategic role*	Factory role*	Subsidiary role*
Manufacturing network related keywords	Manufacturing network*	1	2	3	4	5
	Production network*	6	7	8	9	10
	Plant network*	11	12	13	14	15
	Factory network*	16	17	18	19	20
	Multi-plant*	21	22	23	24	25
	Multiplant*	26	27	28	29	30

Note: * allows the databases to include the plural form of each keyword

Table 35: Overview of literature sample

Source	Role type	Research methodology	Related search strings
Arellano et al., 2019	Plant	Quantitative survey	2, 3, 4, 12, 13
Arndt et al., 2019	Plant	Simulation	2, 7, 12
Bartlett & Ghoshal, 1986	Subsidiary	Multiple-cases	AS*
Baskici, 2019	Subsidiary	Single-case	5
Birkinshaw & Morrison, 1995	Subsidiary	Quantitative survey	AS
Blomqvist & Turkulainen, 2019	Plant	Multiple-cases	2, 12
Cheng & Farooq, 2018	Plant	Quantitative survey	1, 2, 3, 4, 11, 12, 13
Cheng et al., 2011	Plant	Multiple-cases	2, 3, 4, 12, 13
Cheng, Farooq, & Jajja, 2021	Plant	Quantitative survey	2, 12
Corti et al., 2014	Plant	Multiple-cases	AS
Demeter & Szász, 2016	Plant	Quantitative survey	2, 12, 15
Demeter et al., 2017	Plant	Quantitative survey	2, 12
A. Feldmann & Olhager, 2013	Plant	Quantitative survey	1, 2, 3, 6, 7, 8, 11, 12, 13
A. Feldmann & Olhager, 2019	Plant	Multiple-cases	3, 4, 5, 8, 9, 18, 19
A. Feldmann et al., 2013	Plant	Multiple-cases	1, 2, 3, 4, 6, 7, 8, 11, 12, 13
K. Feldmann et al., 1996	Plant	Conceptual/Theoretical	1, 7
Ferdows, 1989	Plant	Conceptual/Theoretical	AS
Ferdows, 1988	Plant	Conceptual/Theoretical	2, 3, 4, 8, 9, 12, 13, 14, 17, 18, 19
Ferdows, 1997b	Plant	Conceptual/Theoretical	AS
Golini et al., 2017	Plant	Quantitative survey	2, 12
Gupta & Govindarajan, 1991	Subsidiary	Conceptual/Theoretical	AS
Hogenbirk & van Kranenburg, 2006	Subsidiary	Quantitative survey	AS
Jarillo & Martíanez, 1990	Subsidiary	Quantitative survey	AS
Khurana & Talbot, 1999	Plant	Mixed methods	AS
Lampón & Rivo-López, 2021	Plant	Multiple-cases	2, 7
Maritan et al., 2004	Plant	Quantitative survey	2, 3, 4, 7, 8, 12, 13,
Martinez & Jarillo, 1991	Subsidiary	Quantitative survey	AS
Mediavilla et al., 2015	Plant	Single-case	12, 13, 14, 17, 18, 19
Meijboom & Vos, 2004	Plant	Multiple-cases	1, 4, 16, 18, 19
Nassimbeni et al., 2018	Plant	Quantitative survey	AS
Olhager & Feldmann, 2022	Plant	Quantitative survey	2, 6, 7, 11, 12, 21
Poynter & White, 1984	Subsidiary	Multiple-cases	AS
Randøy & Li, 1998	Subsidiary	Quantitative survey	AS
Salgado, 2011	Subsidiary	Multiple-cases	AS
Szász et al., 2019	Plant	Multiple-cases	2, 3, 4, 12, 13
Szwejczewski et al., 2016	Plant	Multiple-cases	1, 2, 3, 4, 11, 12, 13
Taggart, 1996	Subsidiary	Quantitative survey	AS
Taggart, 1997b	Subsidiary	Quantitative survey	AS
Taggart, 1997a	Subsidiary	Quantitative survey	AS
Taggart, 1998b	Subsidiary	Quantitative survey	AS
Taggart & Hood, 1999	Subsidiary	Quantitative survey	AS
Thomas et al., 2015	Plant	Single-case	1, 3
Vereecke & van Dierdonck, 2002	Plant	Multiple-cases	2, 3, 4, 12, 13
Vereecke et al., 2006	Plant	Multiple-cases	2, 3, 4, 12, 13
Vokurka & Davis, 2004	Plant	Quantitative survey	AS

Note: AS denotes an alternative search, i.e., forward and backward search, as well as additional sources derived from discussions with peer researchers

A.2 Development of Reference Framework

Table 36: Selected operationalizations of plant role model dimensions (part 1)

Category	#	Exemplary Operationalization	Sources
External factors	1.1	(1.1) Proximity to market, (1.2) Access to skills and knowledge, (1.3) Access to low-cost factors (labor), (1.4) Proximity to raw materials, (1.5) Access to cheap energy	A. Feldmann & Olhager, 2013
	1.2	(1.1) Europe, (1.2) Americas, (1.3) Asia / (2.1) Developing countries, (2.2) Developed countries	Cheng & Farooq, 2018
Plant mandates from HQ	2.1	(1.1) Product plant, (1.2) Market area plant, (1.3) Process plant, (1.4) General-purpose plant	Schmenner, 1982
	2.2	(1) Production competence ((1.1) Production, (1.2) Technical maintenance, (1.3) Process improvement), (2) Supply chain competence ((2.1) Supplier development, (2.2) Procurement, (2.3) Logistics), (3) Development competence ((3.1) Introduction of process improvements, (3.2) Product improvement, (3.3) Introduction of new product technologies)	A. Feldmann & Olhager, 2013
	2.3	(1.1) Activity performed for a plant site alone (e.g., machine maintenance at shop floor), (1.2) … for a number of selected plants (e.g., the bundling of procurement orders), (1.3) ... for the whole network (e.g., a global hub for product and process knowledge and provision of this knowledge to the network's plants).	Scherrer-Rathje et al., 2014
	2.4	(1.1) Cost efficiency, (1.2) Quality, (1.3) On-time delivery, (1.4) Delivery speed, (1.5) Volume flexibility, (1.6) Product mix flexibility, (1.7) Design flexibility, (1.8) Rate of new product introduction	A. Feldmann & Olhager, 2013
	2.5	(1.1) Domestic, (1.2) Domestic and export, (1.3) International, (1.4) Multiple domestic (1.5) All major national markets, (1.6) Global markets, (1.7) All national markets	Miltenburg, 2009
	2.6	(1) Planning decisions ((1.1) Long range production planning, (1.2) Production scheduling, (1.3) Quality standards, (1.4) Maintenance policies and practices) (2) Production decisions ((2.1) Raw material sourcing, (2.2) Component sourcing, (2.3) Equipment sourcing), (3) Control decisions ((3.1) Human resource policies for management, (3.2) Human resource policies for labor, (3.3) Choice of accounting system, (3.4) Choice of management information system, (3.5) Choice of production planning & control system)	Maritan et al., 2004
	2.7	Incentivization basis … (1.1) … individually for each plant, (1.2) … for a group of plants, (1.3) … identical for all plants	Friedli et al., 2014
	2.8	(1.1) Product line A, (1.2) Product line B, (1.3) Product line C	Blomqvist & Turkulainen, 2019*
	2.9	(1) Process/technology A, (2) Process/technology B, (3) Process/technology C	Cheng & Farooq, 2018*
Level of plant embeddedness	3.1	(1) Intensity of people inflow ((1.1) Low, (1.2) Medium, (1.3) High), (2) Intensity of people outflow ((2.1) Low, (2.2) Medium, (2.3) High) (e.g., managers traveling through the plants)	Vereecke et al., 2006
	3.2	(1) Frequency of communication between plants ((1.1) Low, (1.2) Medium, (1.3) High) (e.g., best practice sharing)	Vereecke et al., 2006
	3.3	(1) Intensity of physical goods inflow from other plants ((1.1) Low, (1.2) Medium, (1.3) High), (2) Intensity of physical goods outflow to other plants ((2.1) Low, (2.2) Medium, (2.3) High) (e.g., components, semi-finished goods, end products)	Vereecke et al., 2006*
	3.4	Implementation level between None, Medium, High of… (1) Informal mechanisms, (2) Design integration, (3) Organizational integration, (4) Technological integration, (5) Integration tools & techniques, (6) Communication technologies, (7) Process standardization	Cheng & Farooq, 2018
	3.5	Implementation level between None, Medium, High of… (1) Sharing information with purchasing department, (2) Joint decision making with purchasing department, (3) Sharing information with sales department, (4) Joint decision making with sales department	Cheng & Farooq, 2018
	3.6	Implementation level between None, Medium, High of… (1) Sharing information with key suppliers, (2) Collaborative approaches with key suppliers, (3) Joint decision making with key suppliers, (4) System coupling with key suppliers	Cheng & Farooq, 2018
	3.7	Implementation level between None, Medium, High of… (1) Sharing information with key customers, (2) Collaborative approaches with key customers, (3) Joint decision making with key customers, (4) System coupling with key customers	Cheng & Farooq, 2018
	3.8	Degree of collaboration between None, Medium, High with… (1) Universities, (2) Governmental research centers, (3) Independent research centers, (4) Labs and other institutions	Corti et al., 2014

Note: * indicates that operationalization is only indirectly mentioned

Table 37: Selected operationalizations of plant role model dimensions (part 2)

Category	#	Exemplary Operationalization	Sources
Plant characteristics	4.1	(1) Sales volume ((1.1) <€10M, (1.2) €10-50M, (1.3) €50-100M, (1.4) >€100M) (2) Number of employees ((2.1) <199, (2.2) 200-499, (2.3) 500-999, (2.4) >1,000)	A. Feldmann & Olhager, 2013
	4.2	(1.1) Young plant, (1.2) Mature plant	Taggart, 1997b
	4.3	(1.1) Component manufacturing, (1.2) Assembly, (1.3) Both (integrated)	A. Feldmann & Olhager, 2013
	4.4	(1.1) Few products only produced by plant (1.2) Many products only produced by plant, (1.3) Products produced at multiple plants	Cheng & Farooq, 2018
	4.5	(1.1) One-of-a-kind, (1.2) Low volume, (1.3) Higher volume, (1.4) High volume	Kotha & Orne, 1989
	4.6	(1) Number of SKUs (end units), (2) Number of setups required, (3) Variations in sizes and shapes of products	Kotha & Orne, 1989
	4.7	(1.1) Mature products, (1.2) Innovative products / (2) Organizational experience with the product in years	Arndt et al., 2019* / Kotha & Orne, 1989
	4.8	(1) Engineer-to-order, (2) Make-to-order, (3) Assemble-to-Order, (4) Make-to-stock, (5) Make- and distribute-to-stock	A. Feldmann & Olhager, 2013
	4.9	(1) Manual with low automation, (2) Machine assistance with medium automation, (3) Fixed program machine with high automation, (4) Programmable control with highest automation	Kotha & Orne, 1989

Note: *indicates that operationalization is only indirectly mentioned

A.3 Structure of Plant Role Models

Table 38: KPIs integrated into plant role models

Complementarity Dimension	Category	KPI	Unit
Location advantage	EXTERN	Blue-white collar share	%
Location advantage	EXTERN	Hourly labor rate	€/h
Plant competitive priorities/performance	HQ	Average operational performance	-
Plant competitive priorities/performance	HQ	Capacity utilization	%
Market scope	HQ	Local market share	%
Market scope	HQ	Number of regions served	#
Plant size	PLANT	Average number of employees	#
Plant size	PLANT	Number of teams per plant	#
Plant size	PLANT	Number of production units per plant	#
Plant age	PLANT	Experience in mass production	years
Product volume	PLANT	Production volume	units/year
*	PLANT	Number of different technology groups	#
*	PLANT	Technology maturity level	1, 2, 3, 4
*	PLANT	Value added (operational performance - direct material costs)	-
*	PLANT	Number of realized projects	# / year
*	PLANT	Organizational classification	-

Note: *indicates that the complementarity dimension is not covered in the reference framework

A.4 Complementarity Dimensions in Plant Role Models

Table 39: Main complementarity dimensions of plant role models

Rank	Complementarity Dimension	Category	#	%	Rank	Complementarity Dimension	Category	#	%
1	Plant competence bandwidth	HQ	7	24%	6	Product customization	PLANT	1	3%
2	Plant focus/specialization	HQ	6	21%		Plant location	EXTERN	1	3%
3	Product supply chain position	PLANT	3	10%		Plant decision autonomy	HQ	1	3%
	Plant comp. priorities & performance	HQ	3	10%		Products produced by plant	HQ	1	3%
5	Location advantage	EXTERN	2	7%		Network competence reach	HQ	1	3%
6	Plant size	PLANT	1	3%		Processes/technologies held by plant	HQ	1	3%
	End-product maturity	PLANT	1	3%					

Note: Only the complementarity dimensions that are at least covered once are listed

Table 40: Distribution of the number of complementarity dimensions of plant role models

Rank	# of Complementarity Dimension in Model	#	%
1	5 dimensions	5	17%
2	6 dimensions	4	14%
	8 dimensions	4	14%
4	4 dimensions	3	10%
	11 dimensions	3	10%
	13 dimensions	3	10%
7	7 dimensions	2	7%
	9 dimensions	2	7%
	10 dimensions	2	7%
10	3 dimensions	1	3%
11	12 dimensions	0	0%
Mean	**7.6 dimensions**		

B. Appendix to Empirical Study 2

B.1 Interview Guide

Table 41: Interview guideline (part 1)

Main topic	Question	Subitem
I. Introduction		
I.1 Individual Introduction	Please briefly introduce your career and background.	• Career and background
I.2 Firm and Organizational Introduction	Please briefly introduce the firm and the manufacturing network.	• International manufacturing network (multi-plant strategy, regions, etc.) • Extent of responsibility (# of plants) • Central manufacturing network function
I.3 Confirming Plant Role Model		• Coverage (BU vs. company-wide, Production unit vs. site, # of plants, time horizon)
1. Creation of Plant Role Model		
1.1 Initiation	Please describe when/ why it was decided to create a plant role model.	• Reason/trigger point for the creation of the plant role model • Who triggered it, top-down vs. bottom-up • Start date, milestones
1.2 Process	Please describe the process to derive the content of the plant role model.	• Top-down vs. bottom-up, usage of interviews and/or surveys, etc. • Functions/people included, how included • Usage of external support and/or literature • Distinct phases to implement the model (e.g., initiation, buy-in, implementation, etc.) • Length of process • Barriers and/or success factors encountered • Extent of changes, trigger of changes • Procedure to define and implement further changes
1.3 Content	Briefly explain the content in your own words.	• Key elements, why, uniqueness to the case • Role of competitive priorities (quality, cost, etc.), competencies, and network effects in the roles • Vertical integration, relationship to corporate and/or manufacturing strategy • Vertical integration, relationship to the plant strategies
2. Deployment of Plant Role Model		
2.1 Process	Please describe the process to derive the deployment process of the plant role model (if any).	
2.2 Deployment Process	Please describe how you make use of the plant role model.	• Formal rules associated with the deployment of the plant roles • Assignment of plants to roles • Clustering/benchmarking of plants based on KPIs, frequency, exemplary KPIs • Plant leader awareness of role, possibility of role upgrade • Frequency of plant role model usage • Derivation of roadmaps/plant strategies based on the plant role model • Interaction of plant leaders with plant role model, behavior without model (e.g., prior to creation)
2.3 Further Use Cases	Please list and describe further use cases of the plant role model.	• Network-level use cases • Plant-level use cases
2.4 Organizational Structure	Please describe how the plant role model deployment is embedded in the organization.	• Owner on the network and plant level • Supporter of the implementation? • Technical elements (e.g., intranet articles or best practice databases)

Table 42: Interview guideline (part 2)

Main topic	Question	Subitem
3. Implementation & Network Effects		
3.1 Implementation Degree	How would you estimate the degree of implementation of the plant role model?	• Quantitative vs. qualitative, measurement of implementation degree • <u>Likert scale assessment (implementation degree):</u> *(0 = none; 1 = very low implementation; 2 = low implementation; 3 = medium implementation; 4 = high implementation; 5 = very high implementation)* • Missing factors for further implementation • Planning to further implement it, why not • Plant leader awareness of role (see above "Deployment Process") • Top management, HQ awareness of plant role mode
3.2 Benefits	What are the main benefits, pitfalls of creating/deploying a plant role model? Can you give examples?	• Main benefits of creating/deploying plant role model • Impact on the interaction between plant and network level • Main pitfalls of creating/deploying plant role model • 1-2 examples of the impact of the plant role model
3.3 Effects on Network Capabilities	How would you estimate the introduction of the plant role model on the following network capabilities?	• <u>Likert scale assessment (before and after plant role model introduction (1) learning ability, (2) manufacturing mobility/flexibility, (3) efficiency ability, (4) strategic targets accessibility):</u> *(0 = none; 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high)* 1. <u>Learning ability</u>: cultures, national circumstances, other market and customer needs, internal learning) 2. <u>Manufacturing mobility/flexibility</u>: dynamic distribution of production volumes and orders in the network, staff exchange, access to specific resources and customers 3. <u>Efficiency ability</u>: economies of scale and scope, reduction of redundancies 4. <u>Strategic targets accessibility</u>: strategic markets, access to labor, materials, product and process technology, managerial skills

B.2 Coding Frames

Table 43: Coding frame for "introduction" (part 1)

Descriptive codes	Pattern codes	Example (Case)
Individual Information		Director factory planning at C for five years now. I've been working in this whole area for ten years now, though. (C)
Company/BU Information		Nonetheless, we are an absolute growth case within the company and also an area where investments are quite strong. (A)
IMN Structure		Each division has plants that are assigned to it, although we also have zebra plants. (D)
IMN Department	Dedicated IMN Department	We have four employees. We also have project managers and employees in the regions. (C)
	Joint Operations & Supply Chain Function	Since the strategy 2025 took place, I have been the global director for operations and supply chain. (B)
Plant Role Model Background	Lead Plant Legacy	The Lead Plant topic was actually the first thing to come up from these three roles. (C)
	Production Units as Role Unit of Analysis	The roles refer only to one unit within the site. (A)
	Definition of Clear Lead Plant	The lead plant is operating a subnetwork which today also includes industrialization. (D)
	Three hierarchical roles defined	We have developed a three-stage model of plant roles for the BU. (B)
	Different implementation degrees in different BU's	In one BU, the ad-hoc decision has been made that we will cancel the plant roles. (A)
Plant Role Model Uniqueness		We have clearly considered which networks to apply this model to and where not. (A)

Note: All quotes were translated from German

Table 44: Coding frame for "creation of plant role model" (part 2)

Descriptive codes	Pattern codes	Example (Case)
Prerequisites for Plant Roles	Technological Linkage	If the plants have no overlap at all in what they do, then there is no point in defining any roles. (A)
	Different Competence Levels Across Plants	There must be a need, especially in terms of the different capabilities of the plants among one another. (A)
	Capability/Resources to Support Network	We have the case that there is not really any more a competence plant. (A)
	No Fully Independent Plants	But if you have plants that function completely independently, then you don't need plant roles. (A)
	Willingness of Union Representatives	The union representatives have to go along with the plant roles. (D)
Initiation Trigger	No Explicit Top Management Mandate	It wasn't a work order, but it was welcome when it was there then. But it was not a triggered activity. (D)
	Top-Down Initiation by Network Management	That came centrally. It has to do with the fact that I have global responsibility for operations and the supply chain. (B)
Initiation Date	Relatively New Phenomenon	In 2018, we developed it, and then it was followed by a rollout. (B)
Initiation Reason	Formalization of Support for Weak Plants	We've always had the issue that product ramp-ups haven't worked out. And the same plants were always asked for help. (C)
	Implementation of Cost-Optimal Manufacturing Footprint	We have developed a calculation methodology on how to calculate how we should position ourselves in the long, medium, or long term based on variable production costs. (C)
	Product Allocation Optimization	Everyone has done what they have done historically. And that motivated us to say we have to look at how we determine who does what. (B)
	Restructuring of Operations Function	There was a very complex operations structure at that time, and there was a need to restructure that. (A)
	Risk Mitigation Between Regions	Decoupling is certainly a key issue, namely the question of how we can ensure competence in the individual blocks. (D)
Creation Phases	Lead Plant Concept as First Step	This lead plant concept was also the first to be actually implemented at that time. (C)
External Support	External Support in Creation	Yes, it was more or less a consulting project. (A)
	Own Creation in IMN Department	There was no external support. (C)
(Plant) Involvement	Strong Involvement of Important Plant Leaders	The plant leaders actually play a very important role here because they can always say what we offer, what is actually asked of us. (C)
Mean of Creation	Workshops to Create Content of Model	We did a workshop week with operations and with R&D and defined the criteria for the individual roles. (B)
Creation Activities		The first step was to find out what the necessary operational capabilities are that we have to achieve with our production assets. (A)
Rollout Process		That lasted from 2018 to ..., two and a half years. (B)

Note: All quotes were translated from German

Table 45: Coding frame for "deployment of plant role model" (part 3)

Descriptive codes	Pattern codes	Example (Case)
Awareness in Organization	Full Transparency in Organization	No, I don't think it's posted anywhere, but it's not a secret. So, where we want to have these roles, they are actually openly communicated. (A)
	Transparency only on Network Level	Plant leaders do not know the roles formally. But I do know that if I only have series production, that I am a series producer. (D)
Ownership & Releases	Lead Plant Responsibility for Processes/Products	There is also the power for the lead plants to define processes that are then also binding for the other plants that are not a lead plant. (A)
	Model Methodological Ownership Separated	The method ownership will be in the central department. However, which plant is what has to be done in agreement with the divisions.
	Release Of Plant Assignment in Direct Line	The operations director has to release new plant assignments. (A)
	Role Name in Plant Employee Title	Lead plant leaders and also our lead engineers deliberately have this "lead" in the title as well. (A)
Embeddedness in Meeting Structure	Usage at Location Planning Process	The use case is within the annual site planning process. (D)
	Usage at Plant Leader Conference	There are four global operations meetings where all the plant leaders come together who have operations responsibilities. And then, such strategic and tactical issues are discussed, and corrections are made. (B)
Incentives	Role-Specific Incentivization	We have also incentivized the lead plant leaders accordingly. With personal goals that go beyond their own plant. (A)
	Role-Unspecific but Global Incentivization	There is a mix of global parameters and local parameters. With this, one can say: The incentivization also supports the model, without it being intended, in some form. (B)
Role Assessment & Assignment	Assignment of Plants to Roles	We use the model to classify our plants. (A)
	Role-Specific Score	We have already formalized, so to speak, what the basic requirements must be to be a lead plant, to be a competence plant. (A)
	Reference to Role in Plant Strategy	The plant strategies refer to these roles. For example, it clearly states that our goal is to be the lead plant or to remain in the lead plant. (A)
Model Change Process		We haven't made any changes to the basic definition. (B)

Note: All quotes were translated from German

Table 46: Coding frame for "network impact" (part 4)

Descriptive codes	Pattern codes	Example (Case)
General Benefits	Plant Leader Involvement	That's a challenge, that plant leaders, of course, have their plant as a target first. (A)
	Network Thinking & Transparency	One success factor is certainly the team approach. (D)
	Interplant Cooperation	We used to have a competition in the past. (C)
	Network Synergies	The implementation of investment projects, but also all other types of projects, now runs much better. (A)
	Product Allocation	The advantage is that you can stringently allocate products and get into a discussion. (C)
General Drawbacks	Over-Centralization	The disadvantage is that it is a structure imposed from the top down, in which everyone has to find themselves. (C)
	Resource Investments	One disadvantage is the designated resource buildup. Of course, this is also a little bit of a cost factor. (A)
Impact on Learning Ability*		It is a motivating factor that the lead plant, which before always felt deprived and had some inhibition to give their knowledge. (A)
Impact on Manufacturing mobility/flexibility		Compared to before the introduction, wherever we have a system assembly center, we can exchange and support each other because of capacities, missing parts, etc. (B)
Impact on Efficiency ability		I think we have become much more efficient now about our roles and understanding of roles (C)
Impact on Strategy targets accessibility		The model is very strong on the customer side. E.g., in rapidly developing markets, we can build a project execution center in half a year due to high standardization. (B)
Impact on other production priorities		Based on our figures, we can say that we are optimizing our contribution margin due to the plant roles. (B)

Note: All quotes were translated from German; * Examples of the impact on network capabilities were already used in the within-case analysis of study 2

C. Appendix to Empirical Study 3

C.1 Data Tables

Table 47: Representative quotes underlying 1st-order concepts (part 1)

1st-order categories	Representative quotes
Sites measured the same	"One thing that does call my attention is the delivering on safety, quality, service, costs do not carry out through the four roles. It's our guiding priorities regardless of our role." (SCA.1) "Should all sites be metricized the same, particularly on the financial front?" (NA.2)
Focus on rates of improvement	"In the end, you've got your scorecard and your rates of improvement, and that's what the big focus is." (NA.1) "We have to build the confidence to drive year-on-year improvements no matter what, the same as every other site" (SEA)
The bigger a plant the better	"In the past, there's always been a perception at [the case company] that bigger is better, and that may not be the case for the overall network, right?" (SCA.1) "I think that in past years and maybe even today there can be this belief that, well, a plant leader exists to grow their site. That is success. And I fundamentally don't subscribe to that." (NA.2)
Not knowing network perspective	"Unless you're very connected to another site, you don't have the whole broader perspective to understand" (SCA.1) "The challenge for me is certainly to know what the network is doing. I can't see what other sites are doing" (WEU.2) "I don't know what goes on in the other sites" (WEU.2)
Not sufficient plant involvement	"The site leadership team has to be involved closer with the strategy team. I think that's a gap here." (WEU.1) "I found that there wasn't probably enough conversation, and it wasn't enough to engage me at the network level to drive that" (WEU.2)
Plant assuming own role	"What happened in the past is that the definition, it's coming from the site, and then the site is the one, the only one that believes our role is X, Y, or Z." (SCA.2) "If a site is meant to have a bit of a bandwidth to farm people out to other sites, like here, I can tell you that's just one thing that we do believe that is one of our roles in the network" (NA.1) "Sometimes you see a role at the site level, but the network might not see it, you know, and vice versa, right?" (WEU.2)
Strategy discussions about technology & complexity	"Core technologies have been such an integral part of how we thought about our network strategy, at least in my understanding." (NA.2) "Core technologies and plant complexity … there's been a lot, probably 80 percent of the whole strategy discussion is focused on those two dimensions." (NA.2) "When I think of complexity and technologies, I was trying to intertwine them a little bit [with the plant role model]" (SCA.3)
Thinking about mega, standard site definition	"I think there was a definition of a site above mega site that we didn't have any, but we were saying that there were only two sites that really should be striving for that" (WEU.3) "The work that was done post the [operations] summit in 2019 … how are we going to define a mega site, a standard site, a large site?" (NA.2)
Remembering playbook definitions	"I was trying to remember how we named it when we've gone through the playbook, right? Like, a center of excellence? It was very technology focused. So, it would be like a center of excellence for a technology versus a distributed technology." (NA.1) "We used to have the operations strategy playbook. Have we overlaid all of that in the evolution of this framework [plant role model] as well to just test for? What are critical elements that we want to make sure that we incorporate? Or are we letting go of those because our business conditions have changed?" (NA.2)

Table 48: Representative quotes underlying 1st-order concepts (part 2)

1st-order categories	Representative quotes
Unifying previous efforts	"I'm just excited that we bring all of these efforts under one umbrella to get a kind of one universal understanding of what our framework is going to be and that all the important elements are represented within it as we go forward." (NA.2) "I feel like that basic architecture [of the plant role model] is what we've done over the years; we don't replicate technologies in many plants … We've kind of tried to select plants that have strengths, et cetera. How do you see differences from that structure what we've done?" (NA.1)
Need for strategic framework	"We need a universal framework to address critical elements of our strategy within the supply chain … Within that framework, we need to make sure that we account for the critical inputs." (NA.2) "I've been trying to push this idea of a global manufacturing strategy where products and activities have a strategic framework first and then a more tactical decision-making afterward when we're miserable." (WEU.1)
Alignment with divisions	"That's also something that if you don't define properly with the divisions, then you have a problem. You can have the perfect model in the manufacturing sites. But if the rest of the organization doesn't commit to that and know what the role is, it can potentially be a big problem and a big disconnect with the organization." (SCA.2) "We are probably expected to take a product from the division and advance it into commercial volume production. That's where the divisional piece for me comes in regard to a proper alignment." (WEU.3)
Defining competencies per plant	"I think … we need to figure out how to, what kind of defining, competency is right at a site" (SEA) "You've got a core capability and a core skill set that's understood that would be very helpful" (WEU.1) "Is the site primarily a component subassemblies supply site versus a finished device supply site?" (NA.1)
Product life cycle funnel per plant	"So there has to be a funnel to them … within that guardrail. So that the sites know if products are dying." (NA.1) "There should be a lifecycle for products … in the sense that certain activities belong in certain places and don't in others." (WEU.1)
Each plant having an individual plan	"we have a very clear individual plan by site as to how we fit into [the macro plan] and actually have a synergy across the site network" (SEA) "What are the key areas, the next steps that we can take that will help us advance?" (WEU.3) "I think if you [had] a strategic discussion every year … about where the site was going and what the site was doing, and that was facilitated by the network, you felt like it was a really good discussion about your site's future" (WEU.2)
Letting plants evolve in guardrails	"there needs to be an evolution all the time because countries don't stay steady, neither do sites so" (WEU.1) "Every site should also have an appropriate development space, degrees of freedom that they can develop so they don't feel they're boxed in but have developed in the context of their role." (WEU.1) "[Network management] can probably counteract sites having too much ambition, maybe are reaching beyond their skills" (WEU.2)
Assignment of acquisitions and products	"When we talk about integrations, when we talk about new products, where you launch these versus an emotional decision, right? I think it [the plant role model] just brings a more structured approach, and it will inform at least initial proposals on decision-making." (SCA.1) "I think as long as we use that [the plant role model] upfront ... a new product or an integration activity and kind of play with the model ahead of time before making the [decision]. That would also be very helpful." (SCA.1) "How do the product portfolio and the divisional products get managed? That is where I see a lot more conversation and a lot more discussions going on …" (WEU.2)
Targeted technology investments	"the other part will be on investments; I think that when we think about where do we need to invest in the next wave of technologies and so on? You could then target investments the way." (SCA.1) "We're trying to have an [single point of contact] in every single site for every single technology." (SCA.2)

Table 49: Representative quotes underlying 1st-order concepts (part 3)

1st-order categories	Representative quotes
Measuring sites differently	"I think an opportunity is even today, what are the metrics that we want to measure the different sites who are doing different things?" (NA.1) "Maybe not every site, depending on its strategic role, is going to be measured a certain way or have the same financial targets" (NA.2) "But be careful of going up too quickly with the set of metrics that drive unintended consequences. That's a bitter experience in a different life" (WEU.1)
Monitoring and rewarding	"How do I get credit for and measure, monitor and reward the things of new product influence or prototyping or development or acquisition work" (NA.1)" "another big one that I have bumped into in two of the three sites I've been a leader in is something as tactical as what are the control limits for the number of product builders at any given site. What's the optimal range plus or minus five percent to that target? What are the constraints we're going to impose on sites within this strategy framework?" (NA.2)
Messaging that all plants have a critical role	"In my mind, we want to send a message that all sites are critical. All sites have a critical role." (NA.2) "All of the sites … have an important role to play in different parts of the team" (WEU.1) "One of the watch outs … is we don't want to imply, in my opinion, that any site is superior to another site based on some title or some role in the network." (NA.2)
Not letting the model do all the talking	"I think the other risk is don't let the model always do all the talking, right?" (SCA.1) "The risk is if the vision isn't painted clearly and if it isn't communicated well and clearly got understanding and buy-in from the sites, it can become counterproductive." (WEU.1)
Having plant leaders involved	"I think we have to find a way where at least the site leads are much more in the tent, in the discussion" (WEU.1) "[A specific plant leader] had not been a part of the internal discussions around standard site, large site, mega site. You know, he had not been directly involved in those conversations; he may have heard things tangentially, so he was kind of consuming all of this for the first time, and you kind of saw that his reaction to what we call things was similar to mine … I think in general you know, ninety-five percent of us would probably react in a similar fashion." (NA.2)
Benefit of knowing plant role	"The benefit is then obvious that you know where you are." (WEU.3) "I think the biggest benefit is that the sites will have a clear mission, right?" (SCA.2) "If you're playing soccer, you do need to know whether you're in goal or whether you're center forward." (WEU.1)
Understanding value proposition to network	"The definitions should help sites and site leaders understand their value." (WEU.1) "general understanding for everybody at the site in terms of our value proposition and kind of where are our boundaries with what value proposition?" (NA.2) "you just have to question is that the best use of the sites in delivering for the network?" (WEU.3)
Plant leaders engaging people locally	"It's critical for me as a site leader to be able to explain to folks why we would make some decisions to bring something in or transfer something out of the site." (NA.2) "As a site leader, it's so important that you can create ambition with your team" (WEU.2) "With this kind of roadmap, we can explain the why behind the what and get people comfortable and proud of the team that they're on" (NA.2)
Common language and vision	"getting clear on the vision, the value of the benefit to the company" (WEU.1) "we all talk the same language, and we understand where we land, it's a great common language and a starting point also to create awareness on those that are not that close by." (SCA.1) "It's a great way to get [everybody] having the same language" (NA.1)
Feeling like a team	"Look at the benefits is getting the network to feel like a supply chain" (WEU.1) "And I will say that the team is a network, not the site." (SCA.2)

Table 50: Representative quotes underlying 1st-order concepts (part 4)

1st-order categories	Representative quotes
Feeling threatened by role hierarchies	"The last thing you want is to inadvertently have sites feel threatened or feel undervalued. That's a feeling that they need to somehow figure out a plan to be something else" (WEU.1) "Like I said, when we did the work around standard, large, mega site, we ran into the same things: Well, what should we call this stuff so that if I'm a standard site, I don't feel bad that I'm not a mega site?" (NA.2) "they were driving that hierarchical model [which caused] a kind of winners and losers mindset" (WEU.2) "I think where the concern might be is that the attention and the investments and the decision-making always go to role A, versus not prioritizing the needs or B or C or D, right?" (SCA.1)
Striving for the best role	"You always want the No. 10 on your shirt, right?" (SCA.2) "But you know everyone's going to want to be lead." (WEU.3) "If everybody wants to play center forward on the team, then we gonna lose." (WEU.1)
Hindering ambition and innovativeness	"The risk is you lose innovation. I think if you get too prescriptive and only one site is going to do this. Then, what's pushing me to be innovative and coming up with new things." (NA.1) "I think the danger of putting this out without the right discussion is that you put sites' ambition into a box" (WEU.2)
Overseeing local opportunities	"The only risk [about the plant role model] I see is that I think things are evolving so quickly and needs are coming faster … We might be missing an opportunity on a site just because it was already focused on a certain purpose." (SCA.1) "[If] I know that's not your role, your role is A, B, and C, then I might not have seen the opportunity [because] I might not have chased it." (WEU.2)

C.2 Plant Role Survey

Table 51: Plant role survey "instructions" (part 1)

As part of a collaboration project with the University of St. Gallen, Switzerland, we are developing a plant role model for the sustainable optimization of our global manufacturing network over the coming years. The initial concept has been discussed and reviewed with all multi-plant managers. To further develop the model, we're looking for your cooperation and insights.

The main objective of this survey is to get additional input from your perspective (plant-level) in order to further detail the plant role model. We will use the completed questionnaires to (1) revise the plant role model and (2) conduct a gap analysis of different perspectives.

Benefits of a site role concept are:

- Make sure that individual strengths of plants (e.g., location, competence) are used appropriately to add value to the company's overall success
- Focus sites on a specific mission to make sure that they do not have to respond to too many conflicting targets (e.g., costs, innovation) resulting in compromises
- Give sites strategic guardrails to ensure both the sites' and the overall networks' objectives are aligned

This questionnaire consists of a total of 17 questions in the categories "General Site Information", "Site Role Concept" and "Future Site Role". The questionnaire takes about 30 minutes to complete and does not require the collection of quantitative data.

Table 52: Plant role survey "general plant information" (part 2)

Main topic	Question	Response option
Please provide us with some general information about you and your managed site.		
Name	Filled out by (name)	*Text field*

Please consider the following list of strategic reasons to initially establish / acquire a site and exploit a plant today and choose the most applicable primary reason from the dropdown (e.g., "take advantage from low-cost labor" --> 2.1)

1. Proximity to suppliers	**5. Socio-political**
1.1 to benefit from rapid/reliable delivery from suppliers and low transport costs	5.1 to benefit from tax breaks and/or investment incentives
1.2 to be close to low-cost suppliers	5.2 to overcome trade barriers
1.3 to facilitate cooperation with suppliers in product design, planning, etc.	5.3 to benefit from favorable or less stringent environmental regulations
1.4 to have access to source of raw materials	5.4 to reduce the impact of exchange rate fluctuations
2. Availability of labor	**6. Competitions**
2.1 to take advantage of low-cost labor	6.1 to be close to major competitors
2.2 to take advantage of the availability of workers	6.2 to prevent major competitors from establishing a manu. facility in the area
2.3 to take advantage of favorable social climate	6.3 to capture/maintain market share
3. Availability of skills and know-how	**7. Energy**
3.1 to take advantage of highly qualified workers	7.1 to take advantage of low-cost energy
3.2 to take advantage of skilled engineers	**8. Other**
3.3 to take advantage of managerial/organizational skills	8.1 to take advantage of highly qualitative environment
3.4 to be close to source of technological know-how	8.2 to create a high quality of life for employees
4. Proximity to market	8.3 to place of residence of the owner
4.1 to provide rapid/reliable delivery to customers at low costs	8.4 to seize a provided opportunity
4.2 to adapt products to local taste and/or to facilitate co-operation with customers in product design, planning, etc.	
4.3 to provide fast service or technical support to customers	

Source: Vereecke and van Dierdonck (2002)

Reason to establish / acquire plant	Please indicate the primary reason for initially establishing /acquiring the plant from your perspective	*Drop-down list*
Reason to run the plant today	Please indicate the primary reason for the plant today from your perspective	*Drop-down list*

Table 53: Plant role survey "plant role model" (part 3)

Main topic	Question	Response option
Please provide us with your perspective on the overall plant role model.		
Labels	Do you agree with the number of distinct plant roles? If you disagree; which plant roles are missing or are not required?	*Text field*
Mission	Please indicate if you do not agree with any of the plant missions. Provide detail on how you would change the respective mission?	*Text field*
Contribution	Please indicate which of the links of the plant roles to the key contributors you would not agree with? Specify how you would change the respective mission?	*Text field*
KPIs	Please indicate what should be the top 3 KPIs for each plant role?	*Text field*
Competen-cies/functions	Please indicate which competencies/functions for the site roles are missing or not relevant?	*Text field*
Definition of plant role ecosystem 1	From your perspective, are there any important dimensions missing or not relevant to differentiate the different plant roles? Please specify?	*Text field*
Definition of plant role ecosystem 2	Please indicate which criteria for the dimensions are missing or not relevant? • Operational Capability (Delivery on: Safety, Quality (Q), Service (S), Cost (C)) • Plant Complexity (Product, Process, People, Supply, Market & Customer) • Special Technologies (Uniqueness, Launches, Technology Responsibility) • Network Support (Coordinate Information, Knowledge Exchange, Support in Industrialization) • Competencies & Functions (Procurement & Supply Chain, New Technology Development) • Talent & Innovation Access (Talent Availability, Talent Attrition Rate, Proximity to Innovation Hub) • Direct Labor & Best Cost Access (Availability, Attrition Rate, Direct Labor Cost Rate) • Further Category	*Text field*

Table 54: Plant role survey "future plant role" (part 4)

Main topic	Question	Response option
Please provide us with your perspective on your site's status in the site role concept.		
Current plant status	Where do you see the current status of your plant, compared to the overall network? • Operational Capability • Plant Complexity • Special Technologies • Network Support • Competencies & Functions • Talent & Innovation Access • Direct Labor & Best Cost Access • Further Category	*Single response* *(emerging; competent, proficient enabler, network leader)* *Text field* *(for explanation)*
Plant priority	Which dimensions do you see as the leading pillars for your optimal contribution to the Network? If indicating more than one area - indicate priority (1,2,3 etc.) • Operational Capability • Plant Complexity • Special Technologies • Network Support • Competencies & Functions • Talent & Innovation Access • Direct Labor & Best Cost Access • Further Category	*Drop-down list* *(for priority)* *Text field* *(for explanation)*
Ability of plant in 2027	In the current environment - where do you expect to see the ability of your plant by 2027, compared to the network? • Operational Capability • Plant Complexity • Special Technologies • Network Support • Competencies & Functions • Talent & Innovation Access • Direct Labor & Best Cost Access • Further Category	*Single response* *(emerging; competent, proficient enabler, network leader)* *Text field* *(for explanation)*
Focus areas in next 3 years	What areas will be focus of development and funding in the next 3 years • Operational Capability • Plant Complexity • Special Technologies • Network Support • Competencies & Functions • Talent & Innovation Access • Direct Labor & Best Cost Access • Further Category	*Text field*
Comments	If you have any general comments, please state them here	*Text field*

CURRICULUM VITAE

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